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Physiological correlates and neural circuitry  
of being moved

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Wassiliwizky, Eugen

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Erstgutachter

Professor Dr. Stefan Kölsch

Zweitgutachter

Professor Dr. Thomas Jacobsen

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Anicca vata sankhara  
Uppada vaya dhammino  
Uppajhitva nirujjhanti  
Tesam vupasamo sukho.

— Siddhartha Gautama (Buddha)

## Abstract

The present dissertation examines the psychophysiological and neural correlates of being emotionally moved in context of aesthetic experiences. Emotional chills and emotional tears are identified, and experimentally drawn upon, as physiological markers of particularly intense episodes of being moved. In a first step, the connection between emotional chills and being moved is established by means of a film clip rating study. The second study focuses on poetic language. In a series of four experiments that use physiological, behavioral, and fMRI neuroimaging data, poetry is shown to be capable of inducing profound emotional engagement as characterized by subjectively reported chills and objectively recorded piloerection (i.e., goosebumps captured by the goosecam). Moreover, although chills represent highly rewarding experiences for which both previous neuroimaging data on music and the present fMRI results on poetry show activations in the mesolimbic reward circuitry, acquisition of facial electromyographic activity reveals strong effects for the facial indicators of negative affect. This co-activation of negative affect and (aesthetic) pleasure represents a key characteristic of the mixed emotional state of being moved.

The second study also provides insight into the temporal organization of peak emotional experiences that are indexed by chills. Using time course plots of skin conductance and the BOLD response, an independent component of physiological arousal prior to the chill was discovered that is accompanied by increased activation in the nucleus accumbens. These findings are discussed in context of neuroscientific theories on reward, anticipation, and predictive coding. Finally, the distribution of chills across the trajectory of poems reveals compositional principles of poetry.

The third study investigates the relation between emotional piloerection and emotional tears triggered by moving film scenarios. The findings show that both physiological markers of being moved can overlap in time, with no particular order of succession. These overlaps of tears and goosebumps signify the very climax in emotional and physiological arousal. Lastly, based on the results of a formal film analysis, the third study elucidates technical film parameters that facilitate the tears response.

## Zusammenfassung

Die vorliegende Dissertation untersucht die neuronalen und physiologischen Korrelate des emotionalen Bewegtseins im Kontext ästhetischer Erfahrungen. Zur Detektion intensiver Momente des Bewegtseins werden zwei distinkte physiologische Marker verwendet — emotionale Tränen und emotionale Gänsehaut/Schauergefühl. Im ersten Schritt wird die Verbindung zwischen emotionalem Schauergefühl und dem Bewegtsein anhand einer behavioralen Filmstudie etabliert. Die zweite Studie konzentriert sich auf poetische Sprache. In einer Reihe von insgesamt vier Experimenten, die von behavioralen, physiologischen und fMRT Daten Gebrauch machen, deckt diese Untersuchung die emotionale Kraft poetischer Sprache auf, welche nicht nur durch subjektiv erfahrene Schauergefühlsmomente geprägt ist, sondern auch durch objektiv nachweisbare Entstehung emotionaler Gänsehaut (erfasst mithilfe eigens dafür gebauter Gänsehautkamera). Obwohl solche Schauergefühle als ausgesprochen angenehm erlebt werden und mit Aktivierungen im mesolimbischen Belohnungszentrum einhergehen—wie in früheren Musikstudien gezeigt und hier für poetische Sprache repliziert werden konnte—zeigt die Untersuchung des emotionalen Gesichtsausdrucks, dass diese Momente auch von elektromyographischen Indikatoren negativen Affekts begleitet sind. Die gleichzeitige Aktivierung negativer Gefühlsanteile und (ästhetischen) Genusses ist ein zentrales Merkmal des gemischten emotionalen Zustandes des Bewegtseins.

Die zweite Studie verschafft außerdem Einblicke in die zeitliche Organisation intensiver Episoden des Bewegtseins, die von Schauergefühlen begleitet sind. Unter Verwendung von Zeitverlaufskurven des Hautleitwerts und des BOLD Signals wird kurz vor dem Einsetzen des Schauergefühls eine distinkte Komponente im physiologischen Arousal sichtbar, die mit maximaler Aktivierung im nucleus accumbens einhergeht. Diese Befunde werden im Kontext neurowissenschaftlicher Theorien zum Belohnungserleben, Erwartungszuständen und dem Vorhersagesystem diskutiert. Schließlich geben die Verteilungen der Schauergefühlsmomente über die Trajektorie von Gedichten hinweg Aufschlüsse über die kompositorischen Prinzipien poetischer Sprache.

Die dritte Studie untersucht den Zusammenhang zwischen emotionaler Gänsehaut und emotionalen Tränen, die beide durch bewegende Filmszenarien ausgelöst wurden. Die Ergebnisse zeigen, dass beide Indikatoren des Bewegtseins überlappen können, wobei keine bestimmte Reihenfolge ihres Auftretens festgestellt werden konnte. Diese Überlappungen emotionaler Gänsehaut und emotionaler Tränen sind von maximalen Werten physiologischer und emotionaler Erregung gekennzeichnet. Schließlich geben die Ergebnisse einer formalen Filmanalyse Einblick in die technischen Filmparameter, die dem Auslösen emotionaler Tränen zuträglich sind.

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## Authorship

With this statement, I declare that I have written this thesis by my own. Furthermore, I confirm that no other sources have been used other than those specified in the thesis itself. The thoughts taken directly or indirectly from external sources are properly marked as such.

The thesis is based on three publications in different international peer-reviewed journals. I am the primary author of these articles. My role was to conceive the ideas, design the experimental setups, conduct the studies, analyze the data, and to write the manuscripts. Valentin Wagner and Thomas Jacobsen assisted with the statistical analyses of the first and third study, respectively, and revised the manuscripts. Stefan Koelsch provided help and guidance with the fMRI part of the second study and revised the second manuscript. Winfried Menninghaus contributed to the writing process by revising all three manuscripts. All four above-mentioned co-authors assisted with the interpretation of the results and gave feedback throughout the entire process. Jan Heinrich and Manuel Schneiderbauer helped with the stimulus part of the third study. In the course of this dissertation, I co-authored further four articles that are tightly related to the main subject of this thesis.

This thesis was not previously submitted to another academic institution.

### List of first-author publications

Wassiliwizky, E., Wagner, V., Jacobsen, T., & Menninghaus, W. (2015). Art-elicited chills indicate states of being moved. *Psychology of Aesthetics, Creativity, and the Arts*, 9(4), 405-416.

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Wassiliwizky, E., Jacobsen, T., Heinrich, J., Schneiderbauer, M., & Menninghaus, W. (2017). Tears falling on goosebumps: Co-occurrence of emotional lacrimation and emotional piloerection indicates a psychophysiological climax in emotional arousal. *Frontiers in Psychology*, 8, 41.

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# Chapter 1: Introduction

## 1.1 What is being moved?

Moving like a wild river, its force is irresistible.

— Marcus Tullius Cicero

*Orator*

In many regards, being moved is a remarkable emotional state. Since antiquity, it has been claimed that being moved can strongly influence human decision making, motivate action, and serve as a source of aesthetic pleasure. The first two functions have been central for the treatises of the Roman orator Marcus Tullius Cicero who regarded being moved, or *movere* as he called it, as one of the three pillars of a powerful speech (along with *docere* and *delectare*, i.e., to inform and to please the audience; [55 B.C.] 2014; 2, 115). In his writings, Cicero notes repeatedly that moving the listeners—in his cases usually judges in a court—is a potent tool in order to take influence on the outcome of the verdict. For instance, in *De oratore* ([55 B.C.] 2014; 2, 129), Cicero states: *It is necessary that someone who is to decide in our favor must either have a natural inclination towards us, or be won by arguments, or be forced by moving his soul* (own translation). Many public speeches that motivate actions of resistance, fighting for civil rights, or even going to war are examples of the powers of emotionally moving an audience, powers that also allow for demagogic misuses. Contrary to cases of being moved by rhetorical speeches, being moved by artworks does not seem to serve any pragmatic purpose whatsoever. Here, the self-rewarding experiential dimension of being moved is most pronounced and largely disconnected from pragmatic aspects of communication. The present thesis focuses primarily on this self-rewarding capacity of being moved. It explores its physiological and neural basis, identifies stimulus characteristics that facilitate its elicitation, and discusses potential evolutionary functions.

Despite its long-standing tradition in the humanities and arts, being moved has rarely been accounted for in psychological catalogues of emotions, let alone investigated by empirical approaches (Tan, 2009). Surprisingly, the rising of young disciplines such as psychology of emotion, affective neurosciences, and neuroaesthetics has changed little about the neglected role of being moved in scientific research. First attempts to outline its main characteristics have chosen a linguistic approach aimed at the conceptual representation of this emotion in the language use of a large sample (Kuehnast, Wagner, Wassiliwizky, Jacobsen, Menninghaus, 2014). The key findings of this investigation confirmed the variety of different contexts in which being moved can be elicited, with significant relationships and critical life events of high personal relevance (birth, death, marriage, reunion) as well as artworks (film and music) representing the most powerful elicitors. Moreover, being moved has been associated with a coactivation of two antithetical emotional ingredients — sadness and joy, which replicates earlier reports on the mixed affective nature of the emotional state of *kandoh*, a Japanese equivalent of being moved (Tokaji, 2003). Finally, terms related to bodily changes and facial expressions (crying, tears, laughing, smiling) yielded a predominantly high level of salience in the conceptual representation within the sample.

A second series of verbal self-report studies conducted by the same group (Menninghaus, Wagner, Hanich, Wassiliwizky, Kuehnast, Jacobsen, 2015) replicated all three key findings although the authors used a different methodological approach than Kuehnast et al. (2014), i.e., closed questionnaires instead of free-associations. Additionally, the investigation by Menninghaus and colleagues (2015) identified a strong link between states of being moved states and a witnessing position of the person

who is moved, along with a high relevance of cognitive appraisals of compatibility with self-ideals, social norms, and prosocial behavior. Thus, artworks appear to rank among the most potent elicitors of being moved, as they typically imply a witnessing position of the audience, involvement of a variety of intense and often negative emotions (Menninghaus, Wagner, Hanich, Wassiliwizky, Jacobsen, Koelsch, 2017), and a strong focus on social interactions, particularly in narrative genres.

## 1.2 Chills and being moved

The recurrent findings of an intensely felt bodily component in states of being moved suggest a link to the research on music-elicited *peak-emotional-experiences* that are accompanied by chills, thrills, shivers-down-the-spine, frissons, or goosebumps<sup>1</sup> (among many others, Goldstein, 1980; Panksepp, 1995; Blood & Zatorre, 2001; Rickard, 2004; Grewe, Nagel, Kopiez, Altenmüller, 2007; Benedek & Kaernbach, 2011; Salimpoor, Benovoy, Larcher, Dagher, Zatorre, 2011). Emotional chills are defined as pleasurable bursts of emotional arousal with a clearly felt on- and offset. This makes them ideal targets for empirical research on otherwise highly subjective and hard-to-grasp emotional responses to artworks. Recent developments of optical devices that videotape the erection of body hair (the “goosecam”, Benedek, Wilfling, Lukas-Wolfbauer, Katur, Kaernbach, 2010) go even further in objectifying the chill response. Importantly, by using relatively vague terms such as “musical emotions” or “heightened emotions”, most of the literature on chills and peak-emotional-experiences has typically avoided to define the actual emotion that reaches its peak when chills occur. What is more, this terminology confines emotional chills to the domain of music. If, however, emotional chills represent physiological markers of intense states of being moved (as the findings of Kuehnast et al., 2014 and Menninghaus et al., 2015 suggest), one should find them in response to a broad range of elicitors that are capable of inducing states of being moved. This hypothesis guides the present studies. They aim at investigating emotional chills outside of the musical domain and to connect them to the recent findings on being moved. The first study was designed to answer the first research question:

### **RQ1: Do art-elicited chills indicate states of being moved?**

The two goals of this study were to investigate a potential correlation between film-elicited chills and states of being moved, and to compare the predictive power of being moved ratings for chills with those of pure sadness and pure joy, as these latter two emotions have repeatedly been shown to represent emotional building blocks of being moved (Tokaji, 2003; Kuehnast et al., 2014; Menninghaus et al., 2015). Importantly, in contrast to their 'pure' variants, sadness and joy that are embedded in episodes of being moved are co-activated, with one emotion dominating over the other. This predominance determines whether the resulting mixed emotional state of being moved is rather of the *sadly moving* type, such as in response to scenarios of funeral eulogies, or of the *joyfully moving* type, such as in response to reunion scenarios (Menninghaus et al., 2015). Both scenarios, however, also contain shares of the opposite emotional antidote (e.g., commemoration of the deceased person in a funeral eulogy or the reactivation of the painful separation before the reunion). Moreover, both sadness and joy that are embedded in episodes of being moved are experienced from a witnessing position and with a high salience of cognitive appraisals of compatibility with social norms, as outlined above.

These additional factors set the purely negative emotion of sadness, as experienced in situations of great loss, apart from being sadly moved, which always involves some pleasurable dimensions (Hanich, Wagner, Shah, Jacobsen, Menninghaus, 2014) and motivates further attending or approaching behavior

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<sup>1</sup> all these terms are used interchangeably in the pertinent literature; however, later we will present evidence that suggests to distinguish between some of these phenomena

(Menninghaus et al., 2015). Critically, this line of thinking implies that the enjoyment of sadness in response to artworks (for empirical evidence, see Oliver, 1993; Hanich et al., 2014; Taruffi & Koelsch, 2014; Brattico, Bogert, Alluri, Tervaniemi, Eerola, & Jacobsen, 2016) is only pleasurable if the sadness is embedded in an episode of being moved. In other words, sadness per se should show no positive relation to enjoyment; it can only contribute to enjoyment by fueling the intensity of being moved. This constitutes the second research question:

**RQ2a: Is the positive relation between sadness and enjoyment mediated by being moved?**

A study by Hanich et al. (2014) has presented first empirical evidence in favor of this hypothesis; it did so by means of performing a mediation analysis for ratings obtained in response to different variants of one and the same saddening scenario (a character or a group of characters learns about the death of a close person). The present investigation seeks to broaden the repertoire of emotional antecedents by including different saddening scenarios and also by including joyfully moving scenarios. The latter diversification allows a similar mediation analysis with joy instead of sadness as the independent variable. This leads to the second part of the second research question:

**RQ2b: Is the positive relation between joy and enjoyment mediated by being moved?**

### 1.3 Chills in response to poetry

The next study used an elicitor of emotional chills that had not been empirically investigated in this capacity before – poetry. Given both the hypothesis that art-elicited chills indicate states of being moved and the empirical evidence that poems are capable of inducing states of being moved (Menninghaus, Wagner, Wassiliwizky, Jacobsen, Knoop, 2017), the research question was:

**RQ3: Are poems capable of inducing emotional chills?**

The broader aim of this study was to investigate in more detail particular properties of the chill response. Specifically, it is important to know how chills behave in experimental paradigms that use stimulus repetitions. Some studies have used the same stimuli multiple times within one study but in different experimental settings (physiological session, PET-session [Positron-Emission-Tomography], and fMRI-session [functional Magnetic Resonance Imaging]), assuming a stability of the chill response over repeated exposure (Salimpoor et al., 2011). This assumption, however, awaits empirical evidence. Moreover, a widely held assumption in the literature states that the elicitation of chills is bound to high degrees of familiarity with the stimulus (Blood & Zatorre, 2001; Rickard, 2004; Grewe et al., 2007; Salimpoor et al., 2009 & 2011; Benedek & Kaernbach, 2011; Sumpf et al., 2015). However, intense states of being moved have been shown to be experienced in response to stimuli that are presented for the very first time (Hanich et al., 2014). Combining this evidence with the hypothesis that art-elicited chills indicate intense states of being moved, suggests that chills can well be elicited in response to unfamiliar stimuli.

**RQ4: Is the elicitation of chills bound to high degrees of familiarity?**

To operationalize this research question, two sets of different stimuli were used: highly familiar poems, self-selected individually by the participants, and experimenter-selected poems. In the latter case, familiarity ratings were collected.

Finally, in the pertinent literature, chills are referred to by different terms, such as thrills, shivers-down-the-spine, frissons, or goosebumps (the technical terms for the latter being *piloerection*, Benedek and Kaernbach, 2011). This inconsistent terminology is a potential case for jingle-and-jangle-fallacies

(Lilienfeld, Sauvigné, Lynn, Cautin, Lutzman, Waldman, 2015), i.e., the error of referring to different concepts by the same name (jingle fallacy) and the error of referring to the same concept by different names (jangle fallacy). Whereas the terms *chills*, *thrills*, and *frissons* all designate a subjective experience, the terms *goosebumps* or *piloerection* refer to a visible response that can be verified objectively (Benedek et al., 2010). It is therefore important to clarify whether subjectively felt chills differ from objectively measured goosebumps.

#### **RQ5: Are chills different from goosebumps?**

More specifically, the goal was to explore whether chills—as indicated by button presses of the participant—behave differently in response to repeated exposure than goosebumps, which are measured objectively by the goosecam<sup>2</sup>. A potential difference in the physiological correlates, such as a habituation effect for only one of the responses, would point to a conceptual difference between these two phenomena.

Using stimuli other than pieces of music, opens up further possibilities to investigate specific properties of the chill response by comparing them across domains. For instance, it has been shown that music-elicited chills are mediated by the subcortical primary reward circuitry (Blood & Zatorre, 2011; Salimpoor et al., 2011) and thus by structures that are associated with experiencing pleasure to biological reinforcers (food, drink, sex). It is well documented that the same brain areas are also affected in drug abuse and chemical substance dependency (Dagher, Bleicher, Aston, Gunn, Clarke, Cumming, 2001; Boileau, Assaad, Pihl, Benkelfat, Leyton et al., 2003; Cox, Benkelfat, Dagher, Delaney, Durand et al., 2009). The involvement of this phylogenetically ancient and basic system in substance-dependent behavior helped greatly to explain the powerful effects of both drug consumption and withdrawal from it. The discovery that music could likewise have access to this system (without the detrimental consequences of drug abuse) was an important step in understanding the ubiquitous presence of music in all cultures around the globe and its long-standing history (Zatorre & Salimpoor, 2013; Koelsch, 2014)<sup>3</sup>. Poetic language, however, is likewise an ancient, cross-cultural, and emotionally powerful variety within the human communicative and expressive repertoire (Schrott, 2009). If RQ3 (Are poems capable of inducing emotional chills?) is answered positively, an almost imperative following research question arises:

#### **RQ6: Which brain structures underlie poetry-elicited chills and do they differ from neural correlates of music-elicited chills?**

In order to answer this question, it is important to make sure that the experimental design and the data analysis of the current investigation is directly comparable to those employed in the respective studies in the musical domain (Blood & Zatorre, 2001; Salimpoor et al., 2011), e.g., by obtaining emotional intensity ratings in order to identify neutral periods that can later be contrasted with the chills episodes.

Finally, in order to arrive at a more comprehensive understanding of emotional chills, it is crucial not just to report the effects on the brain and body but also to investigate the properties of the stimulus that are critical for an explanation of how these responses are produced. Musical psychologists have put repeated efforts in defining acoustic features that trigger, or at least facilitate, the chill response. For example, it has been shown that sudden crescendi, unprepared harmonies, delays of harmonic

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<sup>2</sup> In the following, only these two concepts will be used, with *chills* referring to the responses as indicated by the participant and *goosebumps* as evidenced by the goosecam. (Piloerection will be used as a synonym for goosebumps.)

<sup>3</sup> Jacobs extended this idea in his *Panksepp-Jakobson-Hypothesis* (2015) by suggesting that due to the rapid development of human aesthetic expressions, the brain processes related to art reception draw on already established neural circuitries which evolved over millennia in the course of mammalian phylogenetic history.

resolutions, or violations of expectations in general, as well as the entries of a solo voice are conducive to the elicitation of music-evoked chills (Sloboda, 1991; Guhn et al., 2007; Huron & Margulis, 2010). A similar research agenda arises for poetry-evoked chills:

**RQ7: Which specific features of poetic language facilitate emotional chills?**

Importantly, in answering this question it is crucial to identify the features that are specific to poetic language itself and not to the medium by which the poem is presented, e.g., the voice of the performer including emotional prosody and other acoustic parameters that are known to have an influence on the emotional state of the listener (Rigoulot, Wassiliwizky, Pell, 2013). In other words, the identified chills-driving features should yield the same effect in responses to (professional) recitations and in (silent) self-reading of the same poems.

## 1.4 Interrelation between emotional goosebumps and emotional tears

Emotional chills and goosebumps are, however, not the only correlate of peaking states of being moved. Similarly, emotional tears have been claimed to be physiological markers of intense states of being moved (Scherer & Zentner, 2001; Scherer et al., 2002; Hanich et al., 2014; Kuehnast et al., 2014). However, although both responses have been related to the emotion under scrutiny, details about their temporal occurrence and the levels of physiological arousal associated with them have remained unknown. In other words, is it possible to shed tears and have goosebumps at a time? And does the emotional arousal in such cases reach higher amplitudes than for tears only and goosebumps only? Or does one always precede the other? These are non-trivial questions, because both responses are governed by two antagonistic branches of the autonomous nervous system (ANS). Whereas the pilomotor reflex, that causes the body hair to erect, is controlled exclusively by the sympathetic nervous system (Hellmann, 1963), the release of tears from the lacrimal glands is mediated by the parasympathetic nervous system (Werb, 1983; Dart, 2009). The classical view of these branches is that their activations alternate in time (Pape, Kurz, & Silbernagl, 2014), since the sympathicus is closely related to mobilization (fight-and-flight system), whereas the parasympathicus is known to be involved in regeneration processes (rest-and-digest system). Empirical evidence for a co-activation of these systems, or a particular activation-choreography, would provide new insights into the complex physiological orchestration of being moved.

**RQ8: How do emotional goosebumps interrelate with emotional tears?**

As film stimuli have been demonstrated repeatedly to be among the most powerful elicitors of emotional tears (Frey, DeSota-Johnson, Hoffmann, & McCall, 1981; Kraemer & Hastrup, 1988; Gross, Fredrickson, & Levenson, 1994), the third study followed this line of research. However, similarly as in the case of poetic language, it also aimed to understand which properties of the stimulus are critical for the elicitation of tears.

**RQ9: Which technical features of film making facilitate emotional tears?**

Because a selection of tears-eliciting stimuli by the experimenter could bias the outcomes of such an analysis and because it could also fail in some cases to reliably induce emotional tears, this study intended to rely entirely on film clips that were self-selected by the participants.

## Chapter 2: The link between chills and being moved

### 2.1 Preface

Chapter 2 reports the first study which investigated a potential link between emotional chills and peaking states of being moved (RQ1). Furthermore, it examined whether and to what extent being moved mediates the effect of sadness on enjoyment (RQ2a) as well as the effect of joy on enjoyment (RQ2b). The manuscript was published in *Psychology of Aesthetics, Creativity, and the Arts*: Wassiliwizky, E., Wagner, V., Jacobsen, T., & Menninghaus, W. (2015). Art-elicited chills indicate states of being moved. *Psychology of Aesthetics, Creativity, and the Arts*, 9(4), 405–416. The following text contains the postprint version of this article.

### 2.2 Abstract<sup>4</sup>

Following suggestions by Benedek and Kaernbach (2011), we investigated the hypothesis that art-elicited chills might indicate emotional states of being moved. We focused on two prototypical variants of being moved: one involving sadness as a key component, and the other joy. Thirty participants watched 25 moving film excerpts of either the sadly or the joyfully moving type (e.g., farewell scenarios and reunion scenarios, respectively). They rated how sad, how joyful, and how moved they felt after each film clip, and how much they enjoyed it. They also reported whether or not they experienced chills during the exposure. Multi-level mediation analyses showed that the relation between sadness and enjoyment was almost fully mediated by being moved, whereas no such mediation effect was found for the relation between joy and enjoyment. The results of a logistic regression revealed that the higher the intensity of episodes of being moved, the more likely they were to be accompanied by chills. Moreover, being moved proved to be the best predictor for chills, compared to sadness and joy. Finally, we discuss the importance of distinguishing chills in general from art-elicited chills in particular, as well as the importance of identifying the emotion that underlies art-elicited chills.

**Keywords:** art-elicited chills; being moved; sadness; joy; film

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## 2.3 Introduction

*It was like for a moment, O my brothers, some great bird had flown into the milk bar and I felt all the little hairs on my plott [Russian for body] standing endwise, and the shivers crawling up like slow lizards and then down again. Because I knew what she sang.*  
*It was a bit from the glorious 9th, by Ludwig van.*  
—A Clockwork Orange

In this passage from Kubrick's famous movie *A Clockwork Orange* (based on Anthony Burgess's novel of the same title), the main character Alex portrays in his characteristic fashion an experience that has come to be known in psychological literature as an *aesthetic chill*<sup>5</sup> (e.g., McCrae, 2007; Silvia & Nusbaum, 2011). Goldstein (1980) was the first to study chill responses in contexts of art reception. He understood chills as a physiological concomitant of strong, mainly positive emotions. Following up on this seminal work, several studies have focused almost exclusively on musical stimuli (among many others, Blood & Zatorre, 2001; Guhn, Hamm, & Zentner, 2007; Panksepp, 1995; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011; Sloboda, 1991), thereby giving the impression that only music is capable of inducing chills. To amend this impression, in the present study, we used film stimuli—and hence an art form that is essentially based on narrative plot—to elicit chills<sup>6</sup>. Moreover, previous studies focusing on chills typically circumnavigate a thorough definition of the emotional state that may underlie art-elicited chills by using vague terms such as *musical emotion*, *heightened emotion*, *peak-emotional-experience*, or *unusual aesthetic state*, a maneuver that has been criticized repeatedly (Grewe et al., 2007; Konečni, 2008). Despite the absence of an explicit label for the emotional state underlying chills, however, authors have generally agreed on an inherently pleasurable, rewarding quality of this emotional response (Benedek & Kaernbach, 2011; Blood & Zatorre, 2001; Goldstein, 1980; Grewe et al., 2007; Grewe, Kopiez, & Altenmüller, 2009; Konečni, 2005; Salimpoor et al., 2011).

An exception is Panksepp's study (1995) on chills in response to sad vs. happy songs. Panksepp discovered that sad songs were more effective in eliciting chills than happy songs; this led him to conclude that *sadness* is more likely to underlie art-elicited chills than joy or happiness. However, this understanding appears to be at odds with the pleasurable quality associated with the experience of art-elicited chills and does not provide an answer to the puzzling question of why prototypical sadness should become pleasurable (cf. Benedek & Kaernbach, 2011; Nusbaum, Silvia, Beaty, Burgin, Hodges, & Kwapil, 2014). The situational framing effect of an aesthetic context could be one explanation; thus, cognitive framing studies have shown that the very same photographs of negative emotional content are met with more positive affect and higher ratings for aesthetic liking if they are presented as art photography rather than documentary photographs (Gerger, Leder, & Kremer, 2014; Wagner, Menninghaus, Hanich, & Jacobsen, 2014). A different, though by no means mutually exclusive explanation for the apparent paradox is offered by a study by Hanich, Wagner, Shah, Jacobsen, & Menninghaus (2014). The authors found that art-elicited sadness contributed to positive affect and

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<sup>5</sup> Also referred to as a *frisson*, a *thrill*, a *shiver down the spine*, as well as *goose bumps* and *emotional piloerection*, the latter two terms representing a visible physiological correlate on the skin surface. Notably, all empirical studies that have actually induced chills in the lab relied on artworks as stimuli, as does ours. In order to caution against any unsubstantiated generalization beyond art reception, we therefore speak of *art-elicited chills*.

<sup>6</sup> Please note that we draw on a broad concept of art that includes mainstream entertainment films; this is fully in line with groundbreaking literature in film studies and film theory (Arnheim, 1957; Bordwell & Thomson, 2010; Kracauer, 1997).



aesthetic appreciation only because it was experienced in conjunction with—and mediated by—feelings of *being moved*. Expanding on these findings and connecting them to the literature on chills, the present study advocates the hypothesis that being moved is the emotion that may generally underlie art-elicited chills.<sup>7</sup> This has already been suggested by Benedek and Kaernbach (2011)<sup>8</sup>. The association between chills and being moved has also been put forward by Konečni (2005; Konečni, Wanic, & Brown, 2007). Moreover, several studies have indirectly acknowledged this association by characterizing the eliciting stimuli as moving (e.g., Fukui & Toyoshima, 2014; Goldstein, 1980; Maruskin et al., 2012; Panksepp, 1995; Panksepp & Bernatzky, 2002; Rickard, 2004). However, in line with recent research on being moved (Kuehnast, Wagner, Wassiliwizky, Jacobsen, & Menninghaus, 2014; Menninghaus, Wagner, Hanich, Wassiliwizky, Kuehnast, Jacobsen, 2015), we argue that being moved is in fact a distinct emotional episode and that the chill response needs to be understood in light of this emotional state rather than through reference to a mere stimulus quality.

**Being moved.** Since the appearance of ancient Latin rhetoric and poetics, emotionally moving an audience (lat. *movere*) has ranked among the key goals of the arts, especially of the so-called serious art genres such as sacred music, opera, and tragedy. In 18<sup>th</sup>-century aesthetics, the state of being moved became especially important for conceptualizing the pleasure associated with representations of great life challenges and considerable suffering. Numerous authors have advocated the position that episodes of being moved are inherently self-rewarding, even when they involve readers—or onlookers—in intense negative emotions such as sadness, pity, or worry regarding the main character (cf. Descartes, [1645] 1835; Hume, [1757] 1793; Schiller, [1792] 2006).<sup>9</sup> Importantly, feelings of being moved do not seem to counteract or compensate for negative emotions, but seem rather to integrate them into an overall pleasurable emotional episode. Once feelings of being moved arise, the overall emotional experience becomes a source of pleasure and hence motivates the observer to continue rather than discontinue the exposure and to eventually seek repeated exposure (i.e., approaching behavior; cf. Hanich et al., 2014). Today, emotionally moving an audience continues to be a key objective of the arts. Ads promising a “moving book” or a “deeply moving film” are fairly common. Moreover, as the great success of melodramatic films such as *Titanic* (1997) and *Forrest Gump* (1994) indicates, being moved is still considered an overall positive emotion even in the context of very sad plots (Hanich et al., 2014). Overall, very little empirical work has been devoted to the emotional state of being moved (cf. Tan, 2009). In a first attempt to identify the prototypical emotions that may be experienced along with feelings of being moved, Tokaji (2003) asked 224 participants which emotions are predominant in episodes of being moved. Sadness and joy were the most frequently listed emotions; these findings have been replicated by Kuehnast et al. (2014) as well as by Menninghaus et al. (2015), using different methodological approaches. Sadness and joy were also the two target emotions studied by Panksepp

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<sup>7</sup> Our study focuses exclusively on art-elicited chills that are readily described as pleasurable (e.g., Blood & Zatorre, 2001; Panksepp, 1995; Salimpoor et al., 2011). We are aware of other types of chills that can occur in responses to threats and danger (Maruskin et al., 2012) and thus are physiological correlates of aversive emotions and avoidance behavior.

<sup>8</sup> Note that Benedek and Kaernbach used the term piloerection and specifically linked piloerection to states of being moved. They recorded piloerection via an optical recording device and measured concomitant physiological changes in response to musical stimuli and filmic sound tracks. At the same time, they suggested that “the study of emotional piloerection (i.e., goose bumps) is tightly linked to the study of chills.” which are considered to represent the subjective experience of the same event. We therefore, generalize Benedek and Kaernbach’s suggestion to chills.

<sup>9</sup> None of these treatises, however, mentioned chills or any other physiological correlates associated with states of being moved.

(1995) in the context of art-elicited chills (for similar findings, see Nusbaum et al., 2014). However, Panksepp did not explicitly refer to the state of being moved—or of *being sadly moved* or *being joyfully moved*, as we prefer to conceptualize it. This categorization identifies the predominant emotional ingredient (i.e., sadness or joy), while also emphasizing its integration into an episode of being moved. Given that sadness and joy seem to be among the preeminent emotions in episodes of art-elicited chills as well as in episodes of being moved, we used both sadly and joyfully moving film clips in the present study. In order to test our hypothesis that being moved is the preeminent factor for the elicitation of chills, we asked the participants separately how sad, how joyful, and how moved they felt after each film clip. We also explored which emotion terms film viewers use spontaneously when they are not instructed about the target emotions and not presented with predetermined adjective scales. In other words, in a free verbal response condition, do film viewers use the words *sad* and *joyful* (or synonyms thereof, such as *depressed*, *down*, *glad*, *cheerful*) to designate the predominant emotion they experience in episodes of being moved? And do they additionally use terms such as *moved*, *touched*, and *deeply moved*,<sup>10</sup> or even a combination of both, like *sad and moved* or *joyful and moved*?

**Moving scenarios.** Importantly, feelings of being moved are bipolar not just with regard to their two prototypes (being sadly vs. joyfully moved), but likewise with regard to inherent features of each of these prototypes. For instance, sadly moving episodes were found to imply *positive emotional antidotes* that are frequently associated with prosocial norms and self-ideals, with a character embodying great courage, empathy, selflessness or showing high esteem for a deceased person (Benedek & Kaernbach, 2011; Hanich et al., 2014; Konečni, 2005; Kuehnast et al., 2014; Menninghaus et al. (2015); Tan, 2009; Tokaji, 2003). Thus, the affective composition of being moved comprises a predominant emotion such as sadness *and* an affectively positive emotional antidote such as prosocial emotions. Panksepp (1995) also related his findings on sad songs and the concomitant elicitation of chills to the sudden arousal of social emotions and social bonding.

Inversely, being joyfully moved implies a discrete awareness of some difficulty or plight that is eventually overcome by the protagonist, and hence a *negative emotional antidote* (Menninghaus et al., 2015; Tan, 2009). Hence, in joyfully moving moments a positively evaluated, uplifting event dominates the scene (eliciting joy as a predominant emotion); yet it only becomes moving because either some negatively evaluated memories of a preceding unhappy state are reactivated or some saddening aspects of the scene itself are blended with the positive event. Thus, a forgiveness scenario derives its moving power from past conflicts and difficulties that we still need to keep in mind when watching the positive social event. Similarly, the moving power of a reunion scenario arises from remembering the previous painful separation of the characters. Although these examples imply a linear succession of the opposite emotional building blocks, we assume that the preceding affective component has to be reactivated, or retained, and blended with a temporally subsequent component of opposite valence in order for a mixed-emotional episode of being moved to occur. Thus, even in temporally successive trajectories opposite emotional building blocks can be co-activated by means of oscillation-like feedback loops (cf. Norris, Gollan, Berntson, & Cacioppo, 2010). This has been shown in a close analysis by Hanich and Menninghaus (in press) of a sadly moving excerpt from *21 Grams* (2003), a film which was also included as a stimulus in the present study.

In a nutshell, we suggest that the affective nature of joyfully moving scenarios stages “a positive foreground against a negative background,” and that the reverse holds true for sadly moving scenarios, which have “a negative foreground against a positive background.” The movie clips used in the present

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<sup>10</sup> In German, *being deeply moved* is a stand-alone word (*ergriffen*), distinct from *being moved* (*bewegt*).

study were selected to feature these complementary emotional patterns. The ratings we collected for how sad, how joyful, and how moved participants felt after viewing each film clip also served as a manipulation check for this categorization. We expected significant differences in sadness and joy between the two stimulus subsets, but no significant difference regarding being moved. The free, spontaneous responses were likewise used to provide additional evidence for our assignment of the film clips to the sad or the joyful stimulus subsets.

**Mediation of being moved.** In a recent rating study that used 38 film clips that all focused on one saddening scenario (a character or a group of characters learns about the death of a close person), Hanich et al. (2014) showed that the strong positive correlation between sadness and enjoyment (as estimated by participants' ratings of their motivation to watch the entire movie) was almost fully mediated by being moved. While adopting the general experimental design from Hanich et al. (2014) the present study draws on both a broader repertoire of emotional antecedents and a broader variance in emotional responses by including (a) different sadly moving scenarios such as farewell scenes, funeral eulogies, and deathbed scenes, and (b) joyfully moving scenarios such as forgiveness, victory, reunions, and declaration-of-love scenarios. However, in spite of using different sadly moving scenarios, we expected to replicate the results of the mediation analysis in Hanich et al. (2014), thereby showing the robustness of the mediation effect of being moved. Moreover, conducting a similar mediation analysis with joy as the independent variable, we wanted to test whether the effect of felt joy on enjoyment can likewise be partially explained by mediation through the feeling of being moved. Given, however, that joy—in contrast to sadness—is a pleasant emotion and capable of motivating viewers to seek prolonged or repeated exposure by itself (Burgdorf & Panksepp, 2006; Fredrickson, 2004; Frijda, Kuipers, & ter Schure, 1989), we expected a weaker mediation of being moved in this case.

In sum, the present study pursued two main objectives. First, we hypothesized that chills elicited by sadly and joyfully moving film clips should correlate positively with the intensity of being moved. Moreover, we expected the ratings for being moved to be a better predictor for the occurrence of chills than those for mere sadness or mere joy. Our second hypothesis was that the positive effect of sadness on enjoyment should be mediated by being moved. Additionally, we explored whether and to what extent being moved likewise mediates the effect of joy on enjoyment.

## 2.4 Experiment

**Participants.** In total, 30 participants (14 male, 16 female), all of them students of different disciplines, were recruited for “a study on emotional film moments,” as we called it in the advertisement. The participants were explicitly told that participation was fully voluntary. They all reported themselves to be native speakers of German. Their ages ranged from 18 to 45 years ( $M = 29.06$ ;  $SD = 6.79$ ). Before the study, participants gave their informed consent. At the end of the study, they received 15 EUR as compensation for their participation.

**Stimuli.** As a first step, a large set of nearly 200 moving film clips was gathered, based on several lists on different Internet platforms ranking the most moving film scenes and also on our own expertise. The first selection round eliminated all clips that were longer than five minutes. Next, clips with too complex a narrative structure, that is, one that could not be easily summarized in a synopsis, were excluded. Following that, the clips were categorized as being joyfully or sadly moving. Finally, six experienced judges rated the remaining 40 clips in a paper-and-pencil study that used a slightly modified version of the experimental questionnaire. Based on these ratings, we identified clips with different degrees of

sadness, joy, and being moved to ensure sufficient variance in emotional intensity. Eventually, the final selection of 13 sadly and 12 joyfully moving film clips included different types of scenarios (such as a family reunion, a declaration of love, forgiveness, or the death of a partner), each comprising at most three clips, with an average length of 146 seconds (for a complete list of all film clips, see the Appendix). To smooth the transitions at the beginning and end of each clip, we added two-second black fade-ins and fade-outs. Additionally, each video file was preceded by a short, simple spoken synopsis of the corresponding movie (duration  $M = 50$  s,  $SD = 17$  s), accompanied by a black screen, in order to provide essential information about the overall storyline. These synopses were read by a professional newsreader and recorded in a professional recording studio, and they were digitized at a sampling rate of 48 kHz.

**Film Clip Questionnaire.** The questionnaire used for this study consisted of three main parts. The first addressed the participants' emotional responses, the second their chill responses, and the third the participants' level of enjoyment. While the second and third parts of the questionnaire were the same for all participants, different versions of the first part were designed for the *rating* and the *free-listing* conditions.

In the *rating* condition, following each film clip, participants had to rate their emotional response on twelve 5-point-Likert scales (anchored at 1 with *a little* and at 5 with *strongly*) that were introduced with the words *I felt...* The participants also had the option of reporting that they experienced no emotions whatsoever. The items were arranged in ten versions with different orders, to avoid sequence effects. We measured sadness, joy, and being moved with multiple items by providing several synonyms for all three emotional categories to ensure a higher reliability of our three relevant emotion constructs. For sadness we used *sad* (*traurig*), *depressed* (*deprimiert*), *downcast* (*betrübt*), and *shattered* (*erschüttert*); for joy we used *cheerful* (*fröhlich*), *merry* (*heiter*), *delighted* (*erfreut*), and *amused* (*belustigt*); and for being moved we used *moved* (*bewegt*), *touched* (*gerührt*), *deeply moved* (*ergriffen*), and *excited* (*aufgeregt*). After the experiment, we conducted an item reliability analysis to test the homogeneity of each item group. This led us to decide to leave out the items *amused* and *excited*, as these items had the lowest corrected item-total correlations and a diminished Cronbach's alpha (see Supplemental Material, Tab. S1). The Cronbach's alphas for the aggregated scales that were used in the further analyses were as follows: Sadness: 0.77; Joy: 0.71; Being Moved: 0.79.

In the *free-listing* condition, participants were asked to indicate in an open format which emotion they had felt when watching each film clip. Importantly, participants in this condition were given no instructions regarding the target emotions beforehand. To prime an adjectival response (as in the *rating* condition), participants were prompted to complete the sentence *I felt...*—which in German (*Ich fühlte mich...*) requires an adjectival continuation.

In the second part of the questionnaire, we asked whether participants had experienced chills or goose bumps while watching the film clip. (We also asked participants to identify on a given list the body part(s) where the chills occurred; the results are reported in the Supplemental Material.) Note that in the present study we did not differentiate between chills and goose bumps (i.e. the visible piloerection) since we did not want to overburden our participants by asking them to give two independent ratings for these highly similar phenomena (cf. Benedek & Kaernbach, 2011).

Finally, participants were asked to rate their motivation to watch the entire movie (anchored at 1 with *not at all* and at 5 with *very much*) and to report whether they had seen the entire movie or the scene in question before. Note that the motivation rating was used as a proxy for an enjoyment rating, since straightforwardly asking participants how much they enjoyed or liked a clip has been shown to be

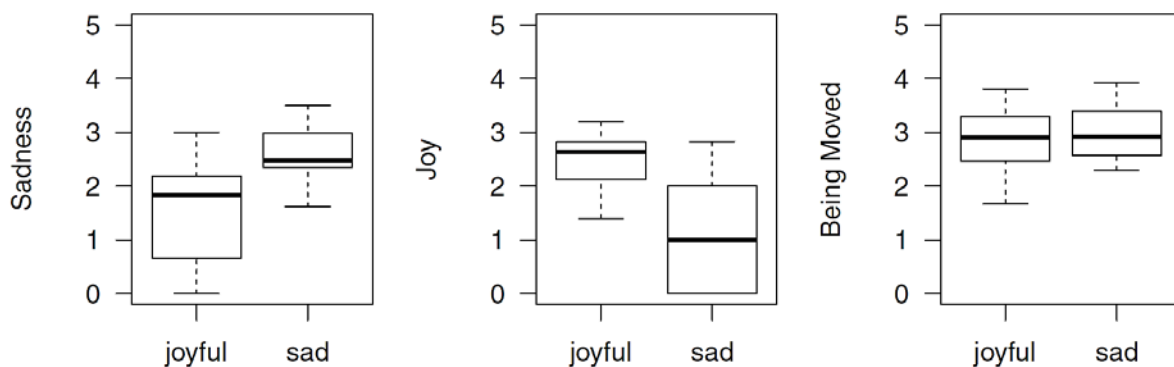
inappropriate wording for collecting affectively positive dimensions of responses to witnessing someone experiencing a deeply sad event (Hanich et al., 2014). People apparently feel that they should not indicate that they enjoyed the representation of someone else's plight. In contrast, seeking repeated exposure to a piece of music or a poem is a typical motivational outcome of aesthetic liking, as is staying tuned to a TV or radio channel rather than switching to another. Please note that in the following the variable in question will be referred to as *enjoyment* although technically speaking the motivation to watch the entire movie has been measured.

**Design and Procedure.** Participants were randomly assigned to the two conditions *rating* (15 participants) and *free-listing* (15 participants). The experiment was administered in four groups, with seven to eight participants per group. The order of the clips was randomized across the four groups. The testing took roughly two hours and was performed in a university lecture hall. Participants were seated far apart from one another in order to limit social interaction effects.

Before the experiment, each participant completed a questionnaire to establish basic demographic information such as age, gender, and native language. After the instructions were presented and participants were given a practice trial and an opportunity to ask questions, the actual study began. The lights were dimmed and the first film clip, introduced by the audio synopsis, was presented to the audience (via video projection on a large screen and an adequate sound system). Then the lights were brought back up and the participants were given two minutes to complete the film-clip questionnaire. This procedure was repeated 25 times.

## 2.5 Results

**Manipulation check.** All analyses were conducted in R (R Development Core Team, 2013). To test the categorization of the clips as sadly or joyfully moving, we conducted t-tests for the aggregated scales Sadness, Joy, and Being Moved.

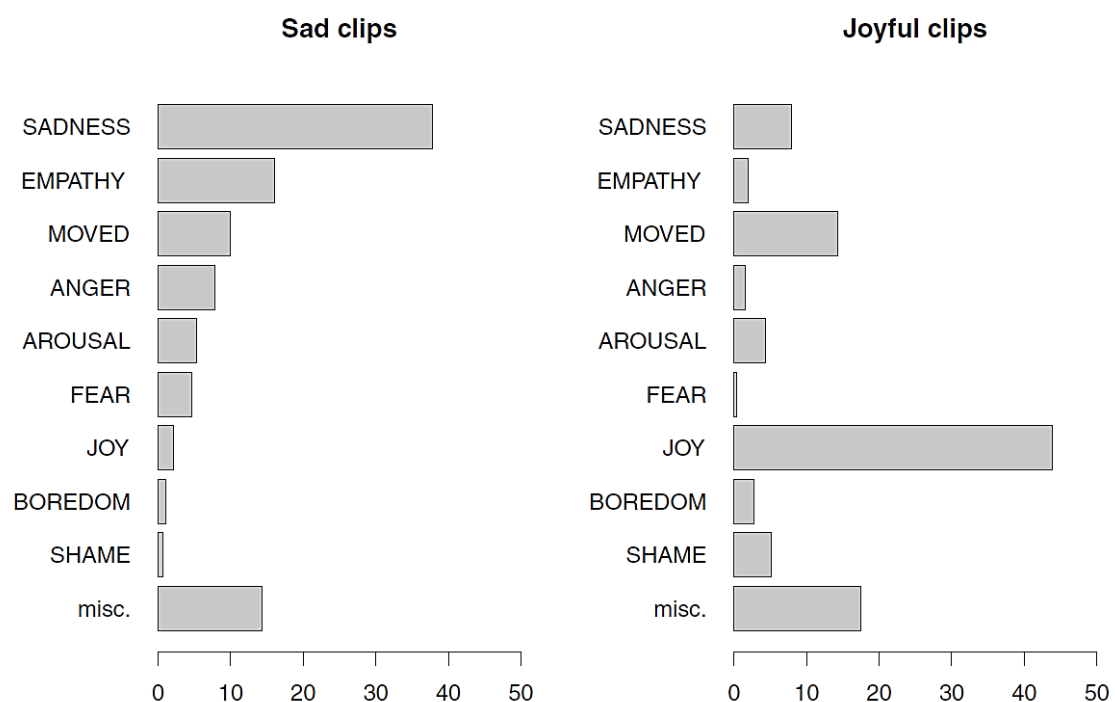


**Figure 1.** Sadness (left), Joy (middle), and Being Moved (right) scale scores as rated in the rating condition in response to film clips preselected for the joyfully moving and sadly moving subsets. Boxplots show the median and the interquartile range.

Figure 1 shows three pairs of boxplots corresponding to the aggregated scales of Sadness, Joy, and Being Moved for the two subsets of film clips. The t-tests confirmed the visual impression that the two subsets of film clips differed significantly for Sadness ( $t = -3.3$ ,  $df = 15.86$ ,  $p < 0.005$ ) and Joy ( $t = 4.6$ ,  $df = 17.88$ ,  $p < 0.001$ ), but showed no significant difference for Being Moved ( $t = -0.59$ ,  $df = 22.07$ ,  $p = 0.56$ ).

**Free responses.** In the free-listing condition, participants produced 572 adjectival responses that included 98 different adjectives. In some cases, when nouns were used (such as *joy*, *sadness*, *happiness*, or *amusement*), we converted them into adjectives (*joyful*, *sad*, *happy*, *amused*). Sometimes participants added phrases to explain the emotional response or describe it in some detail (e.g., [*I felt...*] *deeply moved*, *especially when the boy started to run after the truck*). Such phrases were excluded from further analysis. Adjectives that occurred only once (41 adjectives) were also excluded due to potentially idiosyncratic usage, leaving a total of 531 items (for a similar cutoff procedure, see Fehr & Russell, 1994; Kuehnast et al., 2014; van Goozen & Frijda, 1993).

In analogy to the scale computation in the *rating* condition, we aggregated adjectives that were highly synonymous, such as *joyful* (*freudig*), *delighted* (*erfreut*), *happy* (*glücklich*), *merry* (*erheitert*), and *cheerful* (*fröhlich*), which we aggregated to the collapsed category JOY. In a similar way, we aggregated the other adjectives under the categories SADNESS and BEING MOVED. We also aggregated other affective terms like *annoyed* (*verärgert*) and *angry* (*wütend*) to ANGER and *ashamed* (*beschämt*) and *embarrassed* (*peinlich*) to SHAME (for a complete list, see Tab. S2). Notwithstanding these additional affective terms, in 79% of all cases participants used terms subsumable under at least one of the three categories JOY, SADNESS, and BEING MOVED. Figure 2 shows percentage scores of responses subsumed under the collapsed categories for the sadly moving clips and for the joyfully moving clips.



**Figure 2.** Percentage scores of answers in the free-listing condition for the sad (left) and joyful (right) clip subsets. Synonyms were collapsed to nine emotion categories (see Supplemental Material, Tab. S2); the “misc.” category comprises the remaining adjectives.

The most frequently used category for the sadly moving film clips was SADNESS, and for the joyfully moving film clips it was JOY. This provides further evidence in support of our a priori categorization of the film clips. Furthermore, BEING MOVED was among the most frequently used categories. For sadly moving film clips, spontaneous usages of the category EMPATHY (*compassionate/mitfühlend*, *sympathetic/mitleidig*, *concerned/betroffen*) were even more frequent than uses of BEING MOVED.

Adjectives belonging to the categories FEAR and ANGER were more likely to be listed for sadly than for joyfully moving film clips.

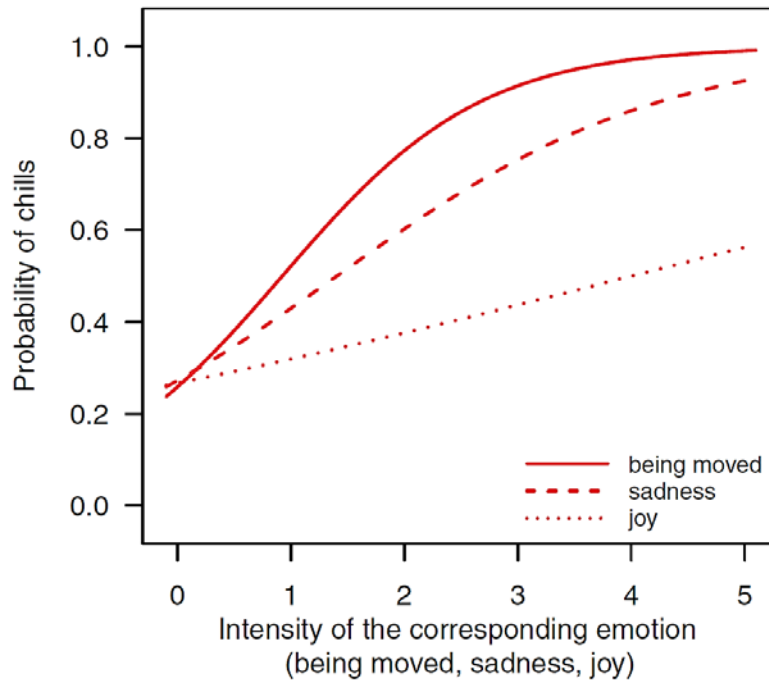
Finally, we analyzed the co-occurrences of the three categories JOY, SADNESS, and BEING MOVED. The analysis revealed that in 64% of all cases, a single category was used (JOY alone: 26%; SADNESS alone: 29.2%; MOVED alone: 8.7%). In 11.5% of all cases, the prototypical emotions were used in combination with being moved (JOY + MOVED: 3.5%; SADNESS + MOVED: 7%; SADNESS + JOY + MOVED: 1%). In 3.5% of all cases, the two prototypical emotion terms were used without a co-occurrence of being moved (SADNESS + JOY). (The remaining 21% of the cases were adjectives belonging to other categories; see Fig. 2)

**Relationship between chills and being moved.** The total number of chills reported was very similar in the two experimental conditions (115 in the *free-listing* condition; 125 in the *rating* condition). The occurrence of chills and familiarity with the film or with the particular excerpt were unrelated ( $\phi = 0.08$ ). Since the data from our questionnaire represent a nested structure with film clips at Level 1 and participants at Level 2, we conducted the following regression analyses using multi-level models and with group mean centered predictors. To account for individual differences in the relationships between the variables, we included random slopes. To test the relationship between the intensity of being moved (in the *rating* condition) and the probability of chills occurring, we computed a logistic multi-level regression model with film clips at Level 1 and participants at Level 2 to predict the discrete outcomes of the occurrence or nonoccurrence of chills. The following multi-level model was tested:

$$\begin{aligned}
 \text{Level 1:} \quad & \text{chill}_{ij} = \beta_{0j} + \beta_{1j} \text{ being moved}_{ij} + \varepsilon_{ij}, \\
 \text{Level 2:} \quad & \beta_{0j} = \gamma_{00} + v_{0j}, \\
 & \beta_{1j} = \gamma_{10} + v_{1j}, \\
 \text{with} \quad & \varepsilon_{ij} \sim N(0, \sigma^2_{ij}), \text{ residual variance,} \\
 & v_{0j} \sim N(0, \sigma^2_{0j}), \text{ random intercept for the participants,} \\
 & v_{1j} \sim N(0, \sigma^2_{1j}), \text{ random slope for the participants.}
 \end{aligned}$$

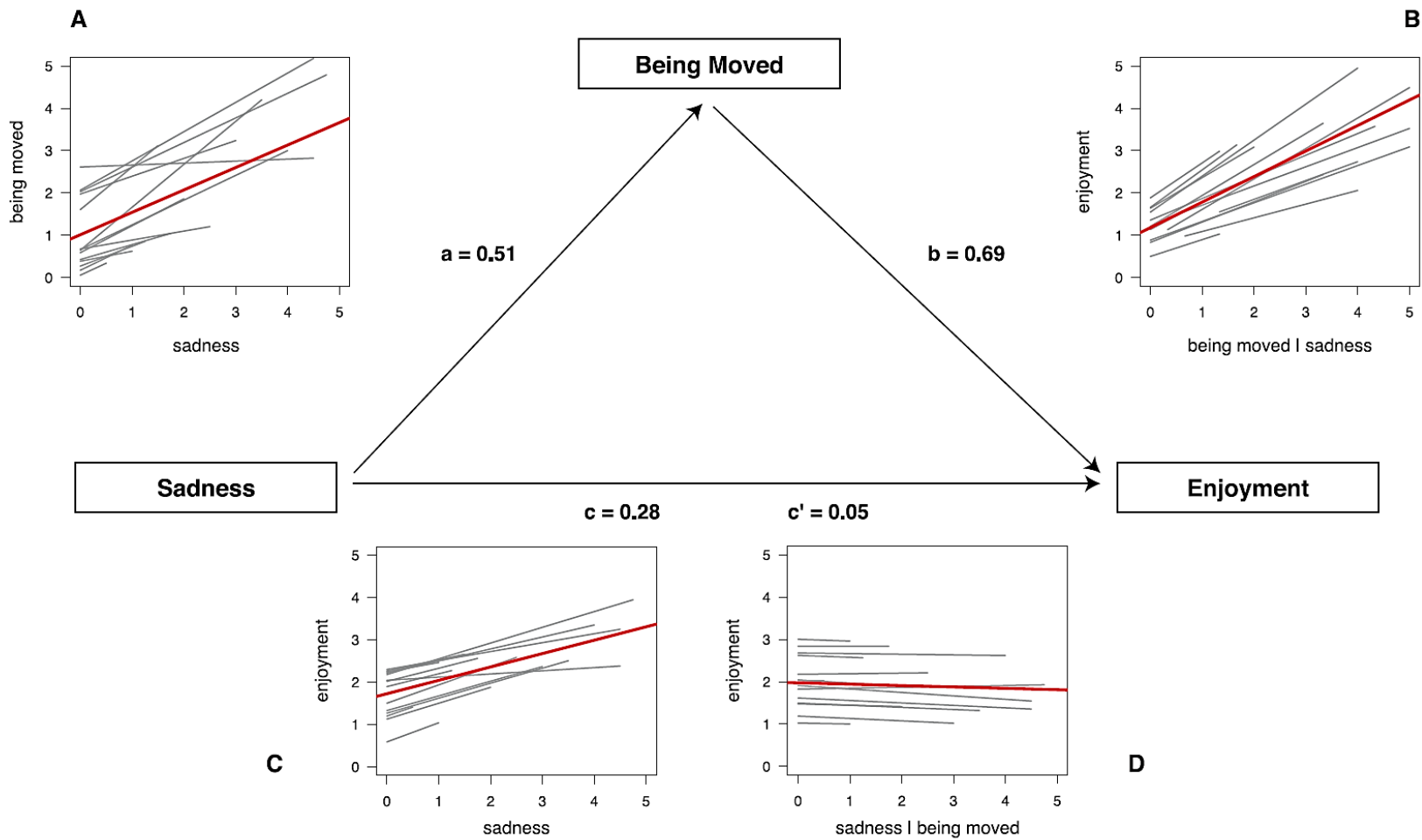
Besides the aggregated Being-Moved scale that served as a predictor for chills, we also computed similar regression models for the aggregated Sadness scale and the aggregated Joy scale.

The results of all three logistic regression models revealed a positive association between the probability of chills and the emotion in question (Figure 3). However, this relationship was strongest for being moved ( $\gamma_{10} = 1.15$ ,  $SE = 0.16$ ,  $p < 0.001$ ), less pronounced for sadness ( $\gamma_{10} = 0.66$ ,  $SE = 0.16$ ,  $p < 0.001$ ), and considerably weaker, indeed statistically insignificant, for joy ( $\gamma_{10} = 0.23$ ,  $SE = 0.16$ ,  $p > 0.1$ ).



**Figure 3.** The logistic function of the estimated fixed effect in the being-moved regression model (solid curve) corroborates the hypothesis that being-moved states of higher intensity are more likely to be accompanied by chills than being-moved states of lower intensity. For the purpose of comparison, the curves for the estimated fixed effect in the sadness regression model (dashed line) and in the joy regression model (dotted line) are shown in the same graphic. Both curves reflect the weaker association of the occurrence of chills with sadness/joy, compared to its association with being moved.





**Figure 4.** Mediation analysis with *sadness* as the independent variable, *being moved* as the mediator, and *enjoyment* as the dependent variable. The values of the coefficients (for *a*, *b*, *c*, *c'*) are shown along the paths. Next to them, the corresponding random-slope plots (A–D) are shown. The gray lines represent the individual slopes of the participants; the thick (red) line represents the mean slope. (A) Random-slope plot for the effect of *sadness* on *being moved* (path *a*). (B) Random-slope plot for the effect of *being moved* on *enjoyment* (path *b*). (C) Random-slope plot for the total effect of *sadness* on *enjoyment* (path *c*). (D) Random-slope plot for the effect of *sadness* on *enjoyment* mediated by *being moved* (path *c'*).

**Mediation analyses.** To test the relationship between the predominant prototypical emotion (*sadness/joy*), *being moved*, and enjoyment, we conducted two mediation analyses according to the procedure in Bauer, Preacher, and Gil (2006). In this procedure, the regression of the mediator (*being moved*) on the independent variable (*sadness* and *joy*) and the regression of the dependent variable (*enjoyment*) are tested within one regression model, using dummy selection variables to toggle between the regressions. This procedure enabled us to compute the full covariance matrix for the random effects and variances, as well as the full asymptotic covariance matrix for fixed effects and variances.

Importantly, the two mediation analyses with *sadness* and *joy* as independent variables were computed over *all* 25 film clips; the results should therefore not be confused with responses to either the sadly or the joyfully moving stimulus subsets alone.

The first mediation analysis tested whether the effect of *sadness* on *enjoyment* was mediated by *being moved* (Fig. 4). The total effect of *sadness* on *enjoyment* was significant (path *c*;  $\beta = 0.28$ ,  $t = 2.82$ ). The effect of *sadness* on *being moved* was significant (path *a*;  $\beta = 0.51$ ,  $t = 4.0$ ). The effect of the mediator *being moved* on *enjoyment*, when controlled for *sadness*, was also significant (path *b*;  $\beta = 0.69$ ,  $t = 6.39$ ). However, once the effect of *sadness* on *enjoyment* was controlled for the mediator *being moved*, it dropped to an insignificant level (path *c'*;  $\beta = 0.05$ ,  $t = 0.5$ ). Thus, the effect of *sadness* on *enjoyment* was fully mediated by *being moved* (estimated indirect effect = 0.34, 99%-CI [0.058; 0.69]).

The second mediation analysis tested whether the effect of *joy* on *enjoyment* was mediated by *being moved*. The total effect of *joy* on *enjoyment* was significant (path *c*;  $\beta = 0.51$ ,  $t = 5.25$ ). The effect of *joy* on *being moved* was not significant (path *a*;  $\beta = 0.01$ ,  $t = 0.08$ ). The effect of the mediator *being moved* on *enjoyment* while controlling for *joy* was significant (path *b*;  $\beta = 0.63$ ,  $t = 6.55$ ). The effect of *joy* on *enjoyment* remained unchanged, when controlled for the mediator *being moved* (path *c'*;  $\beta = 0.5$ ,  $t = 5.64$ ). The estimated indirect effect (0.037, 99%-CI [-0.087; 0.17]) was not significantly different from zero.

## 2.6 Discussion

While most of the previous studies on art-elicited chills are confined to the domain of music, the present study investigated chills in response to the narrative genre of film. We categorized moving film clips a priori as being sadly or joyfully moving (i.e., moving scenarios having a sad event vs. a joyful event in the foreground). The ratings we collected for how sad and how joyful participants felt after each film clip validated our assignment of the clips to the two stimulus subsets. Importantly, the subsets did not differ regarding the intensity of the felt responses of being moved. Furthermore, the a priori assignment was also corroborated by the free responses given in the *free-listing* condition.

**Free responses.** The majority of film viewers in the free-listing condition mostly referred spontaneously to the categories *sadness* and *joy* alone, when asked to identify their emotional state (58.7% of all cases, comprising 531 listed items). In comparison, only in roughly 20% of the overall cases did the participants explicitly use *being-moved* terms (either alone or in combination with *sadness* or *joy*). Given these proportions, one might suspect that our film stimuli failed to effectively induce states of being moved. However, the consistently high scores for *being moved* given by participants in the *rating* condition—i.e., when they were presented with a predetermined being-moved scale—speak against this explanation. Presumably, the relatively low numbers of entries for being-moved-related adjectives as compared to sadness- and joy-related adjectives were due to the fact that *sadness* and *joy* are highly prototypical emotion terms (Fehr & Russell, 1984; van Goozen & Frijda, 1993) that are, moreover, unanimously considered to rank among the “basic” emotions. On the other hand, this is not true of

being moved; therefore, word retrieval is likely to be more difficult for *being moved* than for *sadness* and *joy*.

Interestingly, when participants viewed saddening scenarios, empathy-related terms such as *compassionate* and *sympathetic* were used even slightly more frequently than the being-moved terms. We interpret this in light of the strong link between sadly moving scenarios and prosocial norms and ideals, a link that is both represented by the action of the characters and elicited in the viewers. Stel, van Baaren, and Vonk (2008) demonstrated in an experimental setting that participants showed significantly greater readiness to make generous charitable donations if they were emotionally moved beforehand (for a similar finding in context of a different experimental design see Fukui & Tyoshima, 2014)<sup>11</sup>. This lends support to Tan's (2009) hypothesis that "[b]eing moved probably has a great power in bonding" (p.74). As mentioned earlier, Panksepp (1995), too, related his findings on "deeply moving passages of music" (p. 173) and the concomitant elicitation of chills (which we consider as a physiological marker of being moved) to the arousal of social emotions and social bonding. Confirming these assumptions, Menninghaus and colleagues found that episodes of being moved or touched receive particularly high ratings for the cognitive appraisals related to (pro)social norms and self-ideals (Menninghaus et al., 2015).

The appearance of other negative emotions—fear and anger—in the *free-listing* condition is most likely due to the fact that saddening scenarios may also elicit other negatively evaluated emotions (e.g., Raz et al., 2012); for instance, anger may be directed at whoever caused the event that was sad for the protagonist. However, a closer look at the co-occurrences of the free responses revealed that fear- and anger-related terms were never used together with being-moved terms. This might be taken to suggest that fear and anger could be incompatible with states of being moved. However, further investigation is needed to test this assumption.

**Being moved and chills.** As with most affective phenomena, physiological changes and the underlying mechanisms in the nervous system are likely to play an important role in being moved. Our data provide empirical evidence for previous suggestions (Benedek & Kaernbach, 2011) that art-elicited chills might be a physiological indicator of the emotional state of being moved. The results of our logistic regression models support this hypothesis: The higher the intensity of feelings of being moved, the more likely they were to be accompanied by chills. Moreover, being moved proved to be the best predictor for chills when compared to sadness and joy. This again shows that being moved has its own distinctive characteristics and is not reducible to the accompanying emotional ingredients. The results of the logistic regression also point to the predominance of sadness over joy in the elicitation of chills, thus confirming previous findings by Panksepp (1995; see also Konečni, 2007; Maruskin et al., 2012; Nusbaum et al., 2014). However, from our perspective it is important to emphasize that sadness embedded in an episode of being moved is not coextensive with prototypical sadness as suggested by Panksepp (1995). Rather, sadness embedded in an episode of being moved appears to be a specific and distinct variant of sadness in that it is balanced by a positive emotional antidote. The co-activation of these two ingredients of opposite affective valence (cf. Cacioppo & Berntson, 1999; Norris et al., 2010) is a *necessary* requirement for a sad episode to be experienced as emotionally moving rather than just sad. This hypothesis is testable: If a scenario were to present us with merely saddening content that

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<sup>11</sup> Konečni et al. (2007) could not confirm this relationship; however, in this study the readiness to act more generously was operationalized as the readiness to donate blood. Giving one's blood is likely to represent a kind of sacrifice that is substantially different from donating money or other possessions. Psychological factors such as fear of needles (entetophobia) and aversion to seeing blood may also have influenced the outcome.

does not imply any recuperating moments of relief, hope or soothing modulations, it should neither be labeled as moving nor elicit enjoyment or art-elicited chills.

In principle, the association of chills with intense episodes of being moved having the bipolar nature described above may well apply to sadly moving non-art events as well (such as funerals, regardless of whether they are attended in person or witnessed via media coverage). Further optional modifications of the nature of the felt sadness may depend on the *cognitive framing* of the eliciting scenario as being an artwork (Gerger et al., 2014; Wagner et al., 2014) and on the specific *aesthetic appeal* of the artful representation/performance. However, given that we studied responses to emotionally moving artworks only and that we did not experimentally modify aesthetically important features of these artworks, we could not factor out the effects both of the mere cognitive art framing and of specific aesthetic film techniques based on the ratings we obtained. Thus, while we believe that our findings regarding the nature of being moved and the association of chills with intense episodes of being moved may well generalize beyond the domain of art reception to other eliciting scenarios of an emotionally moving nature, proving this will require substantial additional effort.

Chills are probably not the only physiological concomitant of being moved. Other physiological markers such as tears and a lump in the throat, which have been suggested to be associated with states of being moved (Kuehnast et al., 2014; Scherer & Zentner, 2001; Scherer, Zentner, & Schacht, 2002), are currently being investigated in our research group. Even more importantly, the phenomenon of chills is by no means limited to states of being moved. Chills can accompany quite different emotional states as well as physiological conditions that are not necessarily associated with any emotion whatsoever (e.g., cold, illness, sexual arousal, urination; cf. Goldstein, 1980; Maruskin et al., 2012). Maruskin et al. (2012) showed in several studies that chills that accompany emotions can be characterized as falling into two main kinds: a pleasurable kind and an aversive one. While the chills reported in our study clearly belong to the former category, as revealed by our *enjoyment* ratings, chills in the latter category accompany aversive emotional states such as separation, loss, fear, disgust, and anger in situations of real threat and danger. In such circumstances, chills are most likely to subserve the survival of an organism. Animal piloerection in threatening situations, which makes the body appear larger, has been a well-known fact since at least Darwin (1872).

Therefore, first, it is crucial to differentiate between chills in general and *art-elicited* chills in particular, that are (a) mostly described as pleasurable and (b) accompanied by an emotion, in contrast to chills that are apparently driven by physiological mechanisms alone. Secondly, it is of pivotal importance to explicitly identify the specific emotion that the art-elicited chills accompany, rather than simply speaking of a *heightened emotion* or a *peak-emotional-experience*. We suggest that *being moved* is a particularly powerful, if not *the* most powerful, predictor of chills in art contexts. However, further research is called for to experimentally test whether other art-elicited emotions can also be accompanied by art-elicited chills (e.g., in the context of the horror genre and the uncanny). For instance, a series of more than sixty teenager's horror fiction novels by Robert Lawrence Stine, which have gained tremendous popularity worldwide over the last twenty-five years, were published under the umbrella term *Goosebumps*. Whether such novels are actually able to elicit real goose bumps remains to be shown empirically. Under these circumstances, an explicit identification of the emotional state that underlies an art-elicited chill is all the more needed in order to arrive at a more profound understanding of art-elicited emotions.

**Sadness, joy, and being moved.** The second objective of our investigation was to test whether the relation between sadness and enjoyment was mediated by being moved, as shown by Hanich et al. (2014). The present study broadened the perspective of Hanich et al.'s study by diversifying different types of sadly moving scenarios rather than using only one and by taking into account joyfully moving

scenarios as well. We also conducted an exploratory second mediation analysis with joy as the independent variable to test whether the relation between joy and enjoyment is partially explained by the mediator *being moved*.

The replication of Hanich et al.'s (2014) mediation analysis yielded the same result pattern in spite of drawing on different sadly moving as well as joyfully moving scenarios. This demonstrates the robustness of the mediation effect of being moved and confirms our hypothesis that being moved is essential for taking pleasure in saddening scenarios. Forms of intense sadness elicited by serious content that is often associated with critical life events and existential challenges seem to play a crucial role in episodes of being moved. Even in the case of joyfully moving scenarios, a serious background has to be co-activated in order for the scenario to be potentially experienced as moving. By contrast, a flat-out fun or light-hearted amusement is hardly compatible with states of being moved.

Our second mediation analysis—which was more exploratory rather than driven by a clear hypothesis—investigated the relation between joy, being moved, and enjoyment. While the positive effect of *joy* and *being moved* on *enjoyment* confirmed our expectations, we did not find any positive effect of *joy* on *being moved*, and consequently no mediation effect of being moved. As joy, in direct contrast to sadness, is already by itself a pleasant emotion, we had not expected to find a full mediation of *being moved*; still, the null effect was somewhat surprising. Taken to an extreme, this outcome could be interpreted to suggest that it is not joy itself that contributes to being moved, but primarily the saddening aspects of the overall joyfully moving scene, i.e., the negative background of the positive event. While such an extreme interpretation might be somewhat premature at this point, our results do point to the primacy of sadness over joy in the emergence of being moved (as well as in the elicitation of chills).

**Limitations.** In this study, we provide empirical evidence that art-elicited chills can be elicited by an art form other than music. However, films routinely include musical scores, especially in deeply emotional scenarios such as those selected as our stimuli. Hence, one might argue that the chills reported in this study were induced exclusively or at least primarily by the scene's musical score rather than the narrative content. Since we did not manipulate any features of the film excerpts to guarantee high ecological validity, we cannot rule out this potential explanation. Future research will have to quantify the share the musical score may have had in the elicitation of chills in response to our film clips. Furthermore, as mentioned earlier, language-based stimuli such as political speeches, novels, and poetry, that since antiquity have been attributed the power to emotionally move audiences, should also be investigated regarding their power to elicit chills.

Finally, one could question, whether or not the stimuli we used in the present study truly represent pieces of art (and therefore justify the term art-elicited chills), since the majority of the excerpts were taken from mainstream entertainment films as opposed to art-house cinema. This argument, however, can be challenged on several grounds. Groundbreaking film theorists as Arnheim (1957), Bordwell & Thomson (2010), and Kracauer (2007) claim unanimously that mainstream entertainment movies developed a repertoire of aesthetic qualities of their own (that might differ from art-house cinema) including quality of performance, perspective, camera movement, editing, musical score, lightening, and mise en scène. Moreover, a substantial number of classic films such as *Battleship Potemkin*, *Metropolis* or *Casablanca* that are nowadays considered as artful films were initially designed and marketed as mainstream films.

**Conclusions.** We have shown that emotional states of being moved underlie art-elicited chills. Moreover, compared to sadness and joy, being moved proved to be the best predictor for chills. Additionally, the emotional ingredient of sadness turned out to be more important than joy in episodes of being moved and in the elicitation of concomitant chills. Elicited sadness that is enriched by prosocial emotions appears to be one, if not the most powerful, ingredient of episodes of being moved that are accompanied by art-elicited chills.

**Appendix.** List of films and clips (time codes according to VLC media player 2.1.2)

Film	Country, year	Length	Extraction times	Category
<i>21 Grams</i>	USA, 2003	01:57	00:30:48 – 00:32:38	sad
<i>Across the Universe</i>	USA, 2007	03:09	01:57:28 – 02:00:34	joyful
<i>Adaption</i>	USA, 2002	01:39	01:42:58 – 01:44:42	joyful
<i>Adaption</i>	USA, 2002	02:26	01:32:21 – 01:34:13	joyful
<i>Always</i>	USA, 1989	02:11	00:28:36 – 00:30:52	joyful
<i>An Officer and a Gentleman</i>	USA, 1982	02:24	01:41:38 – 01:43:57	sad
<i>An Officer and a Gentleman</i>	USA, 1982	02:03	01:54:45 – 01:56:47	joyful
<i>Billy Elliot</i>	UK/France, 2000	02:43	01:39:03 – 01:41:30	joyful
<i>Crocodile Dundee</i>	Australia, 1986	02:31	01:10:19 – 01:12:08	joyful
<i>Forrest Gump</i>	USA, 1994	02:59	02:03:14 – 02:06:16	sad
<i>Forrest Gump</i>	USA, 1994	00:58	01:03:42 – 01:04:46	joyful
<i>Forrest Gump</i>	USA, 1994	01:21	01:35:07 – 01:36:21	sad
<i>Goodbye Lenin!</i>	Germany, 2003	01:42	00:15:45 – 00:17:21	sad
<i>Grace is Gone</i>	USA, 2007	02:44	01:12:13 – 01:14:58	sad
<i>Lilja 4-ever</i>	Sweden/Denmark, 2002	02:42	00:08:04 – 00:10:41	sad
<i>Miracle</i>	USA, 2004	02:50	01:59:04 – 02:02:12	joyful
<i>Saving Private Ryan</i>	USA, 1998	01:38	00:30:06 – 00:31:26	sad
<i>Sideways</i>	USA, 2004	02:42	01:50:19 – 01:53:37	sad
<i>Stepmom</i>	USA, 1998	01:32	01:29:09 – 01:30:44	joyful
<i>Terms of Endearment</i>	USA, 1983	03:09	01:54:22 – 01:57:40	sad
<i>The Bucket List</i>	USA, 2007	03:29	01:24:08 – 01:27:43	sad
<i>The Crossing Guard</i>	USA, 1995	04:19	01:36:48 – 01:40:45	joyful
<i>The Thief</i>	Russia/France, 1997	02:47	01:11:37 – 01:14:32	sad
<i>The Thief</i>	Russia/France, 1997	03:22	01:14:46 – 01:18:14	sad
<i>Twins</i>	USA, 1988	01:42	01:36:12 – 01:37:42	joyful

## Chapter 3: Physiological correlates and neural circuitry of being moved

### 3.1 Preface

The second study of this dissertation investigates whether poems are capable of eliciting chills (RQ3), whether high degrees of familiarity are a necessary precondition for chills (RQ4), and whether subjectively felt chills differ from objectively measurable goosebumps (RQ5). It furthermore explores the neural correlates of poetry-elicited chills and compares them to those of music-elicited chills (RQ6). Finally, it aims at identifying specific features of poetic language that facilitate chills, regardless of whether the poems were presented auditory or visually (RQ7). In order to answer these four research questions, a multi-method approach has been applied with four separate sub-studies (physiological, neuroscientific, behavioral, and a self-reading study).

The manuscript has been published (open access) in *Social, Cognitive, and Affective Neuroscience*: Wassiliwizky, E., Koelsch, S., Wagner, V., Jacobsen, T., & Menninghaus, W. (2017). The emotional power of poetry: neural circuitry, psychophysiology, compositional principles. *Social Cognitive and Affective Neuroscience*, 12(8), 1229-1240. <https://doi.org/10.1093/scan/nsx069>

## Chapter 4: Emotional tears and their relation to emotional piloerection

### 4.1 Preface

The third study investigates the relation between emotional goosebumps and emotional tears (RQ8). Furthermore, it elucidates the technical filmic parameters that facilitate emotional tears in response to moving scenarios (RQ9). The manuscript has been published in *Frontiers in Psychology*: Wassiliwizky, E., Jacobsen, T., Heinrich, J., Schneiderbauer, M., & Menninghaus, W. (2017). Tears falling on goosebumps: Co-occurrence of emotional lacrimation and emotional piloerection indicates a psychophysiological climax in emotional arousal. *Frontiers in Psychology*, 8(41). The following text contains the postprint version of this article.

In citing please refer to the original publication: <https://doi.org/10.3389/fpsyg.2017.00041>

### 4.2 Abstract

This psychophysiological study is the first to examine the relationship between emotional tears and emotional piloerection (i.e., goosebumps). Although both phenomena have been related to peak states of being moved, details about their temporal occurrence and the associated levels of physiological arousal have remained unknown. In our study, we used emotionally powerful film scenes that were self-selected by participants. Our findings show that even within peak moments of emotional arousal, a gradation of intensity is possible. The overlap of tears and goosebumps signifies a maximal climax within peak moments. On the side of the stimulus, we found that displays of prosocial behavior play a crucial role in the elicitation of tears and goosebumps. Finally, based on the results of a formal film analysis of the tears-eliciting clips provided by our participants, as compared to randomly extracted, equally long control clips from the same films, we show how the technical and artistic making of the clips was optimized for the display of social interaction and emotional expressions.

**Keywords:** emotional tears; piloerection; being moved; psychophysiology; film



### 4.3 Introduction

It is such a secret place, the land of tears.

— Antoine de Saint-Exupéry,

*The Little Prince*

Being moved to tears by an artwork is certainly nothing one would easily forget. Although many people experience emotional episodes of this type from time to time, emotional lachrimation remains “a secret place” we know very little about. Previous research has distinguished five subgroups of emotional tears<sup>12</sup> dependent on five types of elicitors (Vingerhoets, 2013; Denckla, Fiori, & Vingerhoets, 2014): 1) tears in response to physical pain, 2) tears related to personal loss, e.g., when a close person dies, 3) tears related to empathic pain, e.g. when a close person faces hard times, 4) societal tears, e.g., ritual weeping, and 5) art-elicited tears.<sup>13</sup> Tears of the latter type is the only category that people do not try to avoid. Quite the contrary, a sad film that moves its audience to tears will be regarded as a good film and will be more likely to receive higher ratings on a scale that measures how much viewers want to see the film again (Hanich, Wagner, Shah, Jacobsen, & Menninghaus, 2014; Wassiliwizky, Wagner, Jacobsen, & Menninghaus, 2015). This peculiar phenomenon has been explained by the fact that being moved, although encompassing negative emotional ingredients such as sadness, is an overall pleasurable emotional state (Tokaji, 2003; Tan, 2009; Benedek & Kaernbach, 2011; Hanich et al., 2014; Menninghaus, Wagner, Hanich, Wassiliwizky, Kuehnast, & Jacobsen, 2015; Wassiliwizky et al., 2015). Importantly, sadness has to be balanced by a positive emotional antidote for a scenario to be of the *sadly moving* type (Wassiliwizky et al., 2015). In a farewell scenario, for instance, the predominant emotion of sadness is mixed with positive feelings of social bonding. Conversely, negative affect is routinely an emotional antidote in the case of *joyfully moving* scenarios. Here the predominant building block of joy—elicited, for instance, in a reunion scene—is balanced by a negative antidote, that is, reactivated feelings of the preceding painful separation of the characters. Thus, being moved is a typical mixed emotion (Cacioppo & Berntson, 1999). For empirical research, it is crucial to distinguish between sadness, which is an unpleasant emotional state that humans try to avoid, and being sadly moved—an emotional state for which people willingly spend money when they buy cinema, theater, and opera tickets, film and music recordings, books, and so forth (cf. Cova & Deonna, 2014; Brattico, Bogert, Alluri, Tervaniemi, Eerola, & Jacobsen, 2016).

The linkage between feelings of being moved and tears in the cross-cultural expression “moved to tears” is more than a mere coincidence (“zu Tränen gerührt” in German, “tot tranen geroerd” in Dutch, “ému jusqu’ aux larmes” in French, “commosso fino alle lacrime” in Italian, “conmoviendo hasta las lágrimas” in Spanish, “rastrogan do slez” (растроган до слёз) in Russian, “dojatý k slzám” in Czech, “gǎn dòng de luò lèi” (感动得落泪) in Chinese, “kanrui” (感涙) in Japanese). Several studies have shown that art-

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<sup>12</sup> Emotional tears are determined by the absence of a physical irritation of the eye (e.g., irritation from dust or molecules floating in the air).

<sup>13</sup> The last category is embedded by Vingerhoets in the category of “sentimental tears.” Due to the pejorative usage (Tan & Frijda, 1999; Solomon, 2004) of this term on the one hand, but a strong link to an overall positive emotion that we focus on here (being moved), we prefer to use “art-elicited” rather than “sentimental” (although the latter term may embrace a broader range of antecedents, i.e., not only art-related elicitors but also the beauty of nature, ceremonial acts such as weddings, etc.).

elicited tears can be regarded as physiological indicators of being moved (Scherer & Zentner, 2001; Scherer, Zentner, & Schacht, 2002; Kuehnast, Wagner, Wassiliwizky, Jacobsen, & Menninghaus, 2014). Two other physiological markers have also been shown to accompany feelings of being moved: emotional piloerection, that is, goosebumps (Benedek & Kaernbach, 2011; Wassiliwizky et al., 2015), and a lump in the throat (Scherer et al., 2002). Moreover, all these studies emphasize the salience of the physiological arousal (such as heart palpitations, heavy breathing, sweaty palms) that participants report when shedding art-elicited tears or experiencing goosebumps or a lump in the throat.

To date, however, research on the psychophysiological correlates of emotional tears in general and art-elicited tears in particular is utterly scarce (Kraemer & Hastrup, 1988; Gross, Fredrickson, & Levenson, 1994). Moreover, although there is a good deal of literature on the psychophysiological correlates of emotional goosebumps and chills, which represent the subjective feeling component of piloerection episodes (among others Blood & Zatorre, 2001; Rickard, 2004; Grewe, Nagel, Kopiez, & Altenmüller, 2007; Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009; Benedek & Kaernbach, 2011; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011), we do not know how emotional goosebumps interact with emotional tears. That is, do emotional tears and emotional piloerection overlap, or does one always precede the other? Is there a higher physiological arousal when the two responses overlap? Is it even possible for them to overlap, since they are governed by two antagonistic branches of the autonomous nervous system (ANS) (the sympathetic in the case of piloerection and the parasympathetic in the case of tears)? Moreover, according to a theory put forward by several researchers (Bindra, 1972; Efran & Spangler, 1979; Frijda, 1986), emotional tears initiate a recovery process after a period of peak arousal (which in our case would be indicated by goosebumps). Therefore, the recovery hypothesis would predict that tears should always come after emotional piloerection.

The aim of the present study was to systematically investigate the interrelation between tears and goosebumps, both temporally and in terms of their psychophysiological arousal signatures, including skin conductance, cardiovascular and respirational measures, and facial electromyographic activity. Most of the current theories on emotion agree on the fact that both physiological arousal of the ANS and facial expressions of emotions constitute two major components of an emotional episode (Ekman, 1993; Kreibig, 2010; Scherer, 2009). Two facial muscles—corrugator supercilii and zygomaticus major (cf. Fig. S4)—have repeatedly been demonstrated to indicate negative and positive affect, respectively (Cacioppo, Petty, Losch, & Kim, 1986; Witvliet & Vrana, 1995; Lang, Bradley, Cuthbert, 1998; Larsen, Norris, & Cacioppo, 2003; Aue & Scherer, 2008; Lundqvist, Carlsson, Hilmersson, Juslin, 2008). The unintentional activations of these two muscles thus provide continuous measures of negative and positive affect. Importantly, collecting electromyographic data of these two facial muscles may even allow us to investigate mixed emotional states, if both muscles are activated in periods of tears and goosebumps. This would support former claims about the mixed nature of states of being moved (Tan, 2009; Benedek & Kaernbach, 2011; Hanich et al., 2014; Kuehnast et al., 2014; Menninghaus et al., 2015; Wassiliwizky et al., 2015).

Because emotional piloerection marks states of peak emotional arousal and heightened skin conductance is indicative for physiological arousal driven by sympathetic activity (Benedek & Kaernbach, 2010), one should expect increased skin conductance responses for these emotional episodes. This is exactly what was found in a substantial number of studies on piloerection and chills in response to music and film (Rickard, 2004; Grewe et al., 2007 and 2009; Guhn et al., 2007; Salimpoor et al., 2009 and 2011; Benedek & Kaernbach, 2011; Sumpf et al., 2015). Similarly, several studies have shown increased cardiovascular and respirational activity in piloerection/chills episodes (Blood & Zatorre, 2001; Grewe

et al., 2009; Salimpoor et al., 2009; Benedek & Kaernbach, 2011). However, some studies have failed to replicate these latter effects (Rickard, 2004; Guhn et al., 2007); hence the findings for cardiovascular and respirational activity appear to be less consistent than those for skin conductance. At the same time, the few studies that investigated emotional lacrimation report both increased electrodermal activity, faster rates of heartbeats and breathing in lacrimation periods (Kraemer & Hastrup, 1988; Gross et al., 1994). These results question the validity of the recovery hypothesis (Bindra, 1972; Efran & Spangler, 1979), which predicts reduced sympathetic activity in lacrimation periods and thus lower heart rates, slower breathing, and decreased skin conductance. Our data allowed to test these contrasting predictions against each other.

To ensure maximal responses, we relied on stimuli that were self-selected by participants before the actual study. Specifically, we asked each participant to provide individual film excerpts that reliably move him or her to tears (for a similar approach see, e.g., Blood & Zatorre, 2001; Salimpoor et al., 2009; Salimpoor et al., 2011). Moreover, we measured the piloerection objectively by means of a video recording device, the “goosecam” (Benedek, Wilfling, Lukas-Wolfbauer, Katzur, & Kaernbach, 2010; Benedek & Kaernbach, 2011; Sumpf et al., 2015), which we constructed for this investigation.

One of the most debated issues in research on emotional tears is their (evolutionary) adaptive function. The viewpoints range from a “purposeless, incidental result” (Darwin, 1872, p. 175) to more recent positions that highlight the social benefits of emotional tears (Gross et al., 1994; Vingerhoets, 2013). According to the latter view, people who shed emotional tears are more likely to be empathized with and to receive social support (Balsters, Kraemer, Swerts, & Vingerhoets, 2013; Vingerhoets, van de Ven, & van der Vale, 2016). The importance of a social component on the side of the perceiver as well as in the stimulus has also repeatedly been highlighted in experimental studies on being moved and chills. Panksepp (1995), for instance, associated his findings on sad songs and the concomitant elicitation of chills with the sudden arousal of social emotions and feelings of social bonding in the listener; however, he did not investigate this issue systematically. Similarly, using emotionally moving film scenarios that elicited chills, Wassiliwizky et al. (2015) concluded that sadness accompanied by prosocial emotions is one of the most powerful stimuli for episodes of being moved to occur and to be accompanied by chills. The social component thus appears to play a crucial role in states of being moved.

We wanted to further elaborate on this issue by investigating features of the tears-eliciting clips provided by our participants. Specifically, we expected a high percentage of the clips to display social interactions. We planned to examine the predominant group size of the characters in the narrative foreground as well as the number of onlookers or bystanders. By virtue of being in a witnessing position, this latter group of characters is comparable to that of an actual film viewer, and hence may serve to prepare, prime, and facilitate the responses of the actual film viewer (Hanich et al., 2014; Hanich & Menninghaus, in press). Moreover, we planned to investigate several technical aspects of the clips, such as the camera distance, lighting, and camera perspective. Given our hypotheses regarding the importance of social interactions, we hypothesized that the technical aspects of the scenes would optimize displays of protagonists’ and bystanders’ facial expressions, that is, there would be a predominance of close-ups and eye-level perspectives. Finally, we wanted to identify the dominant film genres in the stimulus pool.

## 4.4 Experiment

**Participants.** Twenty-five right-handed German native speakers (3 men,  $M = 28.8$  years,  $SD = 8.5$ ), all of them university students of different disciplines, were tested. All participants reported having normal vision and hearing. Prior to the study, the participants gave their written consent. They were compensated with 25 EUR at the end of the study. All subjects gave written informed consent in accordance with the Declaration of Helsinki. All procedures were approved by the Ethics Council of the Max Planck Society. There were no vulnerable populations involved.

**Stimuli.** Several weeks before the testing, each participant provided a set of three to six emotionally powerful film scenes which contained peaking moments of emotional arousal and had repeatedly moved him or her to tears in the past. This resulted in a total stimulus pool of 137 different clips (several identical excerpts were chosen by multiple participants). The average clip length was 249 s; the lengths ranged between 53 s and 666 s. Most of the films from which the excerpts were taken were produced in the US (80.28%), followed by the UK (16.90%), Germany (14.08%), and France (9.86%; note that because of co-productions such as Germany/France these percentages do not add up to 100). The production years ranged from 1941 (*Citizen Kane*) to 2012 (*Les Misérables*). For a complete list of the films, see Table S17. All clips from non-German films were shown in the dubbed German version. We did not manipulate any parameters of the clips except for adding two-second black fade-ins and fade-outs to smooth the transitions at the beginning and end of each clip. During the testing, all participants watched only their self-selected clips.

**Procedure.** Participants completed the experiment while sitting comfortably in a reclining armchair, with their non-dominant forearm placed on an armrest. With lights dimmed and all distractions minimized, the lab was turned into a comfortable and relaxed environment. To ensure a private atmosphere, the experimenter left the testing room after providing instructions and attaching the physiological sensors. The testing began with an initial baseline of 5 min, followed by the self-selected film clips in randomized order. Presentation<sup>®</sup>14.9 (Neurobehavioral Systems, San Francisco, USA) was used to present the stimuli. The sound was played binaurally through high-quality K618-DJ headphones (AKG Acoustics, Vienna, Austria). Participants were asked to monitor their emotional responses and to push a button with their dominant hand when they felt moved to tears (for the entire duration of the experience). After each clip, they were requested to rate the intensity of their emotional lachrimation on a 6-point Likert scale. The levels of the scale were verbally anchored as follows: 0 = *no emotional arousal*; 1 = *slight emotional arousal*; 2 = *slight feeling of tears*; 3 = *strong feeling of tears*; 4 = *eyes filled with tears*; 5 = *tears rolling down the cheeks*. A relaxation pause of 1 min followed the rating to prevent potential carry-over effects. On top of collecting the standardized ratings of the intensity of the participants' tear responses after each clip, we explored the subjective feeling component of their tear episodes by asking them for verbal statements during the debriefing after the testing session. Specifically, we asked them to describe how it felt to be moved to tears and whether they experienced this as rather pleasant or unpleasant. (Notably, these latter data were not collected for purposes of a rigid formal analysis—which would require a much larger sample size (cf. Kuehnast et al., 2014)—but rather in an exploratory fashion and with a view to potentially inspire future research on this mostly neglected emotional component). The entire testing took roughly 45 min per participant.

**Measurement and preprocessing.** Psychophysiological data were acquired (Fig. S4) via a 10-channel bioamplifier, the Nexus-10, which included the recording software Biotrace (Mind Media B.V., Netherlands). To collect skin conductance data, two flat 10 mm Ag/AgCl dry electrodes were fixed at

the phalanges of the ring and middle fingers of the non-dominant hand; the sampling rate was 32 Hz. A photoplethysmograph sensor placed on the phalanx of the index finger of the same hand digitally recorded blood volume pulse, sampled at 128 Hz. A belt containing stretch-sensitive sensors was placed around the participants' diaphragms to assess respiratory activity; these data were sampled at 32 Hz. Facial electromyographic (EMG) activity was recorded at a sampling rate of 2048 Hz at the corrugator supercilii and zygomaticus major, in accordance with common recommendations for electrode placements (Fridlund & Cacioppo, 1986). The electrodes were prepared with an isotonic paste (CV-Tronic, Versmold, Germany). Continuous objective measurement of piloerection was carried out by means of a video recording device (the "goosecam") that was constructed according to the instructions of Benedek et al. (2010). Because a recent study had found the legs to be the most likely place for piloerection to occur (Wassiliwizky et al., 2015), participants were asked to roll up one trouser leg, and the device was attached to the lower leg above the right calf muscle (Fig. S4). Further they were asked to keep the leg still during the presentation of a clip in order to prevent movement artefacts. The goosecam had a coverage of 3 × 5 cm of the skin surface. The recorded video data were analyzed offline using the Matlab analysis software Gooselab V1.21 (<http://www.goosecam.de/>), which is based on a two-dimensional discrete Fourier transform for every frame of the video (Fig. S5). The resulting continuous measure of piloerection was compared to the values of the baseline in order to obtain the exact onsets and offsets of piloerection incidents (Benedek et al., 2010; Benedek & Kaernbach, 2011). Additionally, all video recordings were checked in a control inspection using VirtualDub 1.10.4 (<http://www.virtualdub.org/>) in order to confirm the outcomes of the Gooselab analysis and to exclude potential artefacts (no critical artefacts were detected).

Skin conductance data were analyzed using the Matlab analysis software Ledalab V3.4.4 (<http://www.ledalab.de/>). We used Continuous Decomposition Analysis (Benedek & Kaernbach, 2010), which disentangles and extracts single skin conductance responses (SCRs) in a way that ensures that the amplitude of a later response is not influenced by the proximity of the preceding response activity. For our statistical analysis, we used the phasic electrodermal activity (pEDA) component (Benedek & Kaernbach, 2010), which reflects the rapidly varying (over seconds) activity of skin conductance responses, in contrast to the slowly varying (over minutes) tonic activity (i.e., the skin conductance level). In a former study, the tonic activity did not show any significant changes in piloerection phases (Benedek & Kaernbach, 2011). The heart rate was derived from the raw blood volume pulse data by means of a peak detection algorithm integrated in the Biotrace software (sampled at 32 Hz). In a similar way, the respiratory rate was computed based on the signal recorded through the respiration belt, resulting in a continuous measure sampled at 32 Hz. The EMG signal was band-pass filtered within the frequency range of 20–500 Hz, which is the predominant range of facial EMG signals (Fridlund & Cacioppo, 1986), and convolved with a fourth-order Butterworth low-pass filter. From this preprocessed data, root mean square amplitudes were computed for the corrugator and the zygomaticus activity at a sampling rate of 32 Hz. Afterwards, all psychophysiological data were adjusted to account for inter-individual baseline differences among the participants by subtracting the individual baseline score (averaged over 5 min) from the respective signal (resulting in reactivity scores) and dividing the difference scores by the individual standard deviation of the baseline. The resulting normalized (i.e., linearly z-transformed) scores reflect changes from the initial baseline period due to experimental stimulation (for similar normalization procedures see, e.g., Salimpoor et al., 2009; Benedek & Kaernbach, 2011). In a final step, all physiological data were down-sampled to 2 Hz before entering the statistical analysis.

**Statistical analysis.** The statistical analyses were conducted using R 3.2.1 (package nlme; 2015). To account for the hierarchical structure of the physiological data, with stimuli at level 1 and participants at level 2, we used mixed-effect analyses of variances. For each of the physiological measures, we conducted a  $2 \times 2$  mixed-effect ANOVA with two binary factors: “Tears” (coding the occurrence of tears as indicated by button presses) and “Goosebumps” (coding the occurrence of emotional piloerection as captured by the goosecam and analyzed with Gooselab). The statistical model allowed for interaction effects, because we were interested in physiological correlates of the time periods in which tears overlapped with goosebumps. Exposure time spans in which neither tears nor goosebumps were observed were regarded as control time. Thus, all data points of the entire duration of the clips were considered for the statistical analysis. After the ANOVAs, pairwise Tukey post-hoc tests (at a Bonferroni corrected significance level of  $\alpha = 0.05$ ) were conducted using the least-squares means.

**Formal film analysis.** In order to identify formal filmic characteristics that prevail in tears-eliciting clips, we had to compare them with an appropriate control set. To this end, we extracted control clips of the same lengths as the tears-eliciting clips from the same movies. For instance, if a 5 min clip from *Titanic* was used in the study to elicit tears in a certain participant, we extracted a control clip of 5 min from the same movie starting at a random time position. The random time position was generated using R; the extraction began from the next shot change that followed the random time point. If the control clip overlapped with the tears-eliciting clip, another random position was generated. Importantly, this approach keeps a great number of technical, aesthetic, and production related parameters constant between the tears eliciting clips and their matched control clips, thereby allowing for formal statistical testing of which features differ between both sets<sup>14</sup>.

In coding the formal filmic characteristics of both sets, we relied on a standard formal film analysis system by Bordwell and Thompson (2013). First, we focused on the camera’s perspective, the camera distance (also called framing), and the lighting. Both the camera’s perspective and the distance are described in terms of their relation to the depicted character. The distance or framing refers to the scale in which a particular character, or only parts of this character, is shown in the image. In line with Bordwell & Thomson (2013), we considered seven camera distances: close-up (depicts details of the character, most commonly the face), extreme close-up (singles out a portion of the face or magnifies an object), medium close-up (frames the character from chest up), medium shot (frames the character from waist up), medium-long shot (frames from the knees up), long shot (depicts characters in full length), and extreme long shot (depicts landscapes, the human figures are tiny or lost). The perspective refers to the angle at which the camera is positioned in relation to the character and the character’s eyes. We used five different perspectives: eye-level view (also called straight-on angle in which the camera is positioned orthogonally in respect to the object; usually, the camera is at the level of the character’s eyes), low-angle view (the camera is looking up), high-angle view (the camera is looking down), worm’s view (extreme low-angle view), and bird’s view (extreme high-angle view). We also coded point-of-view shots (POV), in which the camera creates an illusion that the film viewer sees through the eyes of the character. With respect to the lighting, we distinguished between high-key lighting (soft lighting, low in contrast, detailed in shadow areas) and low-key lighting (hard lighting,

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<sup>14</sup> Please note that we do not claim that the control set of matched clips was emotionally neutral for the participants. It is possible that due to the random nature of our extraction procedure some control clips could have evoked emotional responses in the participant. However, participants were instructed to focus on emotional peak points (usually one) within the films; moreover, if more than one such peak point had been indicated for a certain film, all of them were used in the study (cf. Table S4). Therefore, it is highly unlikely that the control set had the emotional power to elicit tears in the respective participants.

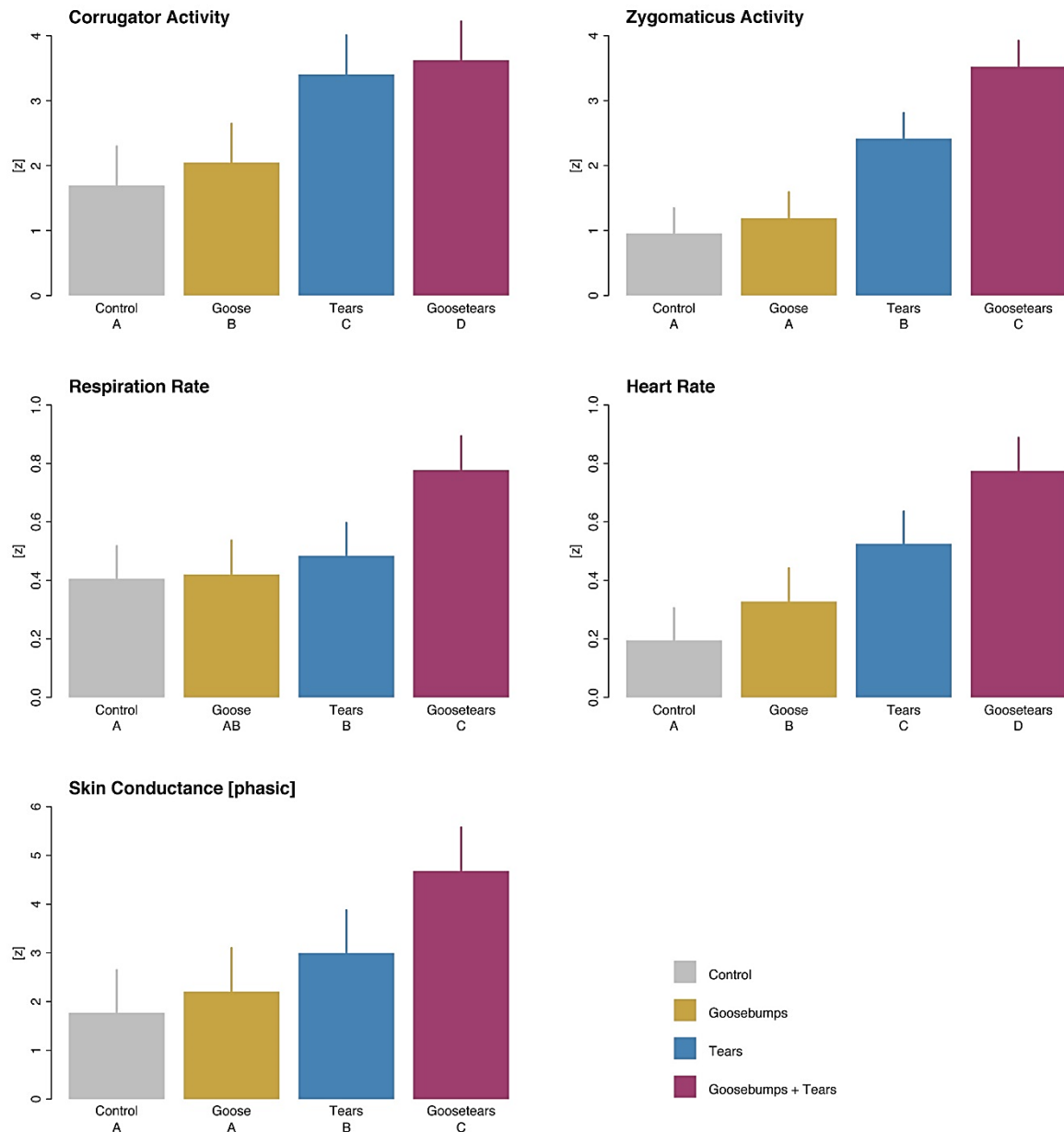
strong contrast, dark shadows, low/no fill light). We also examined the importance of music in the clips: if music was present, we distinguished between music as a musical score outside of the film story world (i.e., non-diegetic), non-diegetic singing with instruments, non-diegetic singing without instruments, depiction of music making within the film story world, and depiction of singing within the film story world. Finally, we coded for the depiction of crying characters. Given the fact that emotional expressions can be contagious for the viewer (Hatfield, Cacioppo, & Rapson, 1994) and that film makers use this phenomenon in order to facilitate emotional arousal in the viewer, we expected to find more crying characters in the tears-eliciting clips than in the randomly chosen control clips. All parameters were coded for each shot of both the experimental (i.e., tears-eliciting) and the randomly chosen, equally long control clips. Because this procedure is extremely time demanding, we restricted the coding to 50 random experimental and 50 corresponding control clips. The coding was performed by an external professional coder (a film scholar), who was not familiar with the details of the analysis.

In addition to the formal filmic characteristics of the clips, we also analyzed the social dimension of the scenarios. First, we identified the clips that depict social interactions (from the complete experimental set of 137 clips); here we differentiated between human interactions, human-animal (and animal-animal) interactions, and interactions with anthropomorphic characters. We further examined the subset with human interactions by categorizing the number of interacting characters (one, two, three, four, or five and more). The same analysis was conducted for bystanders or witnesses, who are typically shown in the background of a scene.

## 4.5 Results

**Occurrence of tears and goosebumps.** All participants indicated that they experienced emotional tears. A total of 308 incidences was reported, translating into 0.55 incidence per minute ( $M = 29.06$  s,  $SD = 1.94$ , range 0.5–325.25 s). The goosecam video recordings of 10 participants (40% of the sample) showed objective piloerection, 75 incidences in total, or 0.32 incidence/min ( $M = 33.81$  s,  $SD = 21.18$ , range 5–121 s). The percentage of the sample showing positive evidence of piloerection is consistent with previous studies that used a variety of other stimuli, such as films, music (40%; Sumpf et al., 2015) and audio film soundtracks (43.1%; Benedek & Kaernbach, 2011). Notably, piloerection appeared primarily (80%) in response to clips that triggered a full-blown lacrimation response (levels 4 and 5 of the tears scale, i.e., eyes filled with tears and tears rolling down the cheeks) rather than a mere “feeling like crying” (levels 2 and 3 on the tears scale).

**Sequence effects.** Of the goosebumps periods, that is, periods during which objective piloerection can be observed in the video recording, 58.7% overlapped with tear periods, that is, periods when the response button was pushed (the overlap time of tears and goosebumps was on average 22.43 s,  $SD = 19.7$ , min = 1.75, max = 100.72). In 59.1% of these cases, the tears response preceded the piloerection, while in the remaining 40.9%, the goosebumps came first. The Pearson’s chi-square test showed no difference between these two distributions ( $\chi^2 = 1.45$ ;  $df = 1$ ;  $p = 0.228$ ). Thus our study observed no apparent temporal order effects for goosebumps and tears.

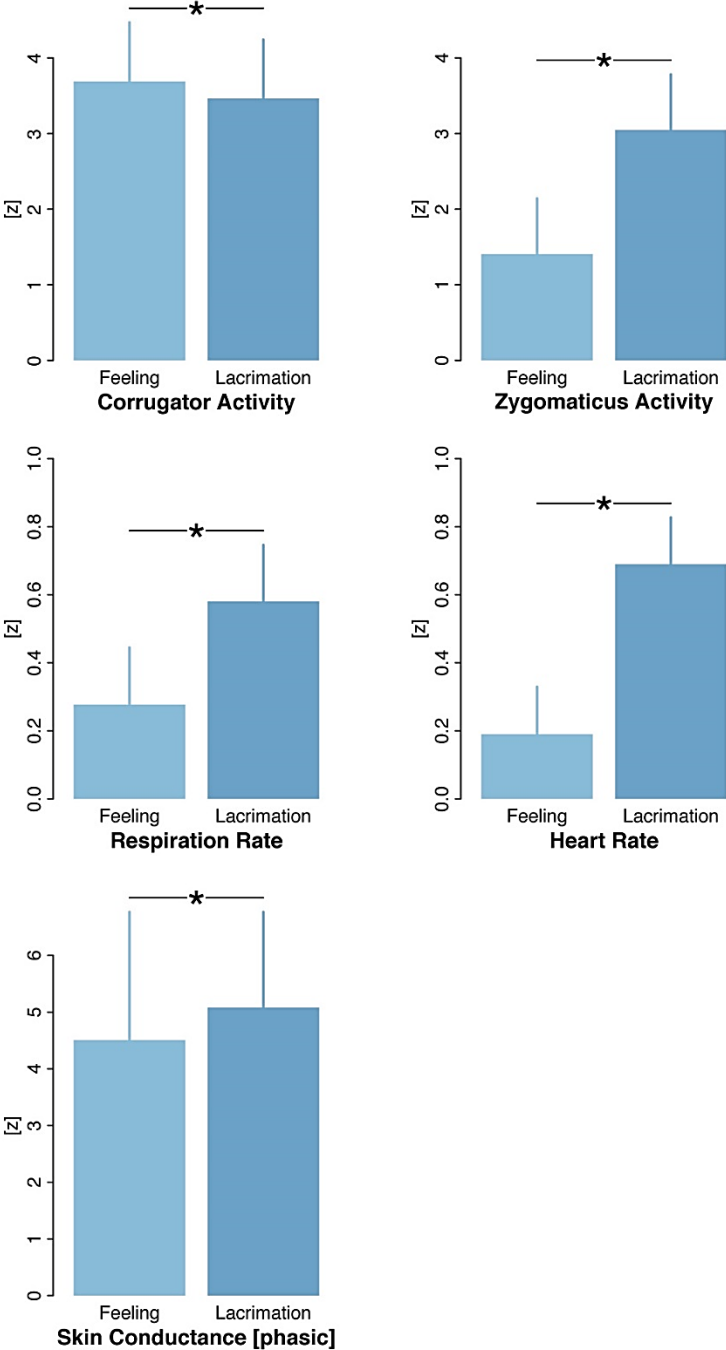


**Figure 10.** Psychophysiological correlates in response to tears-eliciting film clips. A gradual increase of psychophysiological arousal was observed, beginning with emotional piloerection (captured objectively by the goosecam), followed by emotional tears (self-indicated by participants) and then climaxing in the overlap of both responses (control refers to stimulus time stretches in which neither of the two responses was observed). Error bars indicate standard errors as estimated in multilevel mixed-effect models. Bars with the same letter are not significantly different from each other at the 0.05 level. (Please note that for ease of readability, the scaling differs between rows).

**Psychophysiological correlates.** The psychophysiological correlates of the autonomous nervous system and of the electromyographic facial activity revealed a stable result pattern across different domains. In general, emotional piloerection showed greater amplitudes compared to control time, followed by amplitudes for emotional tears and climaxing eventually in periods during which tears overlapped with



goosebumps (Fig. 10; for the underlying statistics see Tab. S11). Moreover, within the tears incidences, periods that were rated 4 and 5 on the tears scale, that is, full-blown lacrimation, triggered higher psychophysiological responses than periods that were rated with 2 and 3 on the tears scale, that is, only a feeling like crying (Fig. 11; for the underlying statistics see Tab. S12).

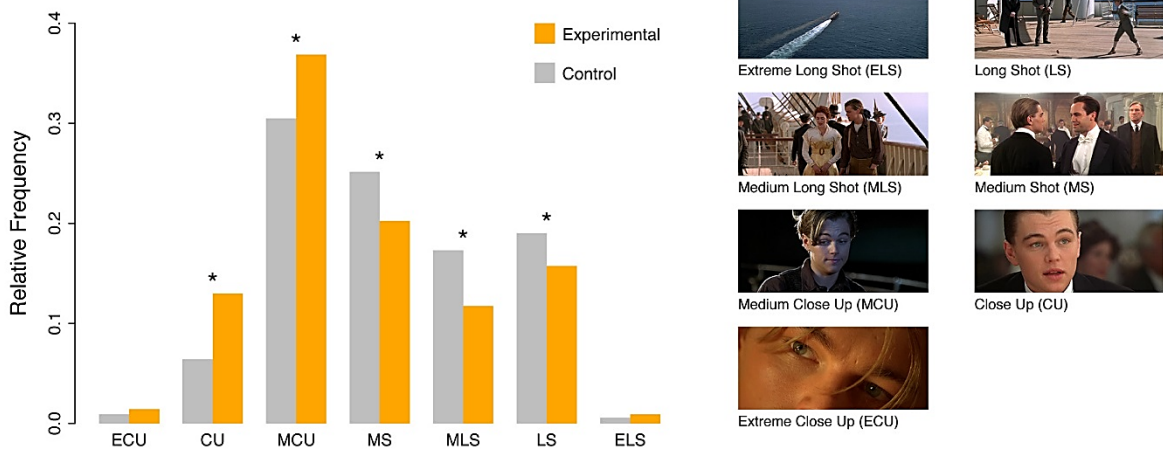


**Figure 11.** Psychophysiological correlates of a second analysis in which the “feeling like crying” was compared with the actual shedding of tears. In general, the full-blown lacrimation triggered significantly higher arousal states (at the 0.05 level) than the mere feeling like crying. Error bars indicate standard errors as estimated in multilevel mixed-effect models. (Please note that for ease of readability, the scaling differs between rows).

Because the electromyographic activity of the corrugator (which is associated with negative affect) and the zygomaticus (which is associated with positive affect) revealed a similar result pattern, we further examined the co-occurrence of these two activities within clips, and more specifically within episodes of tears as well as within episodes of goosebumps. For this purpose, we performed a correlational analysis for the measures of both muscles after they were averaged per participant for the entire clip (for the first analysis), for the tear episodes (for the second analysis), and for the goosebumps episodes (for the third analysis). Pearson's product-moment correlation of the corrugator and zygomaticus activities for the entire clips amounted to  $r = 0.20$  ( $t_{130} = 2.38, p = 0.0187$ ); for the tear episodes,  $r = 0.24$  ( $t_{109} = 2.62, p = 0.0099$ ); and for the goosebumps episodes,  $r = 0.21$  ( $t_{28} = 1.17, p = 0.2535$ ). Thus, the analyses show a moderate but significant co-activation of both muscles at the level of the entire clips and at the level of tear episodes.

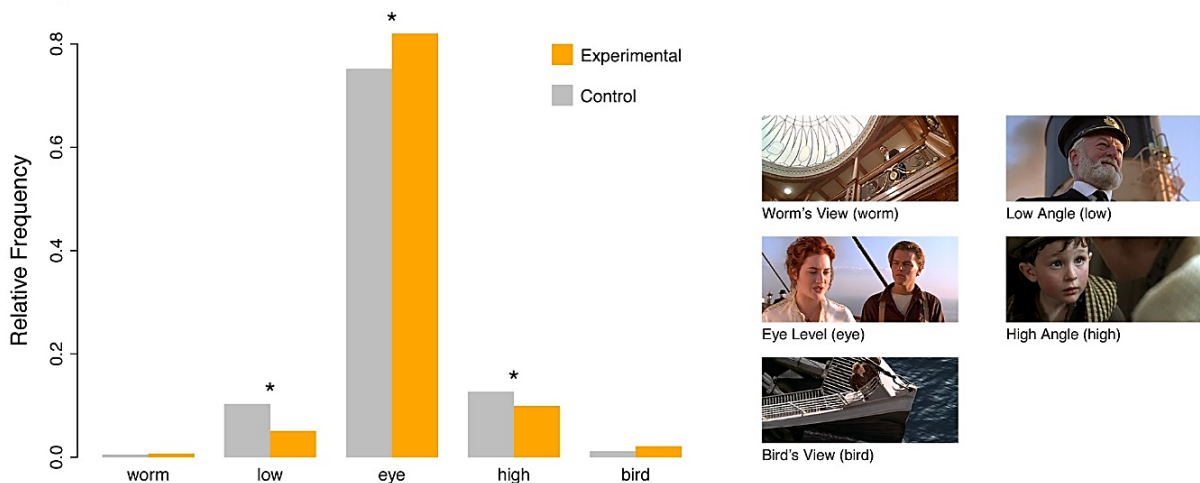
**Formal film analysis.** In the first step, we identified the prevalent genres that the clips were taken from (according to the classification of the Internet Movie Data Base, IMDb; <http://www.imdb.com/>). Figure S6 shows that Drama was the most common genre (38.60%), followed by Romance (18.54%), Comedy (7.90%), and Biography (5.17%). All remaining genre types figured below 5%. This outcome fits well with the scenario types, which primarily focused on saddening content (67.15% of the clips) such as death bed scenarios, break-ups, and farewell scenarios. In contrast, 32.85% of the clips focused on joyful events, such as reunions and the achievement of important goals (for a detailed list of scenario types, see Tab. S17). In the technical part of the formal film analysis, that compared the experimental tears-eliciting clips with matched control clips, we focused primarily on camera distance and camera perspective. Figure 12 shows profiles of camera distance usages for both sets, differing significantly from each other in a Pearson's chi square test ( $\chi^2 = 126.64$ ;  $df = 6$ ;  $p < 0.001$ ). Although both the tears-eliciting and the control clips tended to draw mostly on medium close-ups, this preference was significantly higher for the tears-eliciting clips: Whereas roughly 37% of the total time of the analyzed 50 tears-eliciting clips were shot in a medium close-up, the matched control set used this framing only in about 30% of the total time of all 50 clips (for statistical details, see Tab. S13). Similarly, tears-eliciting clips used significantly more close-ups, whereas the matched controls showed significantly more medium shots, medium-long shots, and long shots.

### Camera Distance



**Figure 12.** Comparison of camera distances between tears-eliciting clips and a matched control set. The ordinate shows the relative frequency accumulated over the duration of all clips in a respective stimulus set. In general, tears-eliciting clips tended to draw predominantly on camera positions close to the character (i.e., significantly more close-ups and medium close-ups), whereas for the control set significantly more longer camera distances (i.e., medium shot, medium long shot, long shot) were found (for details, see Tab. S13). The pictures illustrating different camera distances were taken from *Titanic* (1997).

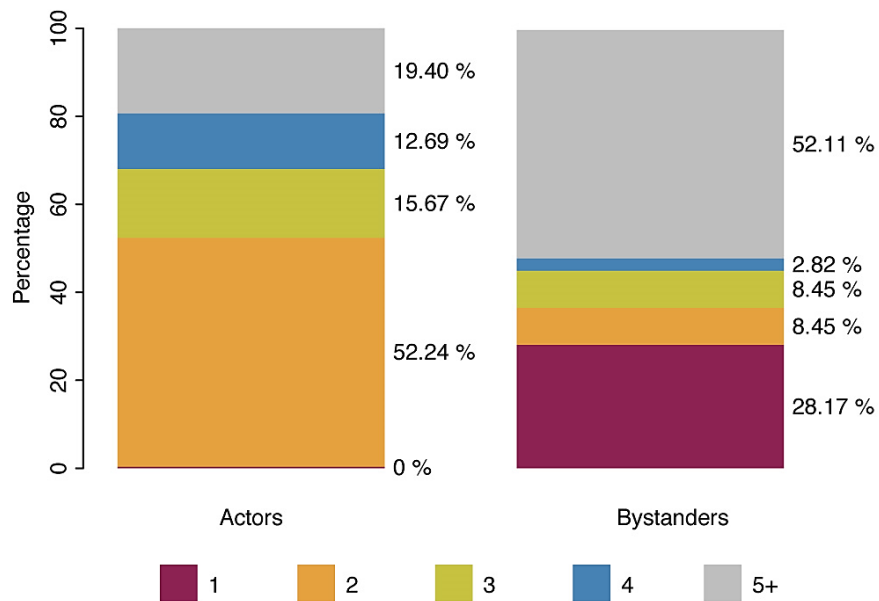
### Perspective



**Figure 13.** Comparison of camera perspectives between tears-eliciting clips and a matched control set. Tears-eliciting clips used significantly more eye-level/straight-on views, whereas for the control set significantly more high and low angle perspectives were found (for details, see Tab. S14). The pictures illustrating different perspectives were taken from *Titanic* (1997).

Regarding the perspective, the eye level (or straight-on angle) was predominant for both sets (Fig. 13). Tears-eliciting clips, however, used this perspective significantly more than their matched controls, which in turn showed more low and high angle perspectives (the distributions differed significantly from each other in a Pearson's chi square test:  $\chi^2 = 68.08$ ;  $df = 4$ ;  $p < 0.001$ ; see also Tab. S14). For the lighting, we found a general predominance of high key lighting (Fig. S7). Tears-eliciting clips, however, used significantly less high key and consequently more low key lighting ( $\chi^2 = 61.73$ ;  $df = 1$ ;  $p < 0.001$ ; see also Tab. S15). Although point-of-view shots are generally rare (Fig. S7, Tab. S15), tears-eliciting clips used slightly more of them than the control set ( $\chi^2 = 14.43$ ;  $df = 1$ ;  $p < 0.001$ ). Similarly, clips that elicited tears in the participants, depicted significantly more crying characters than randomly chosen control clips ( $\chi^2 = 183.97$ ;  $df = 1$ ;  $p < 0.001$ ; see also Fig. S7 and Tab. S15). For the usage of music, we observed a greater tendency for tears-eliciting clips both to underlie scenarios with music and songs from outside of the story world and to depict singing characters within the story world ( $\chi^2 = 251.43$ ;  $df = 5$ ;  $p < 0.001$ ; see also Fig. S7 and Tab. S15).

As we expected, the majority of the experimental clips, 93.66%, displayed social interactions: 69.72% displayed human interactions, 12.68% human-animal or animal-animal interactions, and 11.27% interactions with anthropomorphic characters (e.g., E.T., the extra-terrestrial); only 6.34% displayed no interactions at all (i.e., a single character was depicted). We further examined the number of interacting characters as well as the number of bystanders/witnesses (45% of the clips displayed only main characters, with no bystanders in the narrative background). The results are shown as stacked bar plots in Figure 14. Regarding the number of interacting characters, we observed a strong tendency towards dyads (52.24%), followed by groups with five or more characters interacting with each other (19.40%). Three and four persons were each displayed in about 15% of the clips. Regarding the bystanders, we observed a diverging pattern. Here, single witnesses (28.17%) and groups of five up to large crowds (52.11%) were the most common types. The differences in the group sizes for actors and bystanders were significant in a Pearson's chi-squared test ( $\chi^2 = 83.12$ ;  $df = 4$ ;  $p < 0.001$ ).



**Figure 14.** Percentages of tears-eliciting clips displaying different numbers of actors and bystanders in the foreground and background of the scenario. Note that whereas dyads tended to dominate for the main characters in the foreground, single witnesses and groups of five or more were particularly frequent for the bystanders in the background. The difference was significant in a Pearson's chi-squared test ( $\chi^2 = 83.12$ ;  $df = 4$ ;  $p < 0.001$ ).

## 4.6 Discussion

It has been claimed that emotional tears are a uniquely human phenomenon (Frey, 1985; Provine, 2012; Trimble, 2012; Vingerhoets, 2013). Typically, humans weep in response to unpleasant or painful stimuli and unfortunate events. However, shedding tears in contexts of exposure to artworks and media products (which readily include elicitation of negative emotions) has been associated with very intense moments of the pleasurable emotional state of being moved (Scherer & Zentner, 2001; Scherer et al., 2002; Hanich et al., 2014; Kuehnast et al., 2014). Likewise, emotional piloerection has been demonstrated to correlate with the peaks of states of being moved (Benedek & Kaernbach, 2011; Wassiliwizky et al., 2015). The first aim of our study was to examine the psychophysiological correlates of these two indicators along with their interrelation. The results show a gradual effect in the intensity of psychophysiological arousal: the intensity was highest for tears combined with goosebumps, followed by tears only and goosebumps only<sup>15</sup>. This gradual effect was observed in all psychophysiological channels that were measured (Fig. 10). As emotional empathy seems to play a crucial role in states of being moved (as discussed in more detail below), the present findings of heightened physiological arousal can be interpreted as lending support to the consistent reports of physiological activation when witnessing and empathizing with others in need (e.g., Sze, Gyurak, Goodkind, & Levenson, 2012).

To date, psychological and neuroscientific studies have reported the occurrence of goosebumps or chills during moments of peak emotional arousal in different aesthetic contexts (for music, see Salimpoor et al., 2011; for films, see Wassiliwizky et al., 2015). A few studies have also reported emotional tears during peak moments of art reception (Scherer & Zentner, 2001; Scherer et al., 2002; Hanich et al., 2014). Our data present evidence for a gradual increase in emotional arousal even within peak emotional moments, with overlapping tears and goosebumps representing the climax of arousal. The close relatedness of tears and goosebumps became obvious in the co-occurrence pattern both at the level of individual periods (almost 60% of the goosebumps periods overlapped with tears) and at the level of clips (goosebumps appeared primarily, in 80% of the cases, in clips that triggered a full-blown lacrimation, in contrast to “feeling like crying”). The distinction between an actual shedding of tears and a mere awareness of an upcoming period of crying, i.e., without production of tears (cf. Pelowski, 2015), was corroborated by psychophysiological data that showed higher arousal states for the former category (except for the corrugator activity, Fig. 11; the reverse effect for the corrugator activity can be interpreted as higher tension of facial muscles, which indicates negative affect before the emotional release happens, i.e., the lacrimation).

The overlap and close alliance of piloerection and lacrimation involves a complex underlying physiological orchestration. After all, these responses are governed by two antagonistic divisions of the ANS, which is generally concerned with regulation of fundamental bodily functions related to the activation of organs and tissues. Whereas the pilomotor reflex of the arrector pili muscles (around the hair follicles), which causes body hair to erect, is controlled exclusively by the sympathetic nervous system (SNS; Hellmann, 1963), the release of the lacrimal secretion from the lacrimal glands, in contrast,

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<sup>15</sup> Thus our data suggest that goosebumps are although strong, but not *peak* emotional responses, as unanimously assumed in the pertinent literature. Rather, the very peak levels of physiological arousal are exclusively reached by combinations of goosebumps and tears (goosetears), with a substantial gap between goosetears and goosebumps only. Because, to our knowledge, no study on piloerection and chills collected additional ratings regarding emotional lacrimation, one could speculate that in former studies goosebumps and goosetears were conflated. Critically, the presence of the latter category could have unknowingly amplified the physiological outcomes of the former one.

is modulated by the parasympathetic nervous system (PNS; Werb, 1983; Dart, 2009). The core functions of these two divisions of the ANS have classically been associated with mobilization of energy in demanding situations (the SNS) and regeneration in the absence of environmental stressors (the PNS) (Cacioppo, Tessinary, Berntson, 2007). This has led researchers to assume that emotional lacrimation should bring about recovery and suppression of sympathetic activity (Efran & Spangler, 1979). Our present findings, however, point in the opposite direction (see also Kraemer & Hastrup, 1988; Gross et al., 1994), since we observed increased sympathetic activity (as reflected by the skin conductance and heart rate data) in periods of tears and no apparent effect of order (with tears always following goosebumps). Our results show that emotional tears, although governed by parasympathetic activation, can be accompanied by maximal sympathetic arousal when they overlap with emotional goosebumps.

Although most organs and glands are innervated by both the SNS and the PNS (Pape, Kurz, & Silbernagl, 2014) in order to either activate or relax the respective effector, the antagonistic activations tend to alternate in time. In some complex physiological processes, however—for example, in sexual arousal, the two systems are known to interact simultaneously within the same process (Steger & Weidner, 2011, p. 67). We assume that intense states of being moved that are indicated by tears and goosebumps are likewise mediated by a complex antagonistic interplay of the two subdivisions of the ANS resulting in an intense physiological activation and a unique subjective bodily feeling. The cross-cultural expression of *feeling/being moved* is likely to reflect or at least be strongly informed by the experience of this heightened bodily arousal (cf. Kuehnast et al., 2014; Menninghaus et al., 2015). Moreover, PNS activation has also been associated with states of helplessness and feelings of being emotionally overwhelmed (Vingerhoets & Bylsma, 2015), which are typically reported by people who cry in response to movies (Denckla et al., 2014). Moreover, our participants reported immediately after the testing session that they felt greatly relieved after a period of tears (i.e., a cathartic effect; cf. Frey, 1985; Frijda, 1986) and that they enjoyed this experience, although they also reported that negative emotional components were involved (see Tab. S16 for the original wording of the statements given by our participants after the testing session).

The mixed affective nature of the feelings of being moved was also reflected by moderate co-activation effects of the facial corrugator and zygomaticus muscles during periods of tears (and more globally, at the level of the entire clips)<sup>16</sup>. As stated above and elsewhere (Tokaji, 2003; Tan, 2009; Menninghaus et al., 2015; Wassiliwizky et al., 2015), the mixture of a predominant emotional component, for example, sadness, with its emotional antidote is an essential requirement for states of being moved to occur. Frequently, the antidote entails elements of high personal norms, moral goodness, and displays of prosocial behavior that lives up to high social norms and self-ideals. The significance of a prosocial dimension in the tears-eliciting stimuli was corroborated by our formal film analysis, as we will now explain.

First, most of our participants' excerpts were taken from the genres of drama and romance, and hence from two genres that frequently address societal values and virtues such as altruism, bonding, self-sacrifice, faithfulness, and so forth. Moreover, almost all excerpts (about 94%) displayed social interactions involving humans, animals, or anthropomorphic characters. Second, as hypothesized, the formal filmic features of the individual clips were optimized for displaying the facial expressions of the

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<sup>16</sup> An alternative explanation of increased corrugator and zygomaticus activity might be that the process of crying can involve a great number of facial muscles, including the zygomaticus, without any expression of positive emotions. Although our interpretation of mixed-emotion states is backed by both previous research and verbal statements by our participants during the interview, we cannot definitely rule out this alternative interpretation.

protagonists and bystanders; this was reflected in a predominance of close-ups and an eye-level perspective as compared to the matched control clips. The function of an overall predominance of high key lighting (over 80% of total time for both stimulus sets) is to brighten the visibility of details like facial emotional cues (which might be the main reason for the prevalence of high-key lighting in dramas in general, as noted by Bordwell & Thompson, 2013, p. 129). The slight tendency of tears-eliciting clips towards more low-key lighting can be interpreted as further highlighting their gloomy content (cf. the Scenario column in Tab. S17). Moreover, the experimental clips depicted significantly more crying individuals; this adds to emotional intensity by virtue of the tear effect (Provine, Krosnowski, & Brocato, 2009; as discussed in more detail below), and by virtue of emotional contagion (Hatfield et al., 1994). Emotional intensity is further amplified by the use of musical scores and the depiction of singing characters. Music and singing have often been shown to be capable of eliciting peak emotional responses including piloerection/chills and tears on their own (Panksepp, 1995; Blood & Zatorre, 2001; Scherer & Zentner, 2001; Scherer et al., 2002; Rickard, 2004; Grewe et al., 2007 and 2009; Guhn et al., 2007; Salimpoor et al., 2009 and 2011; Fukui & Tyoshima, 2014). Finally, tears-eliciting clips used significantly more point-of-view shots which facilitate perspective taking and thereby empathic responses on the side of the film viewer.

Third, in 55% of all experimental clips picturing human interactions, we observed the presence of bystanders or witnesses in the narrative background of the scenario, such as a family member (e.g., an aunt who witnesses doctors telling the parents of a child who was seriously injured in an accident that their child has died), or a large crowd of strangers who witness the reunion of a couple (the main characters) after many years of separation. In general, we observed a strong tendency towards the display of either a single bystander or larger groups of five or more bystanders in the background of the scenarios. This stands in stark contrast to the general tendency of showing two actors in the narrative foreground of the scenarios. We suggest that this contrast results from the different dramatic functions that the characters fulfill in a scenario. As mentioned above, film makers often use bystanders to prime a particular response (e.g., crying) in the film viewer because the bystanders and film viewers are in similar witness positions. In the case of a single bystander, a considerable number of detailed cues can be displayed that will not escape the film viewer's attention (a sad facial expression, trembling of the chin, sobbing, eyes hidden behind a hand, tears rolling down the cheek). For a large crowd, this level of detail is impossible; therefore, only simple, single cues are displayed by members of the crowd, such as cheering with arms raised. However, the sheer fact of a synchronized response in a large group of people makes for a powerful emotional stimulus. The prevalence of dyads in the narrative foreground, in contrast, might be due to the fact that most moving scenarios touch on issues that typically arise in very close personal and intimate relationships (e.g., romantic break-ups, declarations of love, farewells, marriage proposals, death bed scenarios; cf. the Scenario column in Tab. S17).

The results of our study add to the converging evidence that states of being moved, the peaks of which involve emotional piloerection and/or emotional tears, draw substantially on the emotional resources of social cognition and social norms (cf. Vingerhoets & Bylsma, 2015). Interestingly, recent experimental studies have shown that participants who have been moved by an artwork or media product are more likely to display prosocial behavior in a subsequent behavioral test. Specifically, Stel, van Baaren, and Vonk (2008) demonstrated that participants showed significantly greater readiness to make generous charitable donations if they were emotionally moved beforehand (for a similar line of research see Sze et al., 2012). Likewise, in a dictator game paradigm, Fukui and Toyoshima (2014) found enhanced empathy and altruism in participants who experienced music-elicited chills before playing the dictator



game. Panksepp and Bernatzky (2002) offered an evolutionary explanation for the nexus between emotional piloerection and social cognition: They theorized that chills (which are readily associated with feeling cold) might have originated as a way to urge the organism to seek close social (and bodily) contact with others and thereby re-establish social bonds (see also Benedek & Kaernbach, 2011; Maruskin, Thrash, & Elliot, 2012). Piloerection in response to artworks and media products could hence represent a derivative relic of this phylogenetically ancient response that still retains its function of fostering social bonds and facilitating prosocial behavior. Moreover, the fact that it is highly rewarding for an empathizing viewer to observe altruistic behavior in response to the plight and suffering of others indicates a potential evolutionary function of states of being moved for the reinforcement of group cohesion.<sup>17</sup>

Whereas piloerection urges the organism itself to re-establish social bonds (according to Panksepp's theory, outlined above), the display of emotional tears has a complementary effect of attracting the social support of others for the crying individual. As mentioned earlier, the communicative signal of emotional tears has repeatedly been shown to compel others to provide help or emotional support to the crying individual (Hendriks, Croon, & Vingerhoets, 2008; Vingerhoets et al., 2016). This may result from the fact that visible tears are attributed to greater amounts of emotional suffering. This *tear effect* has been corroborated by a number of studies that manipulated facial images by digitally adding (or removing) tears (Provine et al., 2009; Balsters et al., 2013; Vingerhoets et al., 2016). Moreover, visible tears have been shown to increase the perceived helplessness of the crier and a stronger willingness in the observer to provide help (Vingerhoets et al., 2016). As in the case of art-elicited piloerection, art-elicited tears might also represent an evolutionary relic that still serves the function of fostering social bonds between viewers and facilitates imitation of altruistic behavior (Stel, van Baaren, & Vonk, 2008).

We conclude that the elicitation of feelings of being moved could have a therapeutic value for people with low empathic capacities as well as in educational contexts. Classic cultural ideals as propagated by Schiller, Goethe, Lessing, and many other humanists typically include these transformative effects on the personality of readers, viewers, and listeners as *the* core function of emotionally moving arts altogether (e.g., Schiller, [1795] 2004; for more recent versions of this line of thinking see Nussbaum, 1997 and Oatley, 2016; for empirical evidence, see Kidd & Castano, 2013). Future research will have to assess the effectiveness of artworks and media products that are deeply moving in enhancing a person's long-term capacity for empathy and the cognitive ability to adopt another person's perspective.

**Limitations.** Although we explicitly endorsed the participation of men in our study, only three out of the twenty-five participants were male. One could therefore question the generalizability of our results. However, a general bias toward the female gender is a well-established, cross-cultural finding in the scientific literature on emotional tears and crying (Bindra, 1972; Lombardo, Cretser, Lombardo, & Mathis, 1983; Becht, Poortinga, & Vingerhoets, 2001; for a review, see Vingerhoets & Scheirs, 2000). Females cry two to four times more frequently than males, starting in childhood (Jellesma & Vingerhoets, 2012) and continuing throughout their lives (Lombardo, Cretser, & Roesch, 2001); moreover, critically for this study, women report higher rates of crying in response to sad films or sad books (Fischer, Bekker, Vingerhoets, Becht, & Manstead, 2004) and also report enjoying these tears more than men do (Van der Bolt & Tellegen, 1996; Vingerhoets, 2013). Moreover, male crying is considerably less acceptable in most societies (MacArthur & Shields, 2015) and males feel more

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<sup>17</sup> The same mechanism of enhancement of (in-)group cohesion might likewise be at work in ritual weeping (Vingerhoets, 2013). Here, deliberately evoked collective crying is used in order to unify the members as a group in times of great difficulties or challenges (cf. Dissanayake, 2008).

confused and irritated when confronted with other individuals—particularly other males—who start crying in their presence (Plas & Hoover Dempsey, 1988; Jessor, 1989).<sup>18</sup> All these factors might have contributed to the bias of our sample towards females.

Since the presence of tears was not monitored objectively in our study and we relied solely on self-reports one could raise concerns regarding the demand characteristics, i.e., participants pushing the response button without actually experiencing tears. Although we initially planned to video record the faces of participants, we eventually refrained from doing so, because preliminary interviews revealed that the majority of the participants preferred a private atmosphere during the experimental session. Many of them even doubted to be able to be moved to tears when monitored by the experimenter or a camera. Moreover, we were also interested in subtle lacrimation states, i.e., feeling like crying, which is not observable neither by a present person nor by a camera. Importantly, however, the after-effects of crying remain visible in most cases in the face of the participant, as indicated by red sclera of the eyes and red areas around the eyes, wet cheeks, smeared make-up, running nose and presence of used tissues. When re-entering the experimental room, the experimenter checked first of all for these visual indicators. More than 90% of the sample showed positive evidence for a recent crying episode. We thus had no reason to be concerned about demand characteristics.

On the basis of converging evidence from this study, our earlier findings, and work reported by other groups, we claim that the display of prosocial behavior is particularly critical for the elicitation of feelings of being moved. This is especially true for art forms that are narrative in nature, such as novels, plays, films, songs, ballads, choreographic performances, and so forth (Schoeller & Perlovsky, 2015). However, the variety of stimuli capable of eliciting states of being moved also includes instrumental music, which does not display a social component as overtly as narrative genres do. Obviously, other processes must be at work to trigger these emotional responses, with musical expectancy representing one important factor (Huron & Margulis, 2010). It should also be noted that the evolutionary origin of instrumental music has been closely related to social activities and social emotions (Sloboda & O'Neill, 2001; Dissanayake, 2008; Panksepp, 2009). Thus, even instrumental music may activate latent associations with social cognition. In fact, music was also a predominant feature in our tears-eliciting stimulus set as compared to the control set. Since we did not manipulate any features of the film excerpts, in order to guarantee high ecological validity, we cannot quantify the share that music had in eliciting the states of being moved, compared to the displays of prosocial behavior. A neat disentanglement of these effects would require considerable additional effort, since original material with separated audio and video tracks would be needed to perform this kind of research. Similarly, we cannot quantify the share of other formal filmic features such as the predominant usage of short camera distances as compared to, for instance, the influence of emotional contagion through depiction of crying characters (which is significantly higher for tears-eliciting clips) or facial emotional expressions in general. Due to the correlational nature of our findings we cannot claim that the short camera distance or the eye-level perspective *produce* the tears response in the viewer. Rather, we think that these technical characteristics facilitate other effects: For example, in order to depict facial emotional expressions that are contagious for the viewer, both a short camera distance in regard to the face of the character and an eye-level perspective are almost mandatory. If the character's face expressing a certain emotion is

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<sup>18</sup> For all these reasons, several studies on emotional tears have even limited their samples to female participants alone (e.g., Frey, DeSota-Johnson, Hoffmann, & McCall, 1981; Kraemer & Hastrup, 1988; Gross et al., 1994).

shot from a long distance or from a worm's view, chances are low that this emotional expression will be detected by the viewer.

As mentioned in the introduction, scientific research on tears distinguishes five categories of emotional tears, with art-elicited tears representing one of these. Having studied emotional tears exclusively in response to film clips, we cannot generalize our findings to the other four categories of emotional tears. Since previous research has often conflated different types of emotional tears, we would like to emphasize once more that art-elicited tears may differ from other types of emotional tears because of their unique ability to be concomitant with an overall positively valenced emotional state of being moved.

**Conclusions.** By identifying the psychophysiological correlates of art-elicited tears, their relationship to emotional piloerection, and the stimulus characteristics that facilitate these intense emotional responses, our study contributes to resolving some of the mysteries of “the secret land of tears” and promotes the understanding of a phenomenon that is unique to humans.

## Chapter 5: General Discussion

The present thesis investigated the emotional state of being moved through the lens of three distinct physiological markers (chills, goosebumps, tears), psychophysiological and neural correlates, and compositional principles of the eliciting stimuli. To start with, it was crucial to investigate into the hypothetical link between states of being moved and the chill response which to date was not associated with any specific emotion but rather treated as a global marker of peak emotional arousal (e.g., Salimpoor et al., 2009, 2011). The first study therefore aimed to answer the question:

### **RQ1: Do art-elicited chills indicate states of being moved?**

The logistic regression analyses revealed that the intensity ratings for being moved were positively associated with the probability of chill occurrences (Fig. 3). In other words, the higher the participants felt moved, the more likely they were to experience chills<sup>19</sup>. Moreover, the analyses provided evidence for being moved to be the best predictor for chills, as compared to pure sadness and pure joy. This latter outcome is remarkable given the fact that, in the free-listing task, participants were more prone to refer to the emotion they experienced by using the terms "sadness" or "joy" (Fig. 2). Obviously, the predominant emotional building block of sadness or joy, which is embedded in an episode of being moved, is so salient in the proprioception (and the word retrieval is so much easier for "sadness" and "joy" than for the far less prototypical emotion term "being moved"), that participants tend to reduce *being sadly moved* to just being *sad* and *being joyfully moved* to just being *joyful*. However, once the term "being moved" is explicitly offered as a response option, along with sadness and joy terms, people associate their emotional experience in a stronger fashion with the term "being moved" than with "joy" and "sadness".

Interestingly, this phenomenon applies not only to lay people but also to academic researchers, who refer to being sadly moved as sadness (e.g., Panksepp, 1995; Huron, 2011; Vuoskoski, Thompson, McIlwain, Eerola, 2012; Mori & Iwanaga, 2014; Sachs, Damasio, Habibi, 2015; Taruffi & Koelsch, 2015; Brattico et al., 2016). The fact that art-elicited sadness can be highly enjoyable (for reviews, see Sachs et al., 2015 and Menninghaus, Wagner, Hanich, et al., 2017) leads inevitably to conceptual problems, such as the sad-film-paradox (Oliver, 1993). Some researchers tried to circumvent this problem by adding a qualifying adjective "aesthetic" and thus distinguishing regular sadness from "aesthetic sadness" (Nusbaum, Silvia, Beaty, Burgin, Hodges, & Kwapil, 2014). However, this solution falls short of acknowledging the mixed affective nature of this emotional state, because sadness is balanced by a positive emotional antidote (Hanich et al., 2014; Menninghaus et al., 2015; Wassiliwizky et al., 2015). Being sadly moved, on the contrary, highlights that the negatively valenced state of sadness is embedded in a positively valenced state of being moved. Importantly, this is not just a matter of nomenclature, since scientific usage of terms should accurately reflect empirical findings regarding distinctive properties of the objects they refer to (Lilienfeld et al., 2015). Thus, the term "being sadly moved" is preferable to that of "aesthetic sadness" or just "sadness".

The fact that sadness per se is not enjoyable, was the answer to the second research question:

### **RQ2a: Is the positive relation between sadness and enjoyment mediated by being moved?**

The mediation analysis revealed a full mediation of being moved on the effect of sadness on enjoyment, thus confirming earlier results by Hanich et al. (2014). This finding suggests that, although sadness is a

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<sup>19</sup> A recently published study confirmed this relationship for two different samples from the U.S. and Norway (Seibt, Schubert, Zickfeld, Fiske, 2017).

vital component of being sadly moved, its primary function is to fuel the overall emotional intensity. After all, negatively valenced emotions are particularly powerful in catching and securing attention and amplifying the emotional involvement (Menninghaus, Wagner, Hanich, et al., 2017), as discussed in more detail below. Interestingly, a similar mediation analysis with joy as the independent variable showed no mediation effect, thus answering the second part of the second research question:

**RQ2b: Is the positive relation between joy and enjoyment mediated by being moved?**

Consequently, the positive effect of joy on enjoyment is a direct effect, without any detour via being moved. Given the fact that the enjoyment of a positive emotion is a straightforward phenomenon and that comedies are among the most ancient genres, this result is not in need of any elaborate interpretation. However, the missing link between joy and being moved was surprising. While further research is needed to replicate this outcome, it does point into the direction that in joyfully moving scenarios such as reunions it is primarily the subordinate negative component (e.g., reactivation of the painful separation) that contributes to the overall moving quality. The finding also strengthens the notion that being moved is primarily bound to a serious component in the stimulus, which is why serious art genres such as tragedies, dramas, operas, or sacred music are among the most moving elicitors (as also became evident in the genre analysis of the third study).

Poems are also known to dwell heavily on negative affective contents such as unrequited love, loneliness, fleetingness, fragility, farewells, and death. Already the fact that these serious issues are presented in an artfully elaborated and pleasing language (which Aristotle referred to as the *sweetness* of diction, [335 B.C.] 2005) suggests a blend of sadness (elicited by the content) and affectively positive responses (elicited by the form<sup>20</sup>). Unsurprisingly, poems are known to be potent elicitors of being moved (Menninghaus, Wagner, Wassiliwizky, et al., 2017). However, to date it was not clear whether poems are capable of evoking peak emotional experiences.

The second study showed that both chills and goosebumps can be elicited not only in response to highly familiar self-selected poems, but also to the unfamiliar experimenter-selected ones. This result gives an answer to both the third and the fourth research questions.

**RQ3: Are poems capable of inducing emotional chills?**

**RQ4: Is the elicitation of chills bound to high degrees of familiarity?**

The follow-up behavioral study even revealed strong emotional engagement and elicitation of chills for participants that had no particular inclination toward poetic language or expertise in reading poetry<sup>21</sup> (Tab. S6). Although it was well-known from former research that poems are capable of inducing – rather mild – affective states (e.g., Obermeier et al., 2013; Lüdtkke, Meyer-Sickendieck, Jacobs, 2014), this is the first (physiological) evidence granting poetic language an emotional power comparable to that of music, songs, and films. The fact that poems can elicit both subjectively felt chills and objectively measured goosebumps allowed to address the next research question.

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<sup>20</sup> This distinction between form-elicited and content-elicited emotional reactions is consistent with Oatley's (1995) taxonomy of emotions in response to literary texts. Of course, positive affective responses, such as joy or relief, can also be elicited by narrative elements within a primarily sad poem, thereby blending the antithetical emotions within the same category of Oatley's taxonomy.

<sup>21</sup> A recent study by Kraxenberger and Menninghaus (2017) provided evidence that affinity to poetic language can influence aesthetic appreciation of poems, thus, showing the very opposite of the present results. However, it is important to note that whereas Kraxenberger and Menninghaus presented their stimuli visually as text, the current study used professional recitations which might be more powerful in eliciting strong emotional responses and therefore reach even participants without any affinity to poetic language.

### **RQ5: Are chills different from goosebumps?**

A potential difference between chills and goosebumps has been investigated by implementing a repetition paradigm, i.e., presenting all stimuli twice. The results show that the physiological correlates of subjectively felt chills habituated over time, i.e., from the first to the second run. Conversely, the physiological signature of objectively measured goosebumps revealed a sensitization effect. A similar outcome for piloerection incidents has already been reported by Benedek and Kaernbach (2011). They found the probability of piloerection to increase over the course of the experimental session. In order to explain this finding, the authors speculated that the increasing comfort of the participants with the experimental setting might have allowed stronger engagement with the stimuli and therefore more piloerection incidents. However, this reasoning cannot explain why increased comfort did not yield a similar effect for chills as well in the present study (let alone why the very reverse, i.e., a habituation effect, was found for them). The present data rather indicate a genuine dissociation between chills and piloerection. Further investigation is clearly needed in order to confirm this finding and to further elaborate on the question of how much delay between the first and second presentation of the stimuli is critical for these effects to be observed. In any event, the present outcomes imply that multiple usages of the same stimuli within one study (e.g., within the fMRI scanner and in the immediately following rating study) are a moderating variable that has to be taken into account in future investigations.

### **RQ6: Which brain structures underlie poetry-elicited chills and do they differ from neural correlates of music-elicited chills?**

The question of which neural correlates underlie poetry-elicited chills became all the more pressing after discovering that the corrugator was deeply involved in the experience of peak emotional responses to poems (Fig. 5B). The zygomaticus, on the other hand, showed significantly less activity than the corrugator (Fig. 5D and Tab. S3B). A long tradition in psychophysiological research associates these facial muscles with experiencing positive (zygomaticus) and negative (corrugator) affect across different perceptual domains (Cacioppo et al., 1986; Witvliet & Vrana, 1995; Lang et al., 1998; Larsen et al., 2003; Aue & Scherer, 2008; Lundquist et al., 2008; Delplanque et al., 2009). These findings and the well-established fact of high levels of pleasure in context of chills, which is mediated by the mesolimbic reward system (Blood & Zatorre, 2001; Salimpoor et al., 2011), would rather have predicted the zygomaticus to be more prominent in episodes of chills. Importantly, the present fMRI study confirmed the involvement of the primary reward circuitry in the episodes of poetry-elicited chills and the anticipatory periods (of roughly 4 sec) prior to chills, thereby providing the first strong support for the claim that “metered poetry [is] an ideal technique for stimulating and sensitizing the endogenous reward system of the brain” (Jacobs, 2015).

However, although these findings seem paradoxical at first glance, they are fully in line with the theoretical concept of being moved, for which already Schiller coined the following formula: “Being moved, rigorously understood, designates the mixed sentiment of suffering and the pleasure taken in this suffering” (translated and quoted by Menninghaus et al., 2015). The current results accurately reflect this definition: for the same participants and stimuli,<sup>22</sup> both corrugator activity is heightened in the moments of chills, indicating negative affect (“suffering”), *and* the neural activity in the mesolimbic reward circuitry indicating experiences of enjoyment (“pleasure”). In future studies, it will be necessary to solidify these co-activations by a simultaneous acquisition of both corrugator electromyography and functional magnetic resonance imaging (Heller, Greischer, Honor, Anderle, Davidson, 2011).

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<sup>22</sup> Note that the stimuli were almost identical (over 85 %), because two experimenter-selected poems were replaced in order to test effects for entirely unfamiliar stimuli (no such effects could be observed). The self-selected poems were identical.

These co-activations are further consistent with the verbal self-report measures of the first study which showed a positive effect of experienced sadness on enjoyment (Fig. 4). As described above, a mixed affective nature of being moved states has been reported repeatedly and across different domains (Tokaji, 2003; Benedek & Kaernbach, 2011; Kuehnast et al., 2014; Hanich et al., 2014; Menninghaus et al., 2015 & 2017). The recent comprehensive review by Menninghaus and colleagues (2017) argues that the involvement of negative emotions in aesthetic experiences (such as sadness, horror, or disgust) is an important resource for the arts in general rather than a special license for exceptional art genres. This is likely to be due to a remarkable overlap of the goals of the arts on the one hand and the functions of negative emotions on the other: both are associated with capturing and sustaining focused attention, providing intense involvement, and granting prioritized access to storage in memory. Importantly, these intense feelings are experienced from a witnessing perspective and with the ever-present possibility of withdrawing from the aesthetic stimulus.

Although the findings of the present fMRI study broadly correspond with the outcomes of studies on musical chills (Blood & Zatorre, 2001; Salimpoor et al., 2011), there are also important differences both in regard to the exact locations of neural activity during chills as well as in regard to the temporal neural organization of peak emotional experiences. Notably, the activation clusters for poetry-elicited chills in the chills > neutral contrast (Fig. 7) are shifted to the posterior as compared to the reported results of the same kind of contrast for the music-elicited chills, i.e., mid cingulate vs. anterior cingulate, mid insula vs. anterior insula, and body and tail of the caudate vs. head of the caudate. Some of these findings fit well with Jacobs' fiction feeling hypothesis (2011) and his neurocognitive poetics model (2014 & 2015) which emphasizes, for instance, the importance of the mid cingulate cortex in reading processes that involve (negative) emotional arousal, empathic reactions, and immersion of readers (for empirical evidence, see Hsu, Conrad, Jacobs, 2014<sup>23</sup>). The current study had no a priori hypotheses regarding such potential shifts, and it did not test both music and poetry within the same participants. Therefore, and in order to avoid post hoc explanations of observed neural activity, i.e., a reverse inference fallacy (Poldrack, 2006), these shifts are here not interpreted with regard to any functional meaning. Rather, they encourage further inquiry and should inform the generation of hypotheses in future studies. Similarly, the poetry-specific activations (not reported for music) in the anterior precuneus and SMG await further experimental confirmation from within-subject designs that compare poetry- and music-elicited chills directly. As suggested in the discussion of the second study (Chapter 3), the activations in the precuneus and SMG (as part of the TPJ) could reflect the presence of vivid mental imagery (Cavanna & Trimble, 2006)<sup>24</sup> in particularly moving, chill-inducing text passages (Esrock & Kuzmicová, 2014) and the importance of social cognition (Overwalle, 2009) for being moved, respectively. However, this needs to be demonstrated in an experimental design that either collects continuous ratings, e.g., on the vividness of mental imagery, or modifies the text (cf. van Peer, 1990; Obermeier et al., 2013 & 2016), e.g., by reformulating direct into indirect speech, thereby replacing social address by a narrative representation. In sum, the current findings on poetry-specific activations provide a fruitful basis for a number of concise a priori hypotheses that can be submitted to future empirical examination.

In addition to these poetry-specific findings regarding the location of increased neural activity, the temporal organization of neural activity in the NAcc was also found to differ from that of music-elicited chills. In their time course analysis, Salimpoor and colleagues (2011) found the right NAcc activity to rise

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<sup>23</sup> Due caution should be exercised, however, when transferring assumptions from the reading domain to listening –because of additional factors in the latter, such as emotional prosody– and also from the prose domain to poetry. Moreover, the neurocognitive poetics model was not designed to explain meso- and macrostructural aspects of poems (Jacobs, 2014), which was, however, the focus of the structural analyses here.

<sup>24</sup> Some authors differentiate between visual imagery and mental simulation with the first being a deliberate act and the second an automatic process during reading or listening (Willems & Jacobs, 2016).

immediately *after* the chills sets in, whereas *prior* to the chill the activity of another limbic structure, the right dorsal caudate, showed heightened activity. The authors interpreted this result pattern as an anticipatory period that is mediated by the caudate and a consummatory period that is mediated by the NAcc. However, this interpretation, particularly regarding the NAcc, is at odds with a considerable amount of evidence from other studies across different domains, which suggest the NAcc to be a key region for anticipating salient events such as rewards (Knutson et al., 2001; Gottfried et al., 2002; O'Doherty et al., 2002; Abler et al., 2006; Knutson et al., 2008) but also unpleasant stimuli such as pain (Becerra, Breiter, Wise, Gonzales, Borsook, 2001; Jensen et al. 2003; Carlezon & Thomas, 2009). The present investigation was thus guided by two divergent a priori hypotheses.

The results of both the contrast prechill > chill (Fig. 7 F-H) and the shape of the time course data (Fig. 8) do not support Salimpoor et al.'s (2011) interpretation of the NAcc activity as being a neural correlate of reward consumption. Moreover, no increased activity could be found in the anticipatory period for the dorsal caudate as reported by Salimpoor et al. (2011). This rather suggests, in line with the other research mentioned above, that the NAcc is critical for initializing the peak reward. Additionally, the present data show a bilateral involvement of NAcc rather than a lateralization to the right hemisphere. The absence of bilaterally increased dopamine-related activity in Salimpoor et al.'s study may, however, be due to a small sample size of only nine participants and thus a potentially diminished statistical power that could have prevented the authors from detecting these spatially constricted changes.

A possible explanation for the divergent result pattern of the time course plots of this and Salimpoor et al.'s study may lie in the different methodological approaches that were applied in the extraction of the raw BOLD signal. Whereas in the present study the regions of interest (ROIs) were defined by the significant bilateral clusters in the prechill > chill contrast (Fig. 7 F-H) which *include* the NAcc (along with some surrounding structures), Salimpoor et al. used independent data from a previous PET scan. Specifically, the individual ROIs were defined as voxels *within* the NAcc that showed maximum dopamine release in the neurochemical PET data. Given that the NAcc is divided in several functionally different zones (Berridge, Robinson, & Aldridge, 2009), it could be possible that the time course pattern extracted from a functionally defined, rather small ROI may yield a different outcome than a rather broad ROI which covers the whole NAcc and some neighboring areas around it. In any event, these divergent results, too, call for a future investigation that compares directly the neural correlates and time courses of peak-emotional-experiences in response to both music and poetry.

#### **RQ7: Which specific features of poetic language facilitate emotional chills?**

In empirical aesthetics, it is crucial to understand both the processes on the perceiver's end as well as the characteristics of the aesthetic stimulus which lead to the reactions of the perceiver in the first place. Therefore, the present investigation was also aimed at identifying some of these features which drive peak emotional responses to poetry. It is important to bear in mind, however, that the following outcomes, are based on correlational analyses, since no experimental manipulation of the stimuli has been made use of in this first investigation on poetry-elicited chills. A considerable amount of previous work has already established a link between phonological properties of poetic language and its emotional effects (van Peer 1986; Hanauer, 1996; Whissel, 2002 & 2011; Auracher, Albers, Zhai, Gareeva, Stavniychuk, 2010; Obermeier et al., 2013; Aryani, Kraxenberger, Ullrich, Jacobs, Conrad, 2016; Kraxenberger & Menninghaus, 2016a and 2016b). The present focus was, however, on the compositional and formal features of poems. Specifically, the analyses relied on linking formal features with the local information on the occurrence and accumulation of chills. Two kinds of formal features have been considered: word positions on different levels of a poem (line/stanza/poem; for a similar approach, see Kraxenberger & Menninghaus, 2016b) and linguistic markers of social address. Both formal features were found to predict the occurrence of chills in the self-selected poems and the



accumulation of chills across participants in the experimenter-selected poems. Importantly, these outcomes were replicated in the follow-up self-reading study, thereby ruling out the possibility that phonetic parameters such as the emotional prosody of the performer's voice could have explained the results. Additionally, a further control analysis ruled out a potential multicollinearity between the two formal features under scrutiny (Tab. S9); thus, apparently both features have a distinct predictive power for poetry-elicited chills.

Activating social cognition in the minds of poetry readers or listeners in order to enhance the emotional engagement is a skillful move since social life and human interactions in general are known to be one of the main sources for emotional reactions (Scherer, Wranik, Sangsue, Tran, & Scherer, 2004). Moreover, as mentioned earlier, compatibility with high social standards and prosocial behavior is a recurrent theme in the literature on being moved and chills (Panksepp, 1995; Tokaji, 2003; Tan, 2009; Cova & Deonna, 2014; Fukui & Toyoshima, 2014; Kuehnast et al., 2014, Menninghaus et al., 2015). It is worth noting, however, that the influence of social address is not necessarily bound to the realm of poetic language, as other genres, such as prose, also draw substantially on this very common feature (Leech & Short, 2007). The display of conversations and addresses to all kinds of present or absent communication partners is also a key feature of films and most prominently of theater plays. However, whether for these other genres the usage of social address is also associated with highly emotional, chill-eliciting sequences awaits future investigation. Although highly emotional passages, for instance in novels, are likely to depict social interactions including direct speech, it is nevertheless unlikely that they will have much if any statistical power to predict chills in the context of novels, because social addresses are used in much greater proportions in other genres than in poetry (Leech & Short, 2007). In sum, although the usage of social addresses is not poetry-specific, poems may well make a both relatively rare and compositionally sophisticated use of these passages such that they exert a maximum emotional impact on the reader. Moreover, the close link between peak emotional experiences and passages of social address might be a poetry-specific phenomenon.

The closure effects discovered in the present study (Fig. 9) are likewise not bound to the realm of poetic language as the underlying cadence theory was originally formulated in respect to texts in general and rhetorical speeches in particular (Lausberg, 1998). However, due to their rhythmic nature and highly structured and dense format, poems are in an optimal position to fully exploit the effects of clausula techniques. By virtue of the recurrent features of poetic language, which make the number of syllables in a line as well as the number of lines in a stanza highly predictable,<sup>25</sup> the closing positions become particularly salient for the perceiver. The predictive coding system of the perceiver checks permanently whether the structure of the just heard lines/stanzas complies with the established anticipations, thereby launching tension-resolution processes and a "pleasing sensation of fit and inevitability" (Turner & Poeppel, 1983). Additionally, closing positions are highlighted by the phonological relationship of the rhyming word pairs and by the short pauses at the end of each line (caesura). Consequently, the detection of rhyme violations have been shown to evoke emotional responses (Scheepers, Mohr, Fischer, Roberts, 2013). Together, these poetry-specific features guide strong expectations on different levels of a poem (line/stanza/poem) which are hierarchically organized. This hierarchy is accurately reflected in the present study by the magnitudes of the beta coefficients in all three word position analyses (Tab. S7), granting the word positions of the entire poem more predictive power for chills than word positions within the stanza which in turn have more predictive power than word positions within single lines (experimenter-selected subset:  $b_{poem} = 1.28$ ,  $b_{stanza} = 0.18$ ,  $b_{line} = 0.16$ ; self-selected subset:  $b_{poem} = 2.26$ ,  $b_{stanza} = 0.81$ ,  $b_{line} = 0.29$ ; self-reading study:  $b_{poem} = 0.73$ ,  $b_{stanza} = 0.64$ ,  $b_{line} = 0.17$ ). Thus, in

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<sup>25</sup> In highly formalized poems, such as sonnets, even the number of stanzas is predictable.

contrast to other genres, poets have multifarious and frequent possibilities to make use of the clausula techniques.

Undoubtedly, the arousal of anticipation, tension, and resolution in poetic language has a certain affinity to similar effects in music (Koelsch, 2014; Huron & Margulis, 2010). In his comprehensive analysis on the formal parameters of chill-inducing musical passages, Sloboda (1991) identified a number of features that are, in fact, musical clausula techniques, e.g., *harmonic or melodic acceleration to the cadence* or the *delay of the final cadence*. Thus, the principles of cadence theory are well-established in both music and poetic language. Being at the core of the neural substrates of processing rhythm, statistical learning, i.e., establishing and testing anticipations, and experiencing reward (Troost et al., 2014), it is therefore not surprising that the NAcc is crucially involved in the orchestration of both music- and poetry-elicited chills.

The third study of the present thesis explored the relationship between two physiological markers of intense states of being moved<sup>26</sup>. Participants were explicitly asked to self-select film clips that they regarded as particularly moving (to the degree of tears elicitation). Although the participants were not instructed to consider potential elicitations of emotional piloerection (in fact, they were not informed about this variable at all prior to the study), it was expected, based on previous work reported here, that stimuli that are categorized as highly moving will also elicit emotional piloerection, thereby providing an opportunity to address the next research question:

#### **RQ8: How do emotional goosebumps interrelate with emotional tears?**

Given that these two markers are controlled by two antagonistic branches of the ANS that are responsible for mobilization (sympathicus) vs. recovery (parasympathicus) of physiological energy, as well as a long-standing tradition of theorizing about the temporal dependencies of these two systems with respect to emotional tears (Bindra, 1972; Efran & Spangler, 1979; Frijda, 1986), this research question was far from being trivial. Informed by an ancient and still popular view of tears as having a cleansing, cathartic effect (Aristotle, [335 B.C.] 2005; Breuer & Freud, [1895] 1968; Frey, 1985; Bylsma, Vingerhoets, & Rottenberg, 2008) several physiological theoreticians, particularly Efran and Spangler (1979), put forward the idea that emotional lacrimation should always *follow upon* emotional arousal, thereby cleansing the organism of physical tensions and toxic substances that are released by the body through the eyes (Frey, 1985). In the present context, emotional arousal was operationalized by piloerection periods.

The results clearly show that there is no specific order effect of piloerection and tears. What is more, the majority of piloerection incidents turned out to overlap with periods of tears, thus implying a co-activation of sympathetic and parasympathetic branches of the ANS. On a rather speculative note, the specific bodily feeling component of episodes of being moved in response to various elicitors, which is similar enough to be referred to by the same term, might reflect exactly this co-activation that reaches its peak in overlapping periods of tears and goosebumps. Importantly, the physiological correlates measured in this study corroborate the idea that maximal physiological and emotional arousal is to be found in these overlaps (Fig. 10). Additionally, in line with the theoretical outline of the mixed affective nature of states of being moved, the correlation analyses of the corrugator and zygomaticus activity revealed significant co-activations of these antagonistic indicators of negative and positive affect. Finally, the physiological data showed significant increases in physiological arousal from "feeling like

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<sup>26</sup> A recent investigation, published shortly after the present study (Mori & Iwanaga, 2017), explored likewise emotional chills and emotional tears. However, in contrast to our study, the authors used musical stimuli and, critically, a between-subject design, which prevented a direct comparison between physiological correlates of chills and tears and any conclusions regarding their temporal interrelation.

crying" states to the actual shedding of emotional tears (Fig. 11). It is thus important for future studies to distinguish these responses. Moreover, current attempts to objectify the lacrimation response by the usage of a recording device similar to the goosecam (Benedek et al., 2010) should take into account that this approach will not capture the "feeling like crying" states which might already involve parasympathetic activity.

As in the case of poetic language, the third study addressed technical parameters on the side of the stimulus that are characteristic for highly moving tears-eliciting film clips. Although there is a substantial number of cinematic analyses that investigate formal film parameters (e.g., Cutting, DeLong, Nothelfer, 2010; Cutting & Iricinschi, 2015), they are rarely, if ever, connected to data of actually elicited responses of the viewers. The current study, thus, provides a novel approach to investigate the link between formal filmic features and their effects on the audience.

### **RQ9: Which technical features of film making facilitate emotional tears?**

In order to identify these features that are specific for tears-eliciting film scenarios (and not for film making in general), it was important to define an adequate control set. Extracting random clips from the same films, which are only matched for duration with the participant-selected clips, appeared as the most convincing procedure. This procedure controls for a number of variables that should remain constant between both stimulus sets, such as the production year, genre, director including his particular aesthetic style and general handling of the camera. At the same time, the self-selection procedure suggests that the control clips should have less emotional power as compared to the experimental, tears-eliciting clips, because participants were instructed to choose film passages that were most moving for them (peak states).

The results show that tears-eliciting clips use significantly more close-ups (Fig. 12), eye-level perspectives (Fig. 13), point-of-view shots, displays of crying individuals, low-key lighting, and music including both diegetic and non-diegetic as well as instrumental and vocal music (Fig. S7). Most of these parameters are tools for intensifying emotional engagement. Whereas the straight-on angle and the short distance of the camera (regarding the face of characters) ensure a detailed portrayal of facial emotional expressions including the shedding of tears, the point-of-view shots promote perspective taking. Together, all these features facilitate empathic reactions (Zillmann, 2006) and emotional contagion (Hatfield et al., 1994) on the part of the viewer. Unsurprisingly, music is also heavily drawn upon because of its remarkable capacity to arouse emotions (Gabrielsson, 2001; Zatorre & Salimpoor, 2013; Koelsch, 2014). Given the correlational nature of the present analyses, it is, however, not possible to single out the factors that are most critical for the elicitation of tears or to quantify their respective contribution. Future film studies will eventually have to find possibilities to manipulate filmic material and to produce different experimental versions in order to arrive at a more mechanism-based understanding of the workings of the film.

## Chapter 6: Implications and Conclusions

Throughout this thesis, the social implications of being moved are of preeminent importance, both on the side of the perceiver and on the side of the stimulus. As to the former, cognitive appraisals such as the compatibility with high social norms and ideals (Kuehnast et al., 2014; Menninghaus et al., 2015; Seibt et al., 2017) and the tendency to adopt a more prosocial behavior immediately after an experience of a being moved episode (Stel et al., 2008; Fukui & Tyoshima, 2014) are characteristic features. For the latter, the depiction of (pro)social actions (as demonstrated here for poems and film clips) and the application of technical parameters that are optimized for such displays (Chapter 4) support this understanding. Together, these factors stimulate empathic reactions, strong emotional involvement, and potentially personal transformation. Moreover, the elicitors of being moved, i.e., the artefact itself, such as a poem or a film, but also the creator of the artefact, such as the singer or the film director, are associated with high aesthetic and sometimes also moral value. Unsurprisingly, participants referred to their self-selected stimuli as their most favorite and repeatedly enjoyed poems and films. The intensity of felt episodes of being moved was also a predictor for wanting to come back to the stimulus in the first study.

Thus, apparently the elicitation of being moved states creates an affiliative bond (cf. Tan, 2009) between the artist and the audience and among the members of the audience (or members of the audience and other people)<sup>27</sup>. This effect was recognized and put into practice by Cicero as becomes evident in his aforementioned statement in *De oratore* ([55 B.C.] 2014; 2, 129): *It is necessary that someone who is to decide in our favor must either have a natural inclination towards us, or be won by arguments, or be forced by moving his soul* (own translation). Notably, Cicero also mentions the inclination of the perceiver towards the speaker as one factor for persuasion, given it exists naturally, that is, without any efforts on the part of the speaker. The application of the third factor, i.e., forcing the perceiver's soul by being moved, which Cicero gives a great number of instructions for, obviously also results in an (acquired) inclination of the perceiver towards the speaker. It is also notable that Cicero uses the word "forcing" (lat. cogere) to describe this process which obviously alludes to the emotional power of being moved which is fully in line with the present findings (see also his statement on being moved from *Orator* ([46 B.C.] 1975, 37): *Moving like a wild river, its force is irresistible*; own translation).

Given that feelings of being moved can promote (in-)group cohesion may point to a potential evolutionary function of this emotion. Unifying groups of people and reducing potential in-group conflict is well-known to bring tremendous evolutionary benefits with regard to several aspects of human life, specifically, the basic need of feeling secure, cooperation in collective tasks, and conjointly dealing with threads and challenges (Hoffmann, 2000; Eisenberg, 2003)<sup>28</sup>. The realm of the arts provides an inexhaustible resource of opportunities to induce and cultivate states of being moved. This potential lies at the very heart of classic cultural and educational ideals (e.g., Schiller, [1795] 2004; see also Nussbaum, 1997; Mar & Oatley, 2008; Oatley, 2016).

Importantly, as pointed out earlier, high levels of emotional intensity is crucial for the powers of being moved. This has imperative implications when it comes to the usage of poetry in school curricula (Elster & Hanauer, 2002). In practice, poems are mostly drawn upon in order to exercise capacities for text

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<sup>27</sup> The affiliative bond between the artist/performer and the viewer is also influenced by admiration and adoration on the part of the viewer (Schindler, Zink, Windrich, Menninghaus, 2013). Both phenomena are, however, tightly related to the ability of the artist/performer to move the audience.

<sup>28</sup> As briefly mentioned in the Introduction, elicitation of being moved states can also be used for in-group cohesion combined with the creation of an adversarial out-group. Several examples from different forms of propaganda, speeches, glorification of war in films, poems or songs are expressions of this "dark side" of being moved.

exegesis and analysis. The experiential part of attentive and affective reading and reciting does not play a great role. This misses the purpose of why the poem was written in the first place. Moreover, it leaves the student often unsatisfied and reluctant to engage in poetry altogether. Given the importance of a playful and joyful usage of poetic language in childhood in order to teach children to speak, to count, to memorize, or to regulate emotions (Jacobs & Kinder, 2015; Jacobs, 2016), but at the same time the low percentages of adult poetry lovers (Bradshaw et al., 2004; Gleed, 2013) suggests an unfortunate development between these two periods of life. The present data demonstrate that neither familiarity nor the inclination to poetic language is necessary for adults in order to experience profound emotional engagement and pleasure when listening to professionally recited poems. Given the archaic roots of poetic language (McHale-Moore, 2000; Schrott, 2009; Schrott & Jacobs, 2011), the fast, effortless, and unconscious processing of its features (Vaughan-Evans et al., 2016), and its “*perfect [] design [] for the human brain*” (Turner & Poeppel, 1983, p. 304), this outcome is both comprehensible and encouraging. The present work seeks to contribute not only to the understanding of the mechanisms of poetic language and its impact on the body and the brain, but also to the dissemination of these insights in educational contexts and public awareness.

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**Table S1.** Reliability Analysis. Left: Cronbach’s Alpha and its change if one of the items is dropped. Right: Item-Total Correlations corrected for item overlap and scale reliability

Sadness items	Cronbach’s alpha	Sadness items	r(it)
all four items	<b>0.77</b>		
if <i>sad</i> is dropped	0.75	<i>sad</i>	0.62
if <i>downcast</i> is dropped	0.71	<i>downcast</i>	0.68
if <i>depressed</i> is dropped	0.70	<i>depressed</i>	0.73
if <i>shattered</i> is dropped	0.73	<i>shattered</i>	0.66
Joy items	Cronbach’s alpha	Joy items	r(it)
all four items	<b>0.69</b>		
if <i>cheerful</i> is dropped	0.62	<i>cheerful</i>	0.59
if <i>merry</i> is dropped	0.55	<i>merry</i>	0.70
if <i>delighted</i> is dropped	0.60	<i>delighted</i>	0.63
if <i>amused</i> is dropped	0.71	<i>amused</i>	0.44
Being-Moved items	Cronbach’s alpha	Being-Moved items	r(it)
all four items	<b>0.75</b>		
if <i>moved</i> is dropped	0.60	<i>moved</i>	0.78
if <i>deeply moved</i> is dropped	0.65	<i>deeply moved</i>	0.68
if <i>touched</i> is dropped	0.65	<i>touched</i>	0.38
if <i>excited</i> is dropped	0.79	<i>excited</i>	0.35

**Table S2.** Aggregation of the adjectives from the free-listing condition into categories

Category	Free-response adjectives	Number of entries
SADNESS	<i>sad</i> [ <i>traurig</i> ]	112
	<i>downcast</i> [ <i>bedrückt</i> ]	10
	<i>shattered</i> [ <i>erschüttert</i> ]	4
JOY	<i>joyful</i> [ <i>freudig</i> ]	31
	<i>happy</i> [ <i>glücklich</i> ]	26
	<i>amused</i> [ <i>belustigt</i> ]	15
	<i>cheerful</i> [ <i>fröhlich</i> ]	15
	<i>amused</i> [ <i>amüsiert</i> ]	12
	<i>delighted</i> [ <i>erfreut</i> ]	8
	<i>glad</i> [ <i>froh</i> ]	4
	<i>pleased</i> [ <i>zufrieden</i> ]	3
BEING MOVED	<i>merry</i> [ <i>erheitert</i> ]	2
	<i>stirred</i> [ <i>gerührt</i> ]	25
	<i>moved</i> [ <i>bewegt</i> ]	15

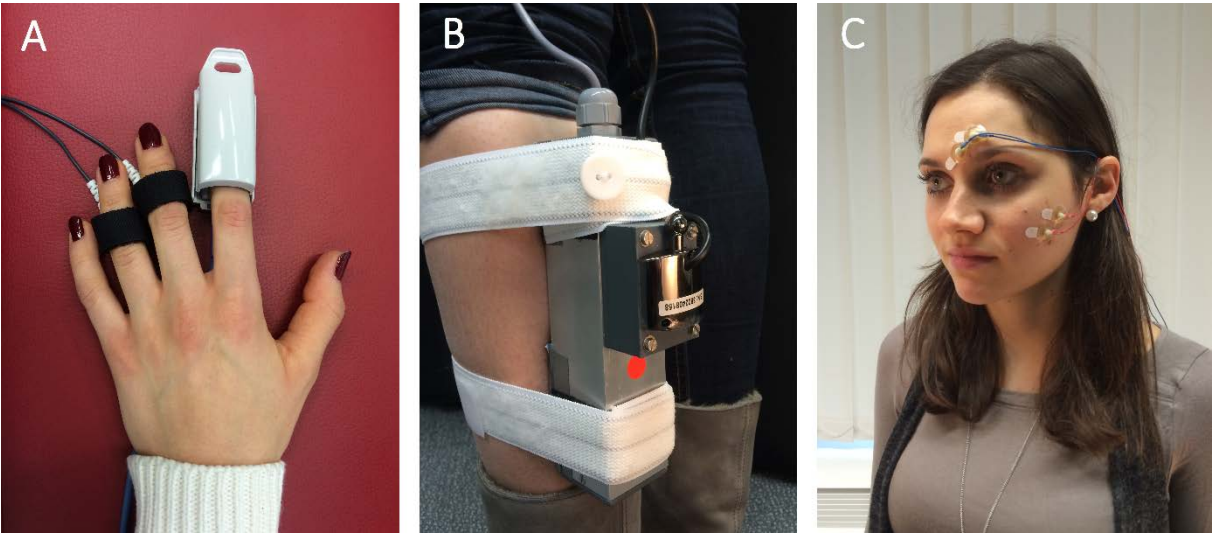
	touched [ <i>berührt</i> ]	14
	moved to tears [ <i>bewegt zu Tränen</i> ]	8
	deeply moved [ <i>ergriffen</i> ]	2
EMPATHY	compassionate [ <i>mitfühlend</i> ]	24
	sympathetic [ <i>mitleidig</i> ]	20
	concerned [ <i>betroffen</i> ]	6
ANGER	angry [ <i>wütend</i> ]	10
	frustrated [ <i>frustriert</i> ]	6
	annoyed [ <i>verärgert</i> ]	5
	irritated [ <i>genervt</i> ]	5
FEAR	fearful [ <i>ängstlich</i> ]	6
	frightened [ <i>erschrocken</i> ]	2
	shocked [ <i>schockiert</i> ]	2
	shocked [ <i>geschockt</i> ]	2
AROUSAL	excited [ <i>aufgeregt</i> ]	11
	electrified [ <i>mitgerissen</i> ]	4
	agitated [ <i>aufgewühlt</i> ]	3
SHAME	ashamed [ <i>beschämt</i> ]	8
	embarrassed [ <i>peinlich</i> ]	7
BOREDOM	bored [ <i>gelangweilt</i> ]	10
Miscellaneous	tense [ <i>angespannt</i> ]	8
	relieved [ <i>erleichtert</i> ]	7
	melancholic [ <i>melancholisch</i> ]	7
	pensive [ <i>nachdenklich</i> ]	7
	kitschy [ <i>kitschig</i> ]	6
	proud [ <i>stolz</i> ]	5
	admiring [ <i>bewundernd</i> ]	4
	aghast [ <i>entsetzt</i> ]	4
	envious [ <i>neidisch</i> ]	4
	desperate [ <i>verzweifelt</i> ]	4
	worried [ <i>besorgt</i> ]	3
	relaxed [ <i>entspannt</i> ]	3
	disappointed [ <i>enttäuscht</i> ]	3
	hopeful [ <i>hoffnungsvoll</i> ]	3
	nervous [ <i>nervös</i> ]	3
	confused [ <i>verwirrt</i> ]	3
	enthusiastic [ <i>begeistert</i> ]	2
	good [ <i>gut</i> ]	2
	interested [ <i>interessiert</i> ]	2
	entertained [ <i>unterhalten</i> ]	2
	at ease [ <i>wohl</i> ]	2

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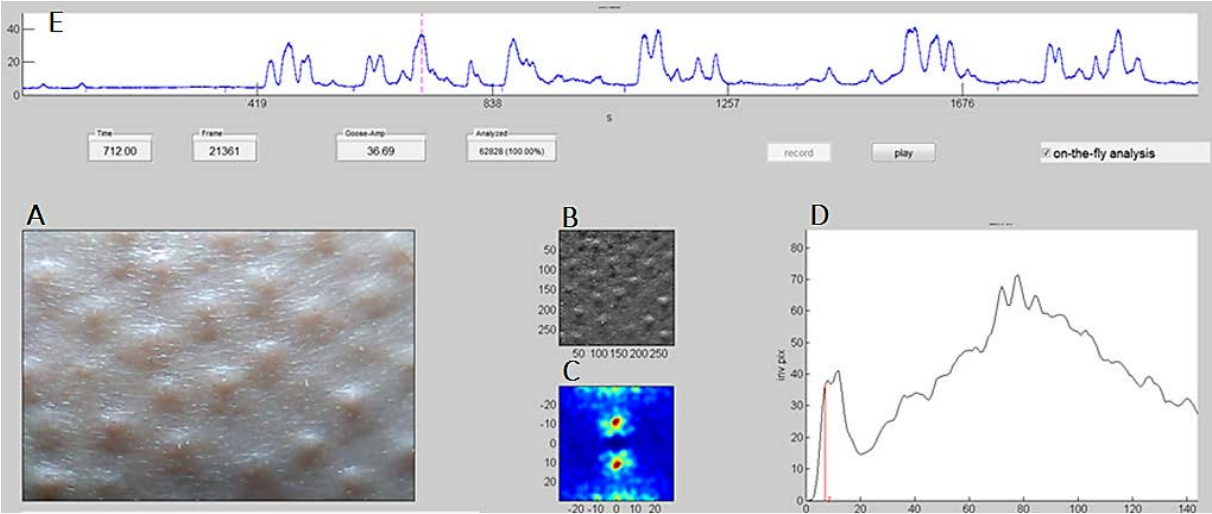
### **Location of the Chill Response**

We provided a list of the following body parts to indicate the location where the chills occurred: left arm, right arm, neck, back, buttocks, left leg, right leg, head, face, and chest. Our aim was to identify the optimal spot for objective measurement of piloerection via an optical recording device that was introduced by Benedek, Wilfling, Lukas-Wolfbauer, Katur, and Kaernbach (2010). Chills reportedly occurred mostly on arms (29% of all reported cases), legs (30% of all reported cases) and along the spine (23% of all reported cases). The remaining 18% were distributed across the other body parts: face (7%), chest (5%), head (4%), and buttocks (2%). In the case of the arms, chills occurred bilaterally, i.e., on both arms simultaneously, in 62%, and in the case of the legs, they occurred bilaterally in 71%. These results suggest that piloerection responses might best be recorded on the extremities and along the spine. Moreover, chills do not always occur on both arms and legs, implying that data collection on only one arm might fail to record the reaction.

Supplemental Material for Wassiliwizky et al. (2017). The emotional power of poetry (doi 10.1093/scan/nsx069)



**Figure S1. Physiological measures.** (A) Measurement of electrodermal activity and blood volume pulse at the non-dominant, left hand; (B) collection of piloerection data via a goosecam, attached to the left lower leg; (C) measurement of electromyographic activity over the corrugator and zygomaticus.



**Figure S2.** Screen shot of the analysis of a goosecam video, using the Matlab based software Gooselab V1.21. After a transformation of the original video frame (A) into a gray scale picture (B), a two dimensional discrete Fourier transform (C) is performed, and converted to a one-dimensional spectrum of spatial frequency (D). Using these data, a continuous measure of piloerection intensity (E) is derived for the whole experimental session (the flat curve at the beginning represents the baseline period). The dashed red cursor in (E) is placed within a piloerection episode.

**Preprocessing of the physiological data.** Electrodermal activity (EDA) was collected at a sampling rate of 32 Hz with two flat 10 mm Ag/AgCl dry electrodes fixed at the phalanges of the ring and middle fingers of the non-dominant hand (Fig. S1 A). A photoplethysmograph sensor placed on the phalanx of the index finger of the same hand recorded a digital blood volume pulse sampled at 128 Hz. Facial electromyographic (EMG) activity was recorded at a sampling rate of 2048 Hz over the left corrugator supercillii and left zygomaticus major (Fig. S1 C) using common recommendations for electrode placement (Fridlund & Cacioppo, 1986). The goosecam was attached to the left lower leg above the calf muscle (Fig. S1 B); this placement follows the recommendation of a recent study (Wassiliwizky et al., 2015) that identified the legs as the most likely place for piloerection to occur. The recorded video data were analyzed offline using the Matlab based software Gooselab V1.21 (Benedek et al., 2010; Fig. S2). Skin conductance data were analyzed using the Matlab analysis software Ledalab V3.4.4 (Benedek & Kaernbach, 2010), specifically the Continuous Decomposition Analysis. For the statistical analysis, we used the phasic EDA (pEDA) component (Benedek & Kaernbach, 2010), which reflects the rapidly varying (over seconds) activity of the EDA (i.e., SCRs), in contrast to the slowly varying (over minutes) tonic activity (i.e., skin conductance level); the latter did not show any significant changes in piloerection phases (Benedek & Kaernbach, 2011). The heart rate was derived from the raw blood volume pulse data by means of a peak detection algorithm integrated in the Biotrace software (sampled at 32 Hz). EMG signals were band-pass filtered within the frequency range of 20–500 Hz, which is the predominant range for facial EMG signals (Fridlund & Cacioppo, 1986), and convolved with a fourth-order Butterworth low-pass filter. Using these preprocessed data, root mean square amplitudes were computed for the corrugator and zygomaticus activity at a sampling rate of 32 Hz. Afterwards, all psychophysiological data were normalized to account for inter-individual baseline differences amongst participants by subtracting the individual baseline score (averaged over 3 min) from the respective signal and dividing the resulting difference score by the individual standard deviation of the baseline, i.e., linear z-transformation. The resulting scores reflect changes from the initial baseline period due to experimental stimulation (for similar normalization procedures see, e.g., Salimpoor et al., 2009;

Benedek & Kaernbach, 2011; Wassiliwizky et al., 2017). In a final step before entering the statistical analysis, all physiological data were down-sampled to 2 Hz.

To ensure that the skin conductance effects obtained for chill passages were not driven by the pushing of the response button, we performed an additional control analysis for the instruction periods when participants had to push a button for the next screen to appear. A time span of 4 s after the button press was considered to be a button-press period. The remaining (reading) time was regarded as control time. A *t*-test did not show a significant difference between reading and button pressing ( $t_{545} = 0.67, p = 0.5$ ). This replicates earlier control analyses showing the same outcome (Rickard, 2004).

**Testing procedure.** Participants completed the experiment while sitting comfortably in a reclining armchair, with their non-dominant forearm placed on an armrest. To ensure a private atmosphere, the experimenter left the testing room after providing instructions and attaching the physiological sensors. The testing began with an initial baseline of 3 min, followed by the first block of self-selected poems. Afterward, participants were presented with the block of poems pre-selected by the experimenter. After a relaxation pause of 3 min, both blocks were repeated in reversed order (experimenter-selected poems followed by self-selected poems). The order of the stimuli within each block was randomized. Presentation<sup>®</sup>14.9 (Neurobehavioral Systems, San Francisco, USA) was used to present the stimuli played binaurally over high-quality headphones, K618-DJ (AKG Acoustics, Vienna, Austria). The entire experiment took roughly 60 min per participant.

**Behavioral follow-up study.** Because our participants had to provide chill-inducing poems prior to the first study, one could question the generalizability of our findings because our sample relied on participants who not only read poetry on their own, but also remember particularly rewarding reading experiences in great detail. Therefore, in order to validate our findings, we conducted a follow-up study with 30 new participants who did not have to meet any requirements.

Thus, a new sample of 30 participants (8 males,  $M = 27.5$  years,  $SD = 7.9$ ) were presented with the five experimenter-selected poems from the physiological experiment and asked to indicate chills by a button press. All poems were presented only once. Additionally, participants rated on 6-point Likert scales their

level of familiarity with the specific poems as well as enjoyment of poetry in their leisure time (preference), general liking of poetic language (liking), and the number of poems they could recite by heart (expertise).

Twenty-three participants (76.7% of the sample) reported experiencing chills (0.52 chills/min). Using the additional ratings as predictors for the number of chills per person in a linear regression model (and for the accumulated time duration of elicited chills in a second regression model), we found no significant effects for preference, liking, or expertise (Tab. S6). This outcome confirms the emotional power of recited poetry to foster strong emotional engagement, even in participants who are not particularly inclined toward poetry.

**Self-reading follow-up study.** For both subsets of poems, we found closing positions and social address to underlie peak emotional responses. However, since we used professional recitations in all of the afore-mentioned studies, we could not rule out the possibility that emotional prosody on the part of the speakers might have contributed essentially to these findings. In order to test whether the impact of closing positions and social address would survive in an experimental setting that presented participants with written text rather than professional recitations, we conducted a follow-up reading study with a new sample of 30 participants (10 males,  $M = 27.9$  years,  $SD = 8.6$ ). They were presented with the five experimenter-selected poems (used in the first study) in writing, rather than auditorily, and they were asked to mark text passages that they experienced as particularly moving (i.e., peak emotional experiences). We did not specify whether the self-reading was to be performed silently or aloud; participants completed the task at home in a private atmosphere.

These data enabled us to use the same statistical models that we had used for the audio versions (i.e., instead of the accumulated number of chills per word, the accumulated number of markings per word was predicted by relative word positions (within the poem/stanza/line) and by the factor Social address). In the word position analysis, we observed an accumulation of markings at the end of entire poems ( $b_{poem} = 0.73$ ,  $p < 0.001$ ), single stanzas ( $b_{stanza} = 0.64$ ,  $p < 0.001$ ), and individual lines ( $b_{line} = 0.17$ ,  $p < 0.001$ ) (Tab. S7). Moreover, the second analysis revealed that passages of social address were more



likely to be marked by participants than narrative or descriptive passages ( $b = 0.48, p < 0.001$ ) (Tab. S8C). This full replication of the outcomes of the first study suggests that the compositional principles of poetic language that we discovered for auditory presented poems are also in place when people read the same poems for themselves.

**Table S3A.** Results of  $3 \times 2 \times 2$  mixed-effect analyses of variance for the psychophysiological signals. The Period factor codes the analysis windows chills vs. piloerection vs. control time; the Subset factor codes the categorization experimenter- vs. self-selected poems; the Run factor codes the first vs. second presentation of the stimuli.

	Fixed Effects	$df_{(num.den)}$	F-value	p-value		
Phasic EDA	Intercept	1, 130218	10.1	< 0.01	**	
	Period	2, 130218	334.4	< 0.001	***	
	Subset	1, 130218	644.5	< 0.001	***	
	Run	1, 130218	0.1	0.78		
	Period $\times$ Subset	2, 130218	81.7	< 0.001	***	
	Period $\times$ Run	2, 130218	42.2	< 0.001	***	
	Run $\times$ Subset	1, 130218	11.5	< 0.001	***	
	Period $\times$ Run $\times$ Subset	2, 130218	3.0	0.05	*	
	Corrugator	Intercept	1, 130218	10.8	< 0.01	**
Corrugator	Period	2, 130218	602.6	< 0.001	***	
	Subset	1, 130218	2.1	0.14		
	Run	1, 130218	0.7	0.42		
	Period $\times$ Subset	2, 130218	12.0	< 0.001	***	
	Period $\times$ Run	2, 130218	99.2	< 0.001	***	
	Run $\times$ Subset	1, 130218	0.0	0.95		
	Period $\times$ Run $\times$ Subset	2, 130218	33.1	< 0.001	***	
	Heart Rate	Intercept	1, 130218	1.9	0.17	
	Heart Rate	Period	2, 130218	250.1	< 0.001	***
Subset		1, 130218	1377.0	< 0.001	***	
Run		1, 130218	225.2	< 0.001	***	
Period $\times$ Subset		2, 130218	24.0	< 0.001	***	
Period $\times$ Run		2, 130218	51.3	< 0.001	***	
Run $\times$ Subset		1, 130218	299.5	< 0.001	***	
Period $\times$ Run $\times$ Subset		2, 130218	2.8	0.06	.	
Zygomaticus		Intercept	1, 130218	2.1	0.14	
Zygomaticus		Period	2, 130218	31.4	< 0.001	***
	Subset	1, 130218	13.2	< 0.001	***	
	Run	1, 130218	116.1	< 0.001	***	
	Period $\times$ Subset	2, 130218	31.0	< 0.001	***	
	Period $\times$ Run	2, 130218	10.8	< 0.001	***	
	Run $\times$ Subset	1, 130218	7.3	< 0.001	***	
	Period $\times$ Run $\times$ Subset	2, 130218	20.3	< 0.001	***	

**Table S3B.** Results of a multilevel regression analysis aimed at testing the difference between corrugator and zygomaticus EMG activity while controlling for the other three factors.

Fixed Effects	$df_{(num.den)}$	F-value	p-value	
Intercept	1, 264090	16.14	< 0.001	***
Subset	1, 264090	4.92	0.026	*
Run	1, 264090	80.34	< 0.001	***
Period	2, 264090	337.57	< 0.001	***
EMG-channel	1, 264090	1885.26	< 0.001	***

**Table S4.** Results of a one-tailed running *t*-test comparing 0.5 s windows of the event-related skin conductance response with the preceding averaged baseline of 1 s (-7 to -6 s). To account for multiple testing, the *p*-values of the 24 individual *t*-tests were corrected by means of a false discovery rate (FDR) procedure.

Time window (s)	<i>df</i>	<i>t</i> -value	<i>p</i> -value (FDR)	
-6 to -5.5	431	1.15	0.155	
-5.5 to -5	431	1.30	0.121	
-5 to -4.5	431	1.42	0.101	
-4.5 to -4	431	1.78	0.059	.
-4 to -3.5	431	2.48	0.012	*
-3.5 to -3	431	3.23	0.002	**
-3 to -2.5	431	3.66	< 0.001	***
-2.5 to -2	431	3.65	< 0.001	***
-2 to -1.5	431	3.37	0.001	**
-1.5 to -1	431	2.95	0.004	**
-1 to -0.5	431	2.57	0.010	*
-0.5 to 0	431	2.37	0.015	*
0 to 0.5	431	1.55	0.083	
0.5 to 1	431	1.03	0.170	
1 to 1.5	431	0.76	0.229	
1.5 to 2	431	0.69	0.250	
2 to 2.5	431	0.79	0.228	
2.5 to 3	431	1.64	0.075	
3 to 3.5	431	2.65	0.009	**
3.5 to 4	431	3.68	< 0.001	***
4 to 4.5	431	4.75	< 0.001	***
4.5 to 5	431	5.13	< 0.001	***
5 to 5.5	431	5.43	< 0.001	***
5.5 to 6	431	5.34	< 0.001	***

**Table S5.** Parameters of significant local maxima for the chills > neutrals contrast and the prechills > chills contrast. In several clusters, activations were spread over neighboring areas (indicated by '+' in the table). Only clusters above  $p < 0.05$ , FWE-corrected, are reported. The coordinates refer to MNI space.

Anatomical location	x, y, z (mm)			t-value	Cluster size
<b><u>chills &gt; neutrals</u></b>					
<b>Left Rolandic operculum</b>	<b>-51</b>	<b>-1</b>	<b>4</b>	<b>7.08</b>	<b>1059</b>
+ right precentral gyrus	51	5	46	6.92	
+ left precentral gyrus	-48	-1	25	6.64	
+ right putamen	33	2	7	6.33	
+ right Rolandic operculum	57	5	13	6.12	
+ right mid insula	42	5	4	5.95	
+ left thalamus	-15	-4	13	5.84	
+ left mid insula	-36	5	7	5.79	
+ left putamen	-27	2	4	5.41	
+ right thalamus	9	-4	7	5.39	
+ left caudate nucleus	-9	-4	16	5.30	
+ right putamen	24	-4	10	5.06	
+ left pallidum	-18	2	1	4.82	
<b>Left Supplementary motor area</b>	<b>-9</b>	<b>-7</b>	<b>58</b>	<b>7.26</b>	<b>606</b>
+ right Supplementary motor area	12	5	49	5.98	
+ left mid cingulate cortex	-9	-22	43	5.76	
+ right mid cingulate cortex	12	14	40	5.48	
+ left superior frontal gyrus	-15	5	70	4.24	
+ right superior frontal gyrus	18	-1	64	4.00	
<b>Left precentral gyrus</b>	<b>-33</b>	<b>-16</b>	<b>52</b>	<b>6.58</b>	<b>503</b>
+ left postcentral gyrus	-27	-40	46	5.99	
+ left supramarginal gyrus	-45	-31	25	5.77	
<b>Right cerebellum, area VI</b>	<b>18</b>	<b>-67</b>	<b>-20</b>	<b>6.01</b>	<b>329</b>
+ right fusiform gyrus	27	-76	-8	5.37	
+ left fusiform gyrus	-30	-64	-11	5.00	
+ right lingual gyrus	21	-79	-14	4.95	
+ left lingual gyrus	6	-70	-8	4.79	
<b>Left precuneus</b>	<b>-18</b>	<b>-61</b>	<b>34</b>	<b>5.85</b>	<b>223</b>
+ left mid occipital gyrus	-30	-88	10	4.91	
<b>Right precuneus</b>	<b>3</b>	<b>-43</b>	<b>49</b>	<b>5.05</b>	<b>118</b>
+ right mid cingulate cortex	18	-37	43	5.37	
<b>Right supramarginal gyrus</b>	<b>66</b>	<b>-25</b>	<b>19</b>	<b>4.76</b>	<b>66</b>
<b><u>prechills &gt; chills</u></b>					
<b>Right caudate nucleus (NAcc)</b>	<b>9</b>	<b>14</b>	<b>-5</b>	<b>5.66</b>	<b>60</b>
+ right caudate nucleus	12	17	-2	5.51	
<b>Left Putamen</b>	<b>-18</b>	<b>11</b>	<b>-5</b>	<b>5.47</b>	<b>57</b>
+ left caudate nucleus (NAcc)	-15	11	10	4.26	
+ left pallidum	-12	5	-2	4.00	
<b>Left anterior insula</b>	<b>-33</b>	<b>20</b>	<b>-5</b>	<b>5.46</b>	<b>77</b>

**Table S6.** Results of two regression analyses for the behavioral follow-up data. The following general linear models were tested:  $\text{Chills}_i/\text{Duration}_i = \beta_0 + \beta_1 \text{Preference} + \beta_2 \text{Liking} + \beta_3 \text{Expertise} + \varepsilon_i$

Fixed Effects	estimate	<i>t</i> -value	<i>p</i> -value	
<b>Number of chills per participant</b>				
Intercept	8.62	1.58	0.13	
Liking	0.93	0.52	0.61	
Preference	-1.90	-0.91	0.37	
Expertise	-0.46	-0.36	0.72	
<b>Duration of chills per participant</b>				
Intercept	110.80	2.01	< 0.05	*
Liking	-13.96	-0.79	0.43	
Preference	6.44	0.31	0.76	
Expertise	-7.94	-0.63	0.54	

**Table S7.** Results for the word position effects. For the **experimenter-selected subset**, the number of chills per word (accumulated over all participants) was predicted in a multilevel Poisson regression model by the word’s relative position within the entire poem, the single stanza, and the single line. The same analysis was conducted for the accumulated markings of the **follow-up reading study**. For the **self-selected subset**, occurrence of a chill at a word was predicted in a multilevel logistic regression analysis by the word’s relative position within the entire poem, the single stanza, and the single line (‘|’ means ‘within’).

Fixed Effects	estimate	std.error	z-value	p-value	
<b>Experimenter-selected subset</b>					
Intercept	0.54	0.14	4.00	< 0.001	***
Word   Poem	1.28	0.04	32.65	< 0.001	***
Word   Stanza	0.18	0.04	4.62	< 0.001	***
Word   Line	0.16	0.04	4.18	< 0.001	***
<b>Self-selected subset</b>					
Intercept	-3.35	0.39	-8.54	< 0.001	***
Word   Poem	2.26	0.08	28.32	< 0.001	***
Word   Stanza	0.81	0.08	10.56	< 0.001	***
Word   Line	0.29	0.07	4.00	< 0.001	***
<b>Follow-up reading study</b>					
Intercept	0.99	0.07	12.96	< 0.001	***
Word   Poem	0.73	0.04	19.91	< 0.001	***
Word   Stanza	0.64	0.04	17.20	< 0.001	***
Word   Line	0.17	0.04	4.66	< 0.001	***

**Table S8A.** Results of the Poisson regression analysis for passages of social address in the experimenter-selected subset. The accumulated number of chills per word was predicted by the binary factor Social address.

Fixed Effects	estimate	std.error	z-value	p-value	
Intercept	1.59	0.13	18.3	< 0.001	***
Social address	0.12	0.02	5.47	< 0.001	***

**Table S8B.** Cross-table with the two binary factors Social address and Chill Word and results of McNemar’s chi-square test for passages of social address vs. narration/description within the self-selected subset. The numbers in parentheses indicate expected values under the  $H_0$  hypothesis. The units of analysis are single words.

	narration/description	social address	$\Sigma$
no-chill word	7311 (7103)	5467 (5684)	12787
chill word	2218 (2426)	2150 (1942)	4368
$\Sigma$	9529	7626	17155

$$\chi^2 = 1378.7; df = 1; p < 0.001$$

**Table S8C.** Results of the Poisson regression analysis for passages of social address in the follow-up reading study.

Fixed Effects	estimate	std.error	z-value	p-value	
Intercept	1.55	0.01	113.34	< 0.001	***
Social address	0.48	0.02	23.23	< 0.001	***

**Table S9.** Results for two control analyses, in which both factors, word position and social address, are used in one model as predictors for the number of chills (multilevel Poisson regression analysis for the experimenter-selected set) and the occurrence of chills (multilevel logistic regression analysis for the self-selected set).

Fixed Effects	estimate	std.error	z-value	p-value	
<b>Experimenter-selected subset</b>					
Intercept	0.53	0.13	3.94	< 0.001	***
Word   Poem	1.28	0.04	32.65	< 0.001	***
Word   Stanza	0.16	0.04	4.05	< 0.001	***
Word   Line	0.16	0.04	4.21	< 0.001	***
Social address	0.05	0.02	1.98	0.0472	*
<b>Self-selected subset</b>					
Intercept	-3.51	0.39	-8.90	< 0.001	***
Word   Poem	2.27	0.08	28.11	< 0.001	***
Word   Stanza	0.80	0.08	10.39	< 0.001	***
Word   Line	0.28	0.07	3.74	< 0.001	***
Social address	0.39	0.05	7.52	< 0.001	***



**Table S10.** List of all poems. The full texts of the main five experimenter-selected poems are given in German and English below this table. For the self-selected poems, the last column indicates the number of participants who selected the poem. (DoB: Date of birth, DoD: Date of death).

Poem	Year	Author	DoB–DoD	Count
<b>Experimenter-selected poems</b>				
<b>Physiological/Follow-up studies</b>				
Abendphantasie <i>Evening Phantasy</i>	1799	Friedrich Hölderlin	1770-1843	
Die Bürgschaft <i>The Hostage</i>	1798	Friedrich Schiller	1759-1805	
Herr von Ribbeck auf Ribbeck <i>Squire von Ribbeck at Ribbeck</i>	1889	Theodor Fontane	1819-1898	
Nis Randers <i>Nis Randers</i>	1901	Otto Ernst	1862-1926	
Sachliche Romanze <i>Objective Romance</i>	1928	Erich Kästner	1899-1974	
<b>Experimenter-selected poems</b>				
<b>Neuroimaging study</b>				
Der Taucher <i>The Diver</i>	1797	Friedrich Schiller	1759-1805	
Die Bürgschaft <i>The Hostage</i>	1798	Friedrich Schiller	1759-1805	
Die Trennung <i>The Separation</i>	1841	Joseph von Eichendorff	1788-1857	
Herr von Ribbeck auf Ribbeck <i>Squire von Ribbeck at Ribbeck</i>	1889	Theodor Fontane	1819-1898	
Nis Randers <i>Nis Randers</i>	1901	Otto Ernst	1862-1926	
<b>Self-selected poems</b>				
Sonett 71	1609	William Shakespeare	1554–1616	1
Sonett 43	1609	William Shakespeare	1554–1616	1
Sonett 23	1609	William Shakespeare	1554–1616	1
An sich	1641	Paul Fleming	1609–1640	1
Prometheus	1774	Johann Wolfgang Goethe	1749–1832	1
Der Fischer	1779	Johann Wolfgang Goethe	1749–1832	1
Erlkönig	1782	Johann Wolfgang Goethe	1749–1832	6
Der Taucher	1797	Friedrich Schiller	1759–1805	1
Junge Leiden	1817	Heinrich Heine	1797–1856	1
Trennung	1826	Joseph Eichendorff	1788–1857	1
Mein Herz ist traurig	1827	Heinrich Heine	1797–1856	1
Er ist's	1829	Eduard Mörike	1804–1875	1
Mondnacht	1835	Joseph Eichendorff	1788–1857	1
Sommerbild	1844	Friedrich Hebbel	1813–1863	1
Die schlesischen Weber	1844	Heinrich Heine	1797–1856	1
O Mensch! Gib acht...	1883	Friedrich Nietzsche	1844–1900	1
Der Herbst	1884	Friedrich Nietzsche	1844–1900	1
Der Herr der Insel	1884	Stefan George	1868–1933	1
John Maynard	1886	Theodor Fontane	1819–1898	2
Vereinsamt	1887	Friedrich Nietzsche	1875–1926	1
Der Rabe	1891	Edgar Allan Poe	1809–1849	2

Schon starb der Tag	1896	Rainer Maria Rilke	1875–1926	1
Und einmal lös ich	1898	Rainer Maria Rilke	1875–1926	1
Du bist so groß	1899	Rainer Maria Rilke	1875–1926	1
Wenn ich gewachsen wäre	1899	Rainer Maria Rilke	1875–1926	1
Ernste Stunde	1900	Rainer Maria Rilke	1875–1926	1
Nis Randers	1901	Otto Ernst	1862–1926	1
Albatros	1901	Charles Baudelaire	1821–1867	1
Traum	1901	Hermann Hesse	1877–1962	1
Che fece... il gran rifiuto	1901	Konstantios Kavafis	1863–1933	1
Der Panther	1902	Rainer Maria Rilke	1875–1926	1
Einsamkeit	1902	Rainer Maria Rilke	1875–1930	1
Wenn Du vor mir stehst	1903	Franz Kafka	1883–1924	1
Im Nebel	1905	Hermann Hesse	1877–1962	1
Herbsttag	1906	Rainer Maria Rilke	1875–1926	3
Der Ölbaumgarten	1906	Rainer Maria Rilke	1875–1926	1
Der Gefangene	1906	Rainer Maria Rilke	1875–1926	1
Blaue Hortensie	1906	Rainer Maria Rilke	1875–1926	1
Ein alter Tibetteppich	1906	Elke Lasker-Schüler	1869–1945	1
Entrückung	1907	Stefan George	1868–1933	1
Heiligtum	1907	Stefan George	1868–1933	1
Liebeslied	1907	Rainer Maria Rilke	1875–1926	1
Die Schwestern	1908	Rainer Maria Rilke	1875–1926	1
Die Liebende	1908	Rainer Maria Rilke	1875–1926	1
Das ist die Sehnsucht	1909	Rainer Maria Rilke	1875–1926	1
Schöne Jugend	1912	Gottfried Benn	1886–1956	1
Mutter	1913	Gottfried Benn	1886–1956	1
Nach dem Fest	1913	Hermann Hesse	1877–1962	1
Soviel du vermagst	1913	Konstantios Kavafis	1863–1933	1
Ich liebe dich...	1914	Else-Lasker Schüler	1869–1945	1
Giselheer dem Knaben	1917	Else Lasker-Schüler	1869–1945	1
Heim	1917	Else Lasker-Schüler	1869–1945	1
Ich bin nicht Ich	1918	Juan Ramon Jimenez	1881–1958	1
Schlaflied für Mirjam	1919	Richard Beer-Hofmann	1866–1945	1
It may not always be so	1923	Edward Estlin Cummings	1894–1962	1
Die Maschinenschlacht	1926	Hermann Hesse	1877–1962	1
Stimmen aus dem Massengrab	1928	Erich Kästner	1899–1974	1
Ihr tratet zu dem Herde	1928	Stefan George	1868–1933	1
Ein Mann gibt Auskunft	1930	Erich Kästner	1899–1974	1
Funeral Blues	1936	Wysten Auden	1907–1973	2
Poem	1941	Selma Meerbaum	1924–1942	2
Todesfuge	1945	Paul Celan	1920–1970	8
Emigranten-Monolog	1945	Mascha Kaléko	1907–1975	1
Entfremdung	1948	Ingeborg Bachmann	1926–1973	1
Noch fürcht ich	1948	Ingeborg Bachmann	1926–1973	1
In Ägypten	1948	Paul Celan	1920–1970	1
Brandmal	1949	Paul Celan	1920–1970	1
Der Gast	1952	Paul Celan	1920–1970	1
Die große Fracht	1952	Ingeborg Bachmann	1926–1973	1
Der Radwechsel	1953	Bertold Brecht	1898–1956	1
Ich hörte sagen	1955	Paul Celan	1920–1970	1
Rudern zwei	1956	Reiner Kunze	1933–	1
Psalm	1961	Paul Celan	1920–1970	1

Unaufhaltsam	1962	Hilde Domin	1909–2006	1
Fadensonnen	1968	Paul Celan	1920–1970	1
Noch bist du da	1981	Rosa Ausländer	1901–1988	1
Bekränkt uns	1983	Wolfgang Hilbig	1941–2007	1
Briefe an Alice	2001	Matthias Göritz	1969–	1
Verschlüsseltes		Anonymous		1

## Abendphantasie

Vor seiner Hütte ruhig im Schatten sitzt  
Der Pflüger, dem Genügsamen raucht sein Herd.  
Gastfreundlich tönt dem Wanderer im  
Friedlichen Dorfe die Abendglocke.

Wohl kehren itzt die Schiffer zum Hafen auch,  
In fernen Städten, fröhlich verrauscht des Markts  
Geschäftger Lärm; in stiller Laube  
Glänzt das gesellige Mahl den Freunden.

Wohin denn ich? Es leben die Sterblichen  
Von Lohn und Arbeit; wechselnd in Müh' und Ruh  
Ist alles freudig; warum schläft denn  
Nimmer nur mir in der Brust der Stachel?

Am Abendhimmel blühet ein Frühling auf;  
Unzählig blühn die Rosen und ruhig scheint  
Die goldne Welt; o dorthin nimmt mich,  
Purpurne Wolken! und möge droben

In Licht und Luft zerrinnen mir Lieb' und Leid! -  
Doch, wie verscheucht von töriger Bitte, flieht  
Der Zauber; dunkel wirds und einsam  
Unter dem Himmel, wie immer, bin ich -

Komm du nun, sanfter Schlummer! zu viel begehrt  
Das Herz; doch endlich, Jugend! verglühst du ja,  
Du ruhelose, träumerische!  
Friedlich und heiter ist dann das Alter.

Friedrich Hölderlin

## Evening fantasy

Before his hut, quietly in the shadows  
Sits the ploughman, contentedly, his hearth smoking  
The evening bell tolls a welcome  
To the peaceful village.

Now the boatmen too turn harbor-ward,  
In distant cities the happy sounds  
of the marketplace settle down; in quiet greenery  
glitters a sociable repast among friends.

Whither shall I go? Mortals live  
By labor and wage, alternating labor and rest  
And all is happiness; why then is it  
That in me alone the thorn allows no repose?

In the evening sky Spring's bloom opens up;  
The roses bloom innumerable and the golden world  
Seems at peace; transport me thence,  
Purple clouds! And may above

My love and passion melt into light and air! -  
But my foolish request causes  
The magic to flee; darkness falls and alone  
beneath the heavens, as ever, I remain -

Come now, soft sleep! For too much does my heart  
Yearn; but in the end, youth smolders too  
Restless, dreamy! Then comes  
Old age, serene and peaceful.

translated by Scott Horton

### Herr von Ribbeck auf Ribbeck im Havelland

Herr von Ribbeck auf Ribbeck im Havelland,  
Ein Birnbaum in seinem Garten stand,  
Und kam die goldene Herbsteszeit  
Und die Birnen leuchteten weit und breit,  
Da stopfte, wenn's Mittag vom Turme scholl,  
Der von Ribbeck sich beide Taschen voll,  
Und kam in Pantinen ein Junge daher,  
So rief er: »Junge, wiste 'ne Beer?«  
Und kam ein Mädle, so rief er: »Lütt Dirn,  
Kumm man röwer, ick hebb 'ne Birn.«

So ging es viel Jahre, bis lobesam  
Der von Ribbeck auf Ribbeck zu sterben kam.  
Er fühlte sein Ende. 's war Herbsteszeit,  
Wieder lachten die Birnen weit und breit;  
Da sagte von Ribbeck: »Ich scheid' nun ab.  
Legt mir eine Birne mit ins Grab.«  
Und drei Tage drauf, aus dem Doppeldachhaus,  
Trugen von Ribbeck sie hinaus,  
Alle Bauern und Büdner mit Feiergesicht  
Sangen »Jesus meine Zuversicht«,  
Und die Kinder klagten, das Herze schwer:  
»He is dod nu. Wer giwt uns nu 'ne Beer?«

So klagten die Kinder. Das war nicht recht -  
Ach, sie kannten den alten Ribbeck schlecht;  
Der neue freilich, der knausert und spart,  
Hält Park und Birnbaum strenge verwahrt.  
Aber der alte, vorahnend schon  
Und voll Mißtraun gegen den eigenen Sohn,  
Der wußte genau, was damals er tat,

### Squire von Ribbeck at Ribbeck in Havelland

Squire von Ribbeck at Ribbeck in Havelland,  
In his garden there stood a pear tree grand,  
And when autumn came round, the golden tide,  
And pears were glowing far and wide,  
Squire von Ribbeck, when noon rang out, would first  
Fill both his pockets full to burst.  
And then, when a boy in his clogs came there,  
He called: "My lad, do you want a pear?"  
He would hail a girl that chanced to pass:  
"Come over, I have a pear, little lass!"

Many years thus went, till the noble and high  
Squire von Ribbeck at Ribbeck came to die.  
He felt his end. It was autumntide.  
Again pears were smiling far and wide.  
"I depart now this life" von Ribbeck said.  
I wish that a pear in my grave be laid".  
And after three days, from this mansard roofed hall,  
Squire von Ribbeck was carried out, `neath a pall.  
All farmers and cottagers, solemm-faced,  
Sang: "Jesus, in Thee my trust is placed",  
And the children lamented, with hearts like lead:  
"Who'll give us a pear, now that he is dead?"

So the children lamented. It was unkind,  
As they did not know old Ribbeck's mind.  
True, the new one is skimping niggardly,  
Keeps park and pears tree `neath lock and key;  
But having forebodings, the older one,  
And full of distrust for his proper son,  
Knew well what he did, when the order he gave,

Als um eine Birn' ins Grab er bat,  
Und im dritten Jahr aus dem stillen Haus  
Ein Birnbaumsprößling sproßt heraus.

Und die Jahre gingen wohl auf und ab,  
Längst wölbt sich ein Birnbaum über dem Grab,  
Und in der goldenen Herbsteszeit  
Leuchtet's wieder weit und breit.  
Und kommt ein Jung' übern Kirchhof her,  
So flüstert's im Baume: »Wiste 'ne Beer?«  
Und kommt ein Mäd'el, so flüstert's: »Lütt Dirn,  
Kumm man röwer, ick gew' di 'ne Birn.«

So spendet Segen noch immer die Hand  
Des von Ribbeck auf Ribbeck im Havelland.

Theodor Fontane

That a pear should be laid in his grave.  
From the silent dwelling, after three years,  
The tip of a pear tree seedling appears.

And year after year, the seasons go round,  
Long since a pear tree is shading the mound.  
And in the golden autumn tide  
Again it is glowing far and wide.  
When a boy is crossing the churchyard there,  
The tree is whispering: "Want a pear?"  
And when a girl chances to pass,  
It whispers: "Come here for a pear, little lass."

Thus blessings still dispenses the hand  
Of von Ribbeck at Ribbeck in Havelland.

downloaded from: <http://www.vonribbeck.de/ribbeck-international/>

### Nis Randers

Krachen und Heulen und berstende Nacht,  
Dunkel und Flammen in rasender Jagd –  
Ein Schrei durch die Brandung!

Und brennt der Himmel, so sieht man's gut:  
Ein Wrack auf der Sandbank! Noch wiegt es die Flut;  
Gleich holt sich's der Abgrund.

Nis Randers lugt – und ohne Hast  
Spricht er: »Da hängt noch ein Mann im Mast;  
Wir müssen ihn holen.«

Da faßt ihn die Mutter: »Du steigst mir nicht ein:  
Dich will ich behalten, du bliebst mir allein,  
Ich will's, deine Mutter!

Dein Vater ging unter und Momme, mein Sohn;  
Drei Jahre verschollen ist Uwe schon,  
Mein Uwe, mein Uwe!«

Nis tritt auf die Brücke. Die Mutter ihm nach!  
Er weist nach dem Wrack und spricht gemach:  
»Und seine Mutter?«

Nun springt er ins Boot, und mit ihm noch sechs:  
Hohes, hartes Friesengewächs;  
Schon sausen die Ruder.

Boot oben, Boot unten, ein Höllentanz!  
Nun muß es zerschmettern...! Nein: es blieb ganz!...  
Wie lange? Wie lange?

### Nis Randers

Thunder and howling, a surf-roaring night;  
lightning affords but an instant of sight-  
a scream through the tempest!

And when the skies burn, you can see it quite clear:  
a ship hit a sandbar and now it is near  
the brink of destruction!

Nis Randers squints hard and looks out to the sea:  
"There's a man on the mast and he can't get free!  
We've seconds to save him!"

His mother grabs hold: "You're not going out there!  
You're all I have left now. Please, don't even dare!  
I beg you, as mother!

"The sea's claimed your father and kin, one by one,  
more than three years missing is Huey, my son,  
my Huey, my Huey!"

Nis tries to break free, but she will not let go;  
he points to the shipwreck and says calm and slow:  
"He, too, has a mother."

Then he leaps to the boat, and with him six more,  
all of true Friesian blood. Each one mans his oar,  
they smash through the breakers!

The boat hits a crest, then it falls out of sight!  
It turns and it twists in a duel of fright;  
it can't last much longer!

Mit feurigen Geißeln peitscht das Meer  
Die menschenfressenden Rosse daher;  
Sie schnauben und schäumen.

Wie hechelnde Hast sie zusammenzwingt!  
Eins auf den Nacken des andern springt  
Mit stampfenden Hufen!

Drei Wetter zusammen! Nun brennt die Welt!  
Was da? – Ein Boot, das landwärts hält –  
Sie sind es! Sie kommen! – –

Und Auge und Ohr ins Dunkel gespannt...  
Still – ruft da nicht einer? – Er schreit's durch die Hand:  
»Sagt Mutter, 's ist Uwe!«

Otto Ernst

The sea's like wild horses that foam and that rear,  
like man-eating dragons that strike every fear;  
all snorting destruction!

Each wave leaps the other in violent clash!  
They writhe and they froth to the thunder's great crash!  
Where are they? WHERE ARE THEY?!--

Three strikes of lightning!!! The bolts just soar!  
What's that--A boat that's headed for shore!  
It's them . . . and they're coming!

All eyes are strained toward the rescue band . . .  
Hugh!-- Is someone shouting?-- Yes, through cupped hand  
"Tell mother,-- it's Huey!"

translated by Peter G. Czerny



### Sachliche Romanze

Als sie einander acht Jahre kannten  
(und man darf sagen: sie kannten sich gut)  
kam ihre Liebe plötzlich abhanden.  
Wie andern Leuten ein Stock oder Hut.

Sie waren traurig, betrogen sich heiter,  
versuchten Küsse, als ob nichts sei,  
und sahen sich an und wussten nicht weiter.  
Da weinte sie schließlich. Und er stand dabei.

Vom Fenster aus konnte man Schiffen winken.  
Er sagte, es wäre schon Viertel nach vier  
und Zeit, irgendwo Kaffee zu trinken.  
Nebenan übte ein Mensch Klavier.

Sie gingen ins kleinste Café am Ort  
und rührten in ihren Tassen.  
Am Abend saßen sie immer noch dort.  
Sie saßen allein, und sie sprachen kein Wort  
und konnten es einfach nicht fassen.

Erich Kästner

### Objective Romance

Eight years they'd known each other well  
(And one can say quite well at that),  
When suddenly their love's light fell  
Like others lose a cane or hat.

And sadness rose, then merry lies,  
And kisses flew to cloud their fate.  
Without a plan they wed their eyes;  
At last she wept, beside her mate.

The ships were close enough to wave,  
When he declared it four-fifteen.  
A coffee might this day still save,  
Next door a piano's scales were lean.

A small café, the smallest lair  
They chose and stirred each with one hand.  
When evening came, they sat still there;  
They sat alone, no words to share,  
And simply couldn't understand.

translated by Hadi Kamil

### Die Bürgschaft

Zu Dionys, dem Tyrannen, schlich  
Damon, den Dolch im Gewande:  
Ihn schlugen die Häscher in Bande,  
"Was wolltest du mit dem Dolche? sprich!"  
Entgegnet ihm finster der Wüterich.  
"Die Stadt vom Tyrannen befreien!"  
"Das sollst du am Kreuze bereuen."

"Ich bin", spricht jener, "zu sterben bereit  
Und bitte nicht um mein Leben:  
Doch willst du Gnade mir geben,  
Ich flehe dich um drei Tage Zeit,  
Bis ich die Schwester dem Gatten gefreit;  
Ich lasse den Freund dir als Bürgen,  
Ihn magst du, entrinn' ich, erwürgen."

Da lächelt der König mit arger List  
Und spricht nach kurzem Bedenken:  
"Drei Tage will ich dir schenken;  
Doch wisse, wenn sie verstrichen, die Frist,  
Eh' du zurück mir gegeben bist,  
So muß er statt deiner erblassen,  
Doch dir ist die Strafe erlassen."

Und er kommt zum Freunde: "Der König gebeut,  
Daß ich am Kreuz mit dem Leben  
Bezahle das frevelnde Streben.  
Doch will er mir gönnen drei Tage Zeit,  
Bis ich die Schwester dem Gatten gefreit;  
So bleib du dem König zum Pfande,  
Bis ich komme zu lösen die Bande."

### The Hostage

Damon, with a dagger in his robe,  
Crept up to Dionysius, the tyrant;  
Whose attendants fell in slumber.  
"What do you seek with that dagger? Speak!"  
The angry voice challenged him.  
"To free the city from the tyrant!"  
"That you will answer upon the cross."

"I am," he rejoined, "prepared to die  
And ask not for my life,  
But grant me mercy,  
I beseech you for three days' time,  
Until my sister is wed to her husband,  
I leave you my friend as hostage,  
Should I flee, you may strangle him."

Then the king smiled with an angry mien  
And after brief deliberation spoke:  
"I'll grant you three days.  
But know this! If they pass by, this deadline,  
Without your return to me,  
Then he will be impaled in your stead,  
Though the penalty be intended for you."

So he went to his friend: "The king ordains,  
That I atone with my life upon the cross  
For my offending attempt,  
Though he grants me three days' time,  
That I may see my sister married,  
Provided that you stand as my guarantor  
Until I come to dissolve the bond."

Und schweigend umarmt ihn der treue Freund  
Und liefert sich aus dem Tyrannen;  
Der andere ziehet von dannen.  
Und ehe das dritte Morgenrot scheint,  
Hat er schnell mit dem Gatten die Schwester vereint,  
Eilt heim mit sorgender Seele,  
Damit er die Frist nicht verfehle.

Da gießt unendlicher Regen herab,  
Von den Bergen stürzen die Quellen,  
Und die Bäche, die Ströme schwellen.  
Und er kommt ans Ufer mit wanderndem Stab,  
Da reißet die Brücke der Strudel hinab,  
Und donnernd sprengen die Wogen  
Des Gewölbes krachenden Bogen.

Und trostlos irrt er an Ufers Rand:  
Wie weit er auch spähet und blicket  
Und die Stimme, die rufende, schicket.  
Da stößet kein Nachen vom sichern Strand,  
Der ihn setze an das gewünschte Land,  
Kein Schiffer lenket die Fähre,  
Und der wilde Strom wird zum Meere.

Da sinkt er ans Ufer und weint und fleht,  
Die Hände zum Zeus erhoben:  
"O hemme des Stromes Toben!  
Es eilen die Stunden, im Mittag steht  
Die Sonne, und wenn sie niedergeht  
Und ich kann die Stadt nicht erreichen,  
So muß der Freund mir erleichen."

And silently the true friend embraced him  
And he delivered himself up to the tyrant,  
As his friend departed.  
And before the third dawn rose,  
He had quickly united his sister with her betrothed,  
And rushed home with a burdened soul,  
In order not to miss the deadline.

Then great rains ceaselessly poured,  
Torrents coursed down from the mountains,  
The creeks and streams swelled  
And so he came with his walking stick to the shore  
And found the bridge swept away by  
The thundering, rampaging waters crushing  
The collapsing arches of the vault.

Irreconcilable, he wandered at the water's edge  
As far as he searched and peered  
His voice, shouting, sending  
Found no voice echoing from the safer shore  
Which would bring him to the hoped-for land,  
No boatsman would launch his ferry  
And the wild stream became like a sea.

He sank to the shore and wept and cried,  
Raising his hands to Zeus:  
"Hold back the rage of these waters!  
The hours rush by, the sun stands  
Now at midday, and when it sets  
If I cannot reach the city,  
Then my friend will perish in my stead!"

Doch wachsend erneut sich des Stromes Wut,  
Und Welle auf Welle zerrinnet,  
Und Stunde an Stunde entrinnet.  
Da treibt ihn die Angst, da faßt er sich Mut  
Und wirft sich hinein in die brausende Flut  
Und teilt mit gewaltigen Armen  
Den Strom, und ein Gott hat Erbarmen.

Und gewinnt das Ufer und eilet fort  
Und danket dem rettenden Gotte;  
Da stürzt die raubende Rotte  
Hervor aus des Waldes nächtlichem Ort,  
Den Pfad ihm sperrend, und schnaubet Mord  
Und hemmet des Wanderers Eile  
Mit drohend geschwungener Keule.

"Was wollt ihr?" ruft er vor Schrecken bleich,  
"Ich habe nichts als mein Leben,  
Das muß ich dem Könige geben!"  
Und entreißt die Keule dem nächsten gleich:  
"Um des Freundes willen erbarmet euch!"  
Und drei mit gewaltigen Streichen  
Erlegt er, die andern entweichen.

Und die Sonne versendet glühenden Brand,  
Und von der unendlichen Mühe  
Ermattet sinken die Kniee.  
"O hast du mich gnädig aus Räubershand,  
Aus dem Strom mich gerettet ans heilige Land,  
Und soll hier verschmachtend verderben,  
Und der Freund mir, der liebende, sterben!"

Und horch! da sprudelt es silberhell,

Still the water's fury rises from anew,  
One wave rises after the next,  
One hour passes after the next,  
Anxiety at last presses him to a courageous act,  
And he flings himself into the surging flood  
Seizing the current with his powerful arms,  
And a God takes pity upon him.

He reaches the other shore and hastens forth,  
Thanking the God his savior,  
When out of the darkened lair of the forest  
Emerged a horde of robbers,  
Blocking his way, and sensing murder  
Preventing him in his haste  
With a cudgel menacingly swung.

"What do you want?" he cried, paled by fear,  
"I have nothing to give but my life,  
And that I owe the king!"  
And with that he snatched the club from the closest of the band,  
"For the sake of my friend, have mercy!"  
And with three powerful blows he struck,  
Dealing death, as the others fled.

And the sun radiates its glowing fire,  
He collapses sinking his knee  
Drained by relentless exertion  
"You have saved me mercifully from the hand of robbers,  
From the flood you have rescued me to the holy land,  
To what end?—that here I should perish miserably  
Leaving the friend who loves me to die!"

But listen! Then it bubbled forth, silver-clear,

Ganz nahe, wie rieselndes Rauschen,  
Und stille hält er, zu lauschen;  
Und sieh, aus dem Felsen, geschwätzig, schnell,  
Springt murmelnd hervor ein lebendiger Quell,  
Und freudig bückt er sich nieder  
Und erfrischt die brennenden Glieder.

Und die Sonne blickt durch der Zweige Grün  
Und malt auf den glänzenden Matten  
Der Bäume gigantische Schatten;  
Und zwei Wanderer sieht er die Straße ziehn,  
Will eilenden Laufes vorüber fliehn,  
Da hört er die Worte sie sagen:  
"Jetzt wird er ans Kreuz geschlagen."

Und die Angst beflügelt den eilenden Fuß,  
Ihn jagen der Sorge Qualen;  
Da schimmern in Abendrots Strahlen  
Von ferne die Zinnen von Syrakus,  
Und entgegen kommt ihm Philostratus,  
Des Hauses redlicher Hüter,  
Der erkennt entsetzt den Gebieter:

"Zurück! du rettetest den Freund nicht mehr,  
So rette das eigene Leben!  
Den Tod erleidet er eben.  
Von Stunde zu Stunde gewartet' er  
Mit hoffender Seele der Wiederkehr,  
Ihm konnte den mutigen Glauben  
Der Hohn des Tyrannen nicht rauben."

"Und ist es zu spät, und kann ich ihm nicht,  
Ein Retter, willkommen erscheinen,

Close by a trickling sound,  
And quietly he paused to listen,  
And from the rocks, evanescent quickly  
Sprang forth murmuring a living source,  
And joyously it stooped down  
Bringing refreshment to the burning limbs.

And the sun cut through the green branches  
Painting gigantic shadows upon the  
Dazzling mats of the trees,  
And two travelers he espied upon the road,  
Scurrying fleet of foot past him,  
And then he heard them utter the words:  
"Now he will be crucified!"

Despair put wings upon his feet,  
The woes tormented him -  
There, reflected in the evening sun,  
From far, the battlements of Syracuse.  
And Philostratus approached him,  
The trustworth guardian of the house,  
He understands in horror the ruler.

"Turn back! You can't save your friend.  
Save your own life!  
He will suffer death, no matter.  
From hour to hour he awaits  
Your return with an aspirant soul  
Your bold faith will not spare  
Him the tyrant's contempt."

"It is too late, no savior will now  
Appear welcome to him,

So soll mich der Tod ihm vereinen.  
Des rühme der blut'ge Tyrann sich nicht,  
Daß der Freund dem Freunde gebrochen die Pflicht,  
Er schlachte der Opfer zweie  
Und glaube an Liebe und Treue!"

Und die Sonne geht unter, da steht er am Tor,  
Und sieht das Kreuz schon erhöht,  
Das die Menge gaffend umsteht;  
An dem Seile schon zieht man den Freund empor,  
Da zertrennt er gewaltig den dichten Chor:  
"Mich, Henker", ruft er, "erwürget!  
Da bin ich, für den er gebürget!"

Und Erstaunen ergreift das Volk umher,  
In den Armen liegen sich beide  
Und weinen vor Schmerzen und Freude.  
Da sieht man kein Auge tränenleer,  
Und zum Könige bringt man die Wundermär';  
Der fühlt ein menschliches Rühren,  
Läßt schnell vor den Thron sie führen,

Und blicket sie lange verwundert an.  
Drauf spricht er: "Es ist euch gelungen,  
Ihr habt das Herz mir bezwungen;  
Und die Treue, sie ist doch kein leerer Wahn -  
So nehmet auch mich zum Genossen an:  
Ich sei, gewährt mir die Bitte,  
In eurem Bunde der Dritte!"

Friedrich Schiller

Yet death may unite me with my friend.  
The tyrant will not be able to boast that  
One friend failed in his duty to the other,  
He will have a double sacrifice  
And will witness love and fidelity."

As the sun sets, he stands at the gate  
And sees the cross already raised,  
Surrounded by a gawking crowd,  
His friend already being hoisted by a cord,  
And powerfully he breaks through the thick crowd:  
"Executioner, strangle me!" he shouts,  
"I am here, the one for whom he stands hostage!"

And shock seized the assembled crowd,  
As the two held each other in their arms,  
Crying for pain and joy.  
No eye was without tears,  
And the wondrous tale is relayed to the king,  
Who, feeling a human stirring,  
Quickly had them brought before the throne.

He gazed upon them long in amazement,  
And then spoke: "You have succeeded,  
You have turned my heart,  
In truth, fidelity is no idle delusion,  
So accept me also as your friend,  
I would be – grant me this request –  
The third in your band!"

translated by Scott Horton

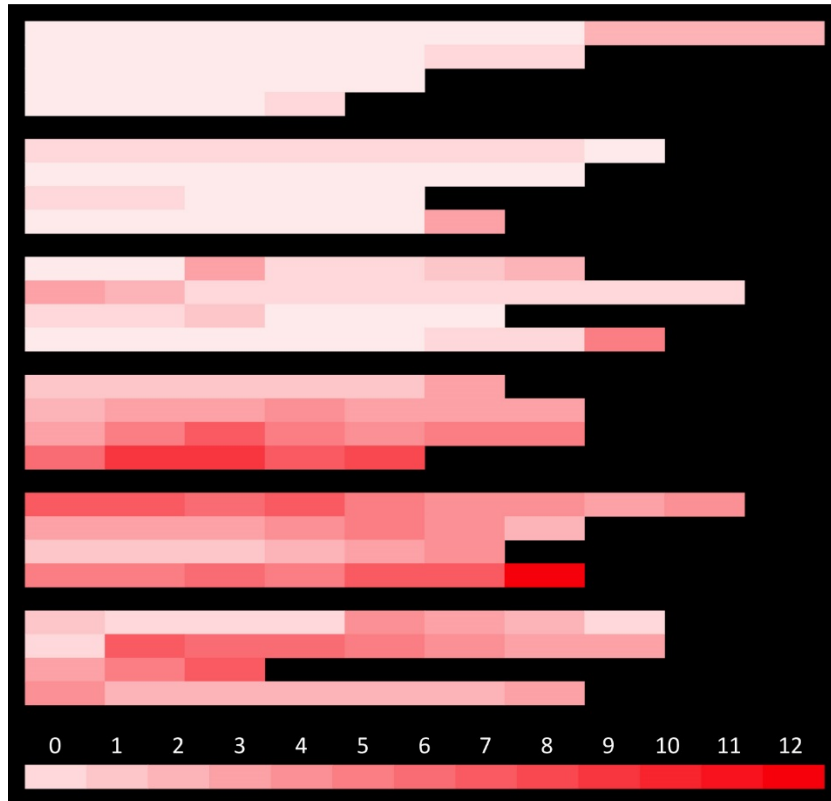


Figure S3A. Heat map for “Abendphantasie”/“Evening Fantasy”

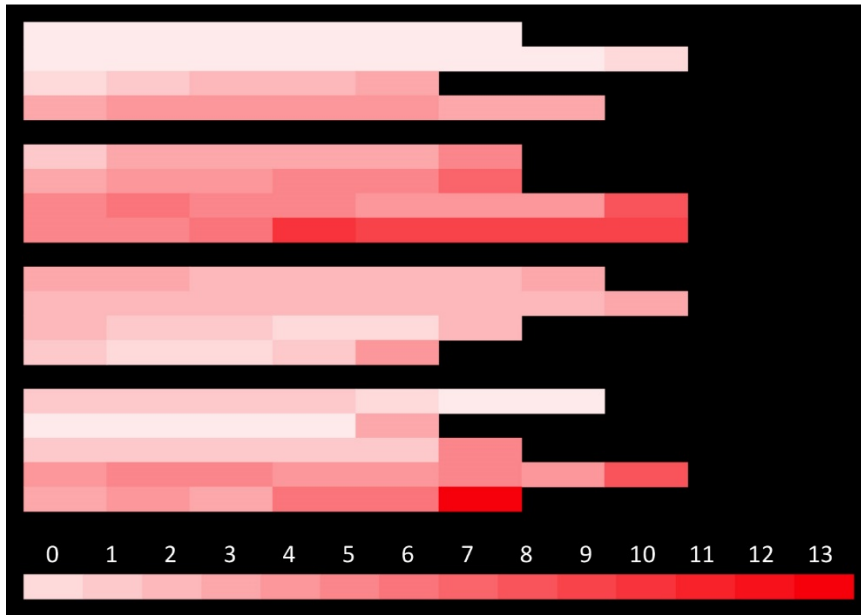


Figure S3B. Heat map for "Sachliche Romanze"/"Objective Romance"



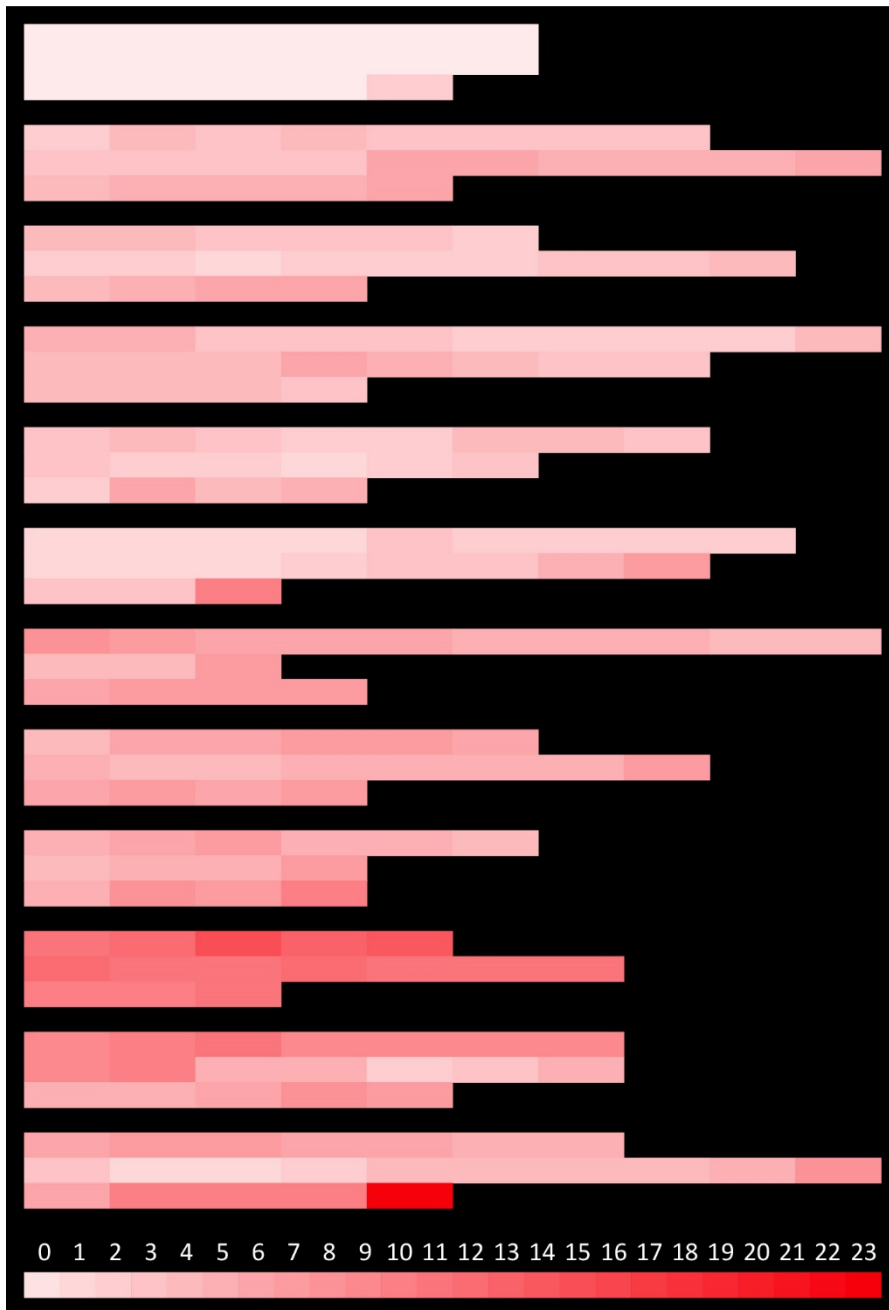
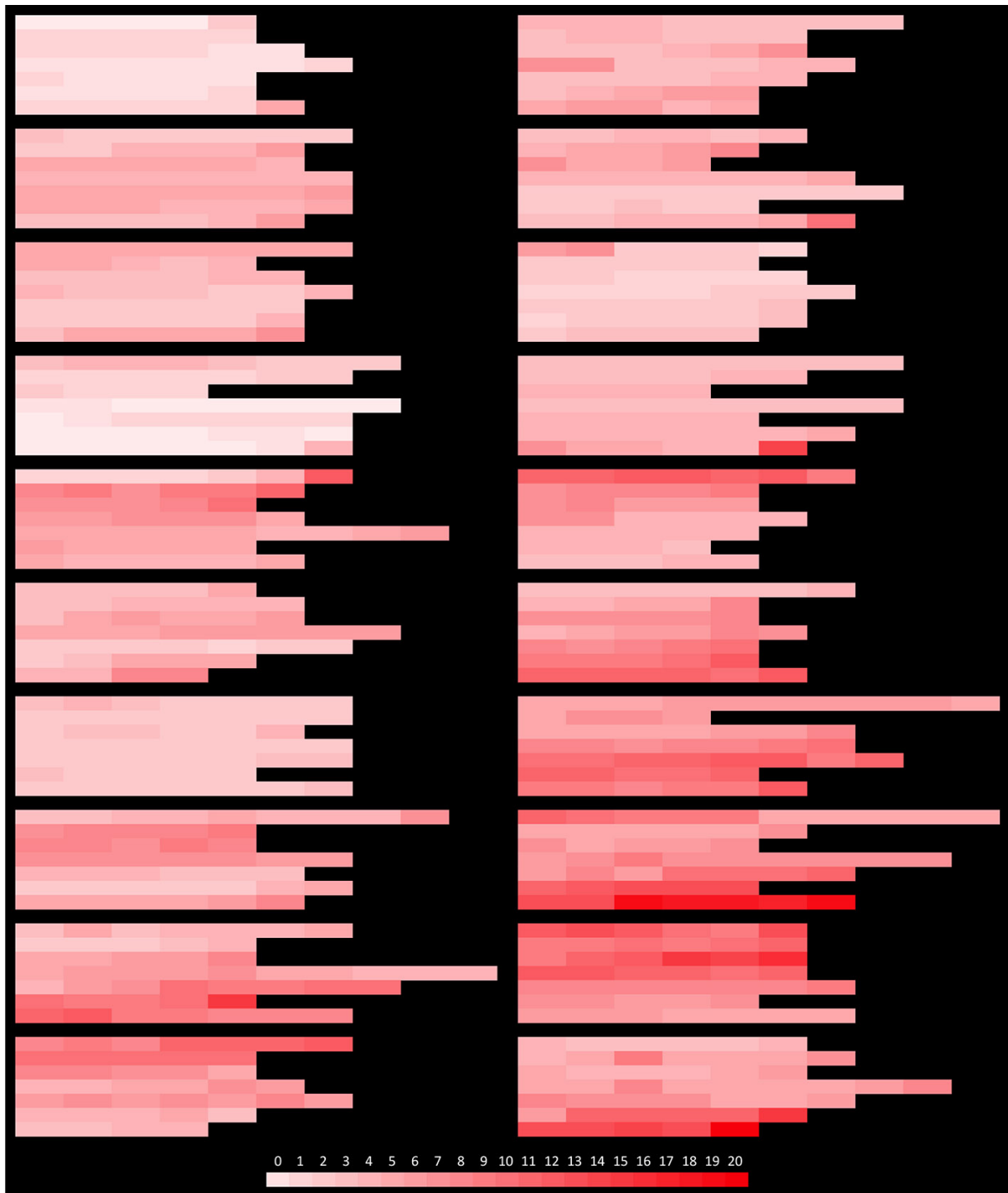


Figure S3C. Heat map for "Nis Randers"

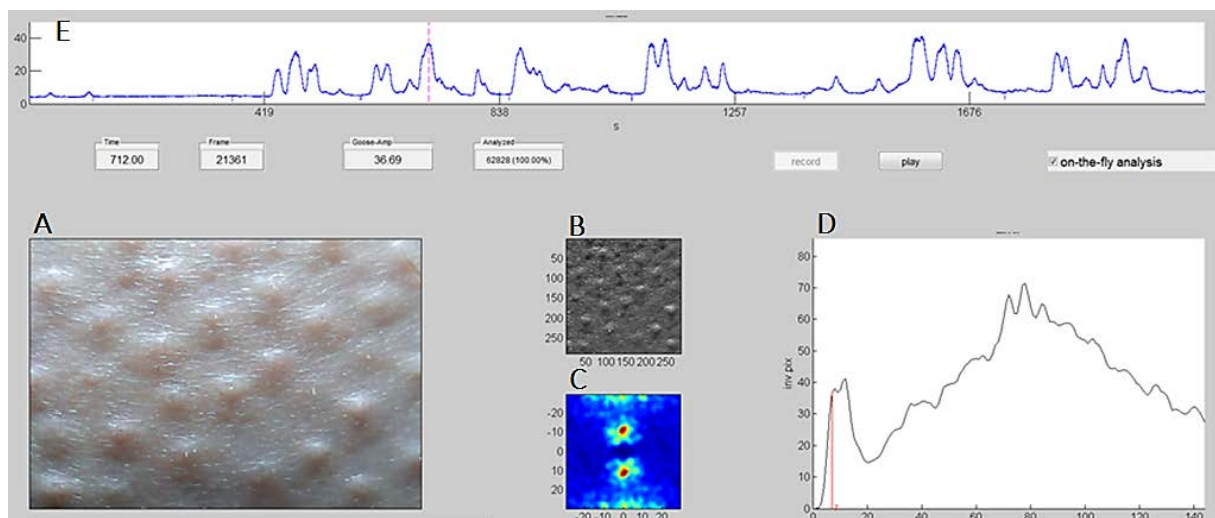


**Figure S3D.** Heat map for “Die Bürgschaft”/“The Hostage”. Due to the length of this poem, the stanzas are shown in two columns (stanzas 1–10 in the left column, stanzas 11–20 in the right column).

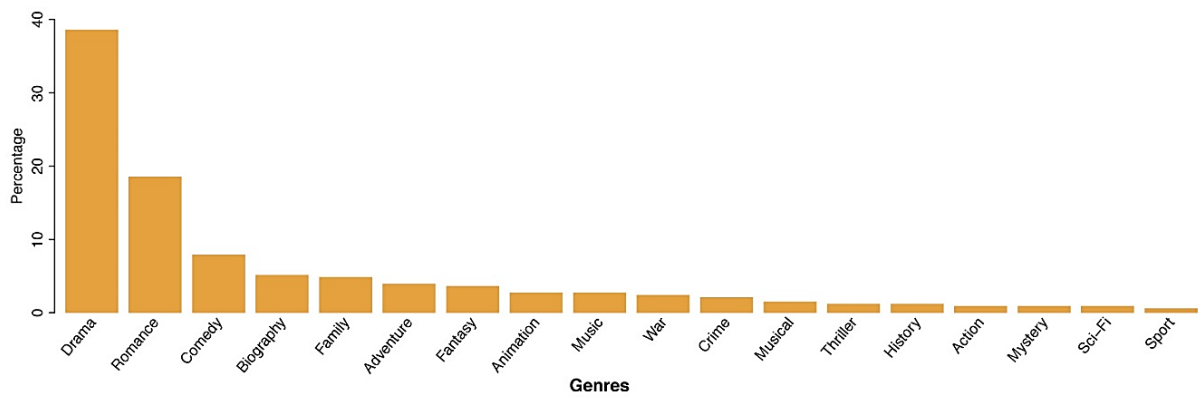
Supplemental Material for Wassiliwizky et al. (2017). Tears falling on goosebumps (doi:10.3389/fpsyg.2017.00041)



**Figure S4. Physiological measures.** (A) Measurement of electrodermal activity and blood volume pulse using two electrodes at the phalanges of the ring and middle fingers and a photoplethysmograph sensor on the index finger; (B) collection of piloerection data via a goosecam attached to the lower leg; (C) measurement of electromyographic activity over the corrugator supercilii above the eyebrow and zygomaticus major at the cheek; (D) collection of respiratory activity using a stretch-sensitive respiration belt placed around the diaphragm.

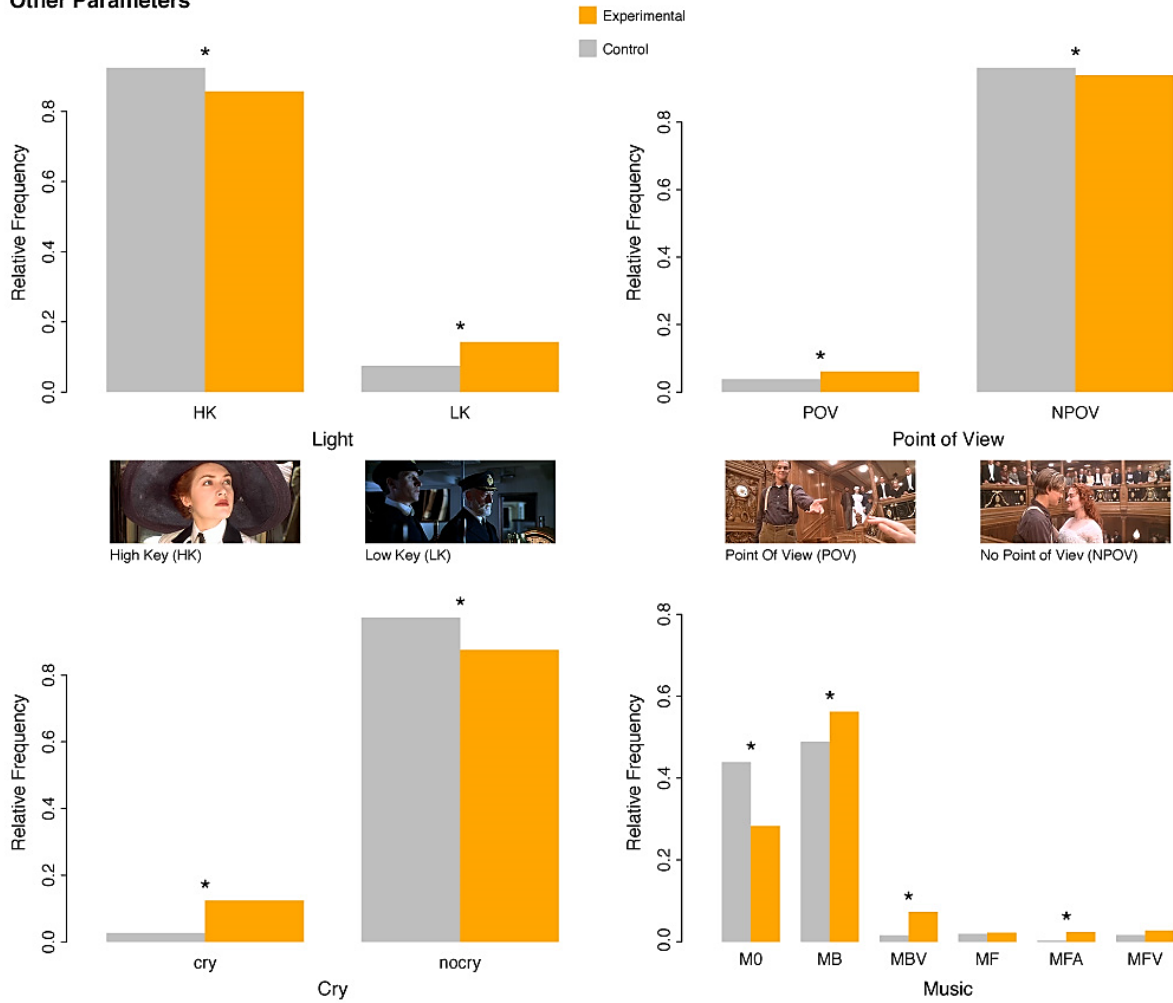


**Figure S5.** Screen shot of the analysis of a goosecam video, using the Matlab based software Gooselab V1.21. After a transformation of the original video frame (A) into a gray scale picture (B), a two dimensional discrete Fourier transform (C) is performed, and converted to a one-dimensional spectrum of spatial frequency (D). Using these data, a continuous measure of piloerection intensity (E) is derived for the whole experimental session (the flat curve at the beginning represents the baseline period). The dashed red cursor in (E) is placed within a piloerection episode.



**Figure S6.** Distribution of the genres (according to the Internet Movie Data Base) from which the self-selected, tears-eliciting film clips were taken. Genres with a strong social tendency, such as the drama and romance genres, dominated the stimulus set. These genres are known to focus explicitly on societal values and virtues such as altruism, bonding, self-sacrifice, and faithfulness.

### Other Parameters



**Figure S7.** Comparison of lighting, point-of-view-shots, depiction of crying characters, and music between tears-eliciting clips and the matched control set. All groups differed significantly from each other in Pearson's chi square tests (for details, see Tab. S15). For music, we differentiated between non-diegetic (i.e., outside of the story world) instrumental musical score (MB), non-diegetic vocal singing with instruments (MBV), diegetic music, i.e., depiction of music making within the film story world (MF), diegetic singing (MFA), and diegetic singing accompanied by instruments (MFV). Shots without any music were coded as M0. The pictures illustrating the lighting and the point-of-view shot were taken from *Titanic* (1997).

**Table S11.** Results of 2 × 2 mixed-effect analyses of variances for the psychophysiological signals.

	Fixed Effects	$df_{(num.den)}$	F-value	p-value	
Phasic EDA	Intercept	1, 64784	6.11	0.0134	*
	Tears	1, 64784	422.33	< .0001	***
	Goose	1, 64784	61.95	< .0001	***
	Tears × Goose	1, 64784	29.24	< .0001	***
Heart Rate	Intercept	1, 66368	7.23	0.0071	**
	Tears	1, 66368	1005.59	< .0001	***
	Goose	1, 66368	72.62	< .0001	***
	Tears × Goose	1, 66368	9.30	0.0023	**
Corrugator	Intercept	1, 66368	16.63	< .0001	***
	Tears	1, 66368	3719.43	< .0001	***
	Goose	1, 66368	28.83	< .0001	***
	Tears × Goose	1, 66368	2.31	0.1285	
Zygomaticus	Intercept	1, 64784	12.58	< .001	**
	Tears	1, 64784	2137.78	< .0001	***
	Goose	1, 64784	94.54	< .0001	***
	Tears × Goose	1, 64784	54.21	< .0001	***
Respiration Rate	Intercept	1, 66368	15.10	< .001	**
	Tears	1, 66368	78.17	< .0001	***
	Goose	1, 66368	37.55	< .0001	***
	Tears × Goose	1, 66368	41.50	< .0001	***

**Table S12.** Results of one-way mixed-effect analyses of variances for the psychophysiological signals with the binary factor Rating (feeling of tears vs. lacrimation).

	Fixed Effects	$df_{(num.den)}$	F-value	p-value	
Phasic EDA	Intercept	1, 17024	17.43	< .0001	***
	Rating	1, 17024	346.24	< .0001	***
Heart Rate	Intercept	1, 17593	17.43	< .0001	***
	Rating	1, 17593	346.24	< .0001	***
Corrugator	Intercept	1, 17593	20.38	< .0001	***
	Rating	1, 17593	9.83	0.0017	**
Zygomaticus	Intercept	1, 17593	13.25	< .001	**
	Rating	1, 17593	330.60	< .0001	***
Respiration Rate	Intercept	1, 17593	9.46	0.0021	**
	Rating	1, 17593	85.58	< .0001	***

**Table S13.** Relative frequencies and standardized residuals from a significant Pearson's chi square test ( $\chi^2 = 126.64$ ;  $df = 6$ ;  $p < 0.001$ ) for different camera distances of the tears-eliciting experimental and the matched control set. The last column indicates significant differences between the two sets; standardized residuals having absolute values greater than 3 indicate significant differences (Agresti, 2007, p.38).

Camera distance	Experimental set		Control Set		
	<i>(rel. frequencies, standardized residuals)</i>		<i>(rel. frequencies, standardized residuals)</i>		
Extreme close-up	0.0144	1.7	0.0092	-1.7	
Close-up	0.130	8.0	0.064	-8.0	*
Medium close-up	0.37	4.8	0.30	-4.8	*
Medium shot	0.20	-4.2	0.25	4.2	*
Medium-long shot	0.12	-5.6	0.17	5.6	*
Long shot	0.16	-3.1	0.19	3.1	*
Extreme long shot	0.0092	1.5	0.0056	-1.5	

**Table S14.** Relative frequencies and standardized residuals from a significant Pearson's chi square test ( $\chi^2 = 68.08$ ;  $df = 4$ ;  $p < 0.001$ ) for different camera perspectives of the tears-eliciting and the control set. The last column indicates significant differences between the two sets; standardized residuals having absolute values greater than 3 indicate significant differences (Agresti, 2007, p.38).

Camera perspective	Experimental set		Control Set		
	<i>(rel. frequencies, standardized residuals)</i>		<i>(rel. frequencies, standardized residuals)</i>		
Worm's view	0.0074	1.1	0.0049	-1.1	
Low angle	0.051	-6.9	0.103	6.9	*
Eye-level	0.82	5.9	0.75	-5.9	*
High angle	0.099	-3.1	0.127	3.1	*
Bird's view	0.021	2.8	0.012	-2.8	

**Table S15.** Relative frequencies and standardized residuals from significant Pearson’s chi square tests for lighting ( $\chi^2 = 61.73$ ;  $df = 1$ ;  $p < 0.001$ ), point-of-view shots ( $\chi^2 = 14.43$ ;  $df = 1$ ;  $p < 0.001$ ), depiction of crying characters ( $\chi^2 = 183.97$ ;  $df = 1$ ;  $p < 0.001$ ), and music ( $\chi^2 = 251.43$ ;  $df = 5$ ;  $p < 0.001$ ; M0: no music, MB non-diegetic instrumental musical, MBV: non-diegetic singing accompanied by instruments, MF: diegetic music, MFA: diegetic singing, MFV: diegetic singing accompanied by instruments). The last column indicates significant differences between the two sets; standardized residuals having absolute values greater than 3 indicate significant differences (Agresti, 2007, p.38).

	<b>Experimental set</b> <i>(rel. frequencies, standardized residuals)</i>		<b>Control Set</b> <i>(rel. frequencies, standardized residuals)</i>		
<b>Lighting</b>					
high key	0.86	-7.9	0.92	7.9	*
low key	0.143	7.9	0.075	-7.9	*
<b>Point-of-view shots</b>					
POV	0.061	3.9	0.037	-3.9	*
no POV	0.94	-3.9	0.96	3.9	*
<b>Depiction of crying</b>					
crying	0.124	14	0.026	-14	*
no crying	0.88	-14	0.97	14	*
<b>Music</b>					
M0	0.28	-11.82	0.44	11.82	*
MB	0.56	4.95	0.49	-4.95	*
MBV	0.072	10.14	0.016	-10.14	*
MF	0.022	0.65	0.019	-0.65	
MFA	0.0236	6.88	0.0025	-6.88	*
MFV	0.027	2.63	0.016	-2.63	



**Table S16.** Participants’ original wording describing the subjective experience of being moved to tears. The “Valence” column shows the overall tendency of participants to label these episodes as rather pleasant, unpleasant, or mixed. Some participants could not (or did not want to) give an answer (–).

Subj	Valence	English Translation	Original Description
#14	–	–	–
#15	pleasant	related to nice memories	verbunden mit schönen Erinnerungen
#21	mixed	not unpleasant, but not pleasant either, right in the middle of these	nicht unangenehm, aber auch nicht richtig angenehm, mitten drin
#34	–	–	–
#44	unpleasant	I like to watch these films repeatedly, because there are also other moments	ich schaue alle Filme gerne mehrmals, weil da auch andere Momente sind
#45	pleasant	liberating; one likes to see it, because the scene is emotional and touching	befreiend; man sieht es gerne, weil die Szene emotional und berührend ist
#46	pleasant	although unpleasant themes, but “true”; good for psychic hygiene	zwar unangenehme Themen, aber „wahr“; gut für seelische Hygiene
#47	–	–	–
#48	mixed	during the experiment rather unpleasant, but at home rather pleasant	im Experiment eher unangenehm, aber daheim eher angenehm
#49	pleasant	beautiful; so sad; warmth is bottled up in the chest, the only way out is through the eyes; liberating	schön; so traurig; Anstauen von Wärme in der Brust, der einzige Weg raus ist durch die Augen; befreiend
#51	pleasant	it feels good to release it; beautiful, because one sympathizes; one is engaged, not distanced; important things in life are shifted to the foreground (obligations and stress are forgotten); one is more by oneself; relaxing; not stressful; one catches one’s breath and sighs; when the tears are over, one is present	rauslassen tut gut; schön, weil man mitfühlt; man lässt sich ein, ist nicht distanziert; wichtige Dinge im Leben werden in den Vordergrund gerückt (Termine und Stress werden vergessen); man ist mehr bei sich; entspannend; nicht stressend; man atmet durch und seufzt; wenn Tränen zu Ende gehen, ist man präsent
#56	mixed	it depends on the mood; sometimes pleasant and liberating; I’m becoming obsessed about it, need time to distance myself from it mentally; it heals only later	hängt von Stimmung ab; manchmal angenehm und befreiend; ich steigere mich rein, brauche einige Zeit, um mich gedanklich wieder davon zu distanzieren; es heilt nach

#71	unpleasant	unpleasant, especially when others are around and see you cry; alone it's okay	unangenehm, v.a. auch wenn andere dabei sind und dich weinen sehen, alleine okay
#77	pleasant	liberating, overwhelming	befreiend, überwältigend
#78	pleasant	beautiful tears, but unpleasant portions resonate, too	schöne Tränen, aber auch unangenehme Anteile schwingen mit
#79	mixed	beautifully sad	schön traurig
#80	mixed	inner pressure is built up and wants to get out at the top; locked feelings; the feeling of tears is a relief	innerlicher Druck, der sich aufbaut und nach oben raus will; verschlossene Gefühle; Tränengefühl ist eine Erleichterung
#81	mixed	physically exhausting; I'd like to flush away the lump in the throat with a glass of water; beautiful stories, though sad	körperlich anstrengend; ich möchte am liebsten das Kloßgefühl wegsülen mit einem Glas Wasser; schöne Geschichten auch wenn traurig
#82	pleasant	liberating	befreiend
#84	pleasant	one cries for joy, too; here it is also a beautiful feeling; difficult to describe; when one cries, it somehow makes you happy, sort of a liberating feeling	man weint ja auch vor Glück; hier ist es auch ein schönes Gefühl; schwer zu beschreiben; wenn man weint, macht es mich danach irgendwie glücklich, so ein befreiendes Gefühl
#85	pleasant	good feeling, tingling; you don't try to avoid it; you sympathize and that's good; you think, you don't want to have this experience yourself	gutes Gefühl, Kribbeln; man geht dem nicht aus dem Weg; man fühlt mit und das ist gut; man denkt, man will es selber nicht erleben
#86	–		–
#87	–		–
#88	pleasant	constricting feeling at the beginning; if one cries, it is liberating, if not, the constricting feeling remains; one feels more alive; intense feeling; the tear-jerking scenes are, however, not my favorite ones	beklemmendes Gefühl am Anfang; wenn man weint, ist es dann befreiend, wenn nicht, bleibt das beklemmendes Gefühl bestehen; man fühlt sich lebendiger; intensives Gefühl; die Heulszenen sind aber nicht meine Lieblingsszenen
#90	mixed	I do like to be touched by scenes; like to watch such movies; that constitutes a good movie	ich mag schon, wenn mich die Szenen berührt; schaue gerne solche Filme; das macht einen guten Film aus

**Table S17.** List of all tears-eliciting clips self-selected by participants. The “Count” column indicates the number of participants who selected the clip. The “Genre” column is based on the classification by the Internet Movie Data Base (IMDb). The “Emotion” column identifies the predominant emotion of the scenario type (sadness or joy).

Clip	Film Title	Year	Country	Length	Count	Genre	Emotion	Scenario
1	Gladiator	2000	USA	03:04	1	Action, Drama	sadness	death of wife and son
2	Lilo and Stich	2002	USA	03:34	1	Animation, Adventure, Comedy	sadness	being lost in a strange world
3	Star Wars: Episode I	1999	USA	04:22	1	Action, Adventure, Fantasy	sadness	leaving enslaved mother behind to become a Jedi
4	Up	2009	USA	07:45	2	Animation, Adventure, Comedy	sadness	wife dies before the fulfillment of her lifetime dream
5	Wall-E	2008	USA	02:06	1	Animation, Adventure, Family	joy	realizing that one’s own hostile reaction was unjustified; reconciliation
6	Wall-E	2008	USA	05:13	1	Animation, Adventure, Family	joy	caring for love interest who is in a state of hibernation

7	Beaches	1988	USA	04:16	1	Comedy, Drama, Music	sadness	death of mother; farewell
9	My Sister's Keeper	2009	USA	05:02	1	Drama	sadness	terminally ill girl consoles her mother, says farewell and dies
10	In Her Shoes	2005	USA, Germany, UK	02:30	1	Comedy, Drama, Romance	joy	two sisters reconcile on one sister's wedding day
11	The Other Woman	2009	USA	03:31	1	Drama	sadness	woman rejected by her husband after her infant dies
12	The Other Woman	2009	USA	04:35	1	Drama	joy	female main character finally bonds with her stepson
13	Hachi: A Dog's Tale	2009	USA, UK	04:25	1	Drama, Family	sadness	memories from dog's perspective; dog dies
14	Hachi: A Dog's Tale	2009	USA, UK	02:01	2	Drama, Family	sadness	widow discovers her deceased husband's dog waiting for him at the train station
15	The Notebook	2004	USA	04:10	1	Drama, Romance	joy	couple on a boat kiss passionately in the rain
16	The Notebook	2004	USA	05:35	1	Drama, Romance	sadness	woman reads letters of regret and cries
17	The Notebook	2004	USA	04:37	1	Drama, Romance	sadness	woman with dementia has a breakdown, forgets that the man in front of her is her former lover
18	The Notebook	2004	USA	05:25	2	Drama, Romance	sadness	couple in nursing home passing away after announcing their mutual love

19	One Day	2011	USA, UK	05:30	1	Drama, Romance	sadness	woman dies on the way home to her partner
20	Titanic	1997	USA	04:07	3	Drama, Romance	sadness	male protagonist frozen to death; woman being rescued against all odds
21	Troy	2004	USA, Malta, UK	06:42	1	Adventure	joy	father finally convinces Achilles to return the bones of his dead son
22	Darjeeling Limited	2007	USA	02:46	1	Adventure, Comedy, Drama	sadness	men try to save drowning children; one child dies; they carry his body to his family
23	Friends	1994–2004	USA	02:35	1	Comedy, Romance	sadness	couple breaks up
24	Marley & Me	2008	USA	04:16	3	Comedy, Drama, Romance	sadness	dog is being euthanized; owner says goodbye
25	Mar adentro	2004	Spain, France, Italy	04:16	1	Biography, Drama, Romance	sadness	paraplegic commits suicide after losing a battle for the legalization of euthanasia
26	Mary Poppins	1964	USA	03:44	1	Comedy, Family, Fantasy	joy	babysitter sings a lullaby
28	Chrono Crusade	2003–2004	Japan	05:15	1	Animation, Adventure, Drama	sadness	male and female protagonists die peacefully together
29	Grey's Anatomy	2005–	USA	02:09	1	Drama, Romance	sadness	woman getting divorced and forced to change her career plan

30	Grey's Anatomy	2005–	USA	04:45	1	Drama, Romance	sadness	two medical coworkers die, one of whom is the girlfriend of the doctor
31	My Girl	1991	USA	04:32	2	Comedy, Drama, Family	sadness	funeral of girl's only friend; daughter can't accept his death; father unable to console her
32	A Single Man	2009	USA	03:49	1	Drama	sadness	man has heart failure while feeling happy for the first time in a long while
33	Citizen Kane	1941	USA	03:03	1	Drama, Mystery	sadness	what remains from a man's childhood is burned in a fire
34	Paths of Glory	1957	USA	04:49	1	Drama, War	sadness	female prisoner of war made to sing in front of soldiers
35	Vertigo	1958	USA	02:26	1	Mystery, Romance, Thriller	joy	man kisses love interest who is thought to be dead
36	21 Grams	2003	USA	02:26	1	Crime, Drama, Thriller	sadness	man shoots himself; dies in hospital after internal monologue
37	Léon	1994	France	07:16	1	Crime, Drama, Thriller	sadness	a girl's mentor is killed; she grieves for him
38	Precious	2009	USA	05:44	1	Drama	sadness	mother relates how she and her daughter were abused by her partner
39	Requiem for a Dream	2000	USA	03:55	1	Drama	sadness	conclusion of the storylines of several drug addicts

40	Almanya	2011	Germany	03:21	1	Comedy, Drama	sadness	family road trip; father dies suddenly
41	Kirschblüten	2008	Germany	05:26	1	Drama, Romance	sadness	mother dies; son regrets not having spent enough time with her
42	Kirschblüten	2008	Germany	04:48	1	Drama, Romance	sadness	man dies; reunited with his wife in death
44	Der Untergang	2004	Germany, Austria, Italy	05:29	1	Biography, Drama, War	joy	end of WW II; female German soldier disarmed and left alive
45	Seven Pounds	2008	USA	02:34	1	Drama, Romance	joy	organ recipients with common donor (who committed suicide for them) meet for the first time
46	Hachi: A Dog's Tale	2009	USA, UK	03:54	1	Drama, Family	sadness	dog waits for his deceased owner at the usual spot
48	Les Choristes	2004	France, Switzerland, Germany	01:29	1	Drama, Music	joy	children find a way to circumvent their detention to say goodbye to a beloved teacher
49	My Sister's Keeper	2009	USA	02:25	1	Drama	sadness	during a court session, the brother of terminally ill sister reveals her wish to die
50	My Sister's Keeper	2009	USA	02:25	1	Drama	sadness	terminally ill child apologizes to her family for being a burden
51	Message in a Bottle	1999	USA	01:28	1	Drama, Romance	sadness	woman throws bottle with a message into the ocean
52	The Pursuit of Happiness	2006	USA	04:02	2	Biography, Drama	sadness	homeless father and son forced to spend the night in a public restroom

53	Dragonfly	2002	USA, Germany	04:03	1	Drama, Fantasy, Mystery	joy	widower visits an African tribe and finds that his wife gave birth to a girl before she died
54	My Sister's Keeper	2009	USA	03:37	1	Drama	joy	family with terminally ill daughter has a nice day at the beach
55	Hilde	2009	Germany	02:23	1	Biography, Drama, Music	joy	woman discovers her passion for singing
56	Hilde	2009	Germany	04:30	1	Biography, Drama, Music	joy	woman is praised for her singing talent
57	La vita è bella	1997	Italy	03:01	1	Comedy, Drama, Romance	sadness	father and son board a train to a concentration camp; father hides the truth with humorous lies
58	La vita è bella	1997	Italy	01:17	1	Comedy, Drama, Romance	joy	woman awakened by the music her husband manages to play in the concentration camp
59	La vita è bella	1997	Italy	02:44	2	Comedy, Drama, Romance	joy	boy is freed from a concentration camp and reunited with his mother
60	Marie Antoinette	2006	USA, France, Japan	01:40	1	Biography, Drama, History	sadness	woman is bored by a social event and wants to leave; daydreams of an officer in battle
62	Rabbit Hole	2010	USA	03:09	1	Drama	sadness	husband accuses wife of trying to erase all memories of their deceased son's existence
65	I Am Sam	2001	USA	01:06	1	Drama	sadness	father and daughter are being separated



66	I Am Sam	2001	USA	02:53	1	Drama	joy	foster mother returns child to mentally handicapped father
67	I Am Sam	2001	USA	02:20	1	Drama	joy	daughter lies to the court in order to stay with her mentally handicapped father
69	Benjamin Button	2008	USA	05:08	1	Drama, Fantasy, Romance	sadness	protagonist dies in the arms of his beloved
70	Ghost	1990	USA	03:39	1	Drama, Fantasy, Romance	joy	passionate scene between two lovers
71	Ghost	1990	USA	04:26	1	Drama, Fantasy, Romance	joy	ghost of a deceased man takes control of a medium's body to dance with his wife
72	Ghost	1990	USA	03:30	1	Drama, Fantasy, Romance	joy	woman sees her deceased husband's ghost one last time before he vanishes
73	The Lion King	1994	USA	05:20	1	Animation, Adventure, Drama	sadness	Simba tries to wake up his dead father and realizes it's not going to happen
74	The Horse Whisperer	1998	USA	06:22	1	Drama, Romance, Western	sadness	two girls have an accident while riding their horses; one girl dies
75	Beginners	2010	USA	03:54	1	Comedy, Drama, Romance	sadness	couple breaks up

76	Beginners	2010	USA	02:12	1	Comedy, Drama, Romance	sadness	father dies peacefully at home with family and friends around him
77	Big Fish	2003	USA	11:06	1	Adventure, Drama, Fantasy	sadness	father dies after son tells him a reassuring fantasy version of how all his friends say goodbye
78	Love Actually	2003	UK, USA, France	06:52	1	Comedy, Drama, Romance	joy	father encourages boy to break through airport security to see his love interest before she flies away
79	Love Actually	2003	UK, USA, France	02:17	1	Comedy, Drama, Romance	joy	man confesses his love to a good friend who is about to marry someone else
80	Finding Neverland	2004	USA, UK	05:45	1	Biography, Drama, Family	joy	children arrange a moving theater play for their sick mother
81	Dumbo	1941	USA	02:51	1	Animation, Family, Musical	joy	little elephant is briefly reunited with his imprisoned mother
82	Komt een vrouw bij de dokter	2009	Netherlands	04:28	1	Drama, Romance	sadness	terminally ill woman has a breakdown; says goodbye to husband and child
83	Les Misérables	2012	USA, UK	02:59	1	Drama, Musical, Romance	sadness	ill beggar on the deathbed; has hallucinations of her daughter
84	My Sister's Keeper	2009	USA	03:48	1	Drama	sadness	terminally ill girl asks her sister to help her resist their mother's intention to treat her illnesses further

85	Soul Surfer	2011	USA	03:24	1	Biography, Drama, Sport	sadness	daughter sees the stump where her arm should be for the first time after a shark attacked her
86	The Last Unicorn	1982	USA, UK, Japan, Germany	03:21	1	Family, Animation, Fantasy	joy	unicorn resurrects dead person, then leaves him
87	E.T. the Extra-Terrestrial	1982	USA	04:10	2	Family, Sci-Fi	sadness	alien leaves planet earth after saying goodbye to a boy who befriended it
88	Sweet November	2001	USA	05:37	1	Drama, Romance	sadness	woman leaves the only man she ever loved because she has cancer and doesn't want him to see her die
89	Lord of the Rings: III	2003	USA, New Zealand	07:28	1	Adventure, Drama, Fantasy	sadness	Bilbo, Frodo, and Gandalf leave middle-earth
90	Barfuss	2005	Germany	04:08	1	Comedy, Drama, Romance	sadness	girl contemplates suicide because she is unable to get in touch with her love interest
91	The Object of My Affection	1998	USA	04:36	1	Comedy, Drama, Romance	sadness	woman falls in love with her friend; he is gay and does not have the same feelings for her
93	The Pursuit of Happiness	2006	USA	03:01	2	Biography, Drama	joy	man finally gets the job he desperately needed
94	Artificial Intelligence: AI	2001	USA	08:07	1	Adventure, Drama, Sci-Fi	sadness	android boy nearly killed another (human) boy; his "mother" leaves him behind in the woods

95	Intouchables	2011	France	05:56	1	Biography, Comedy, Drama	joy	caregiver cheers up a depressed quadriplegic; arranges a date with the woman he is fond of
96	Precious	2009	USA	03:28	1	Drama	sadness	girl breaks down in class after she is told she contracted HIV from her father (who raped her)
98	The Ides of March	2011	USA	01:20	1	Drama	sadness	father gives eulogy at his daughter's funeral
99	The Ides of March	2011	USA	02:18	1	Drama	sadness	man finds his love interest after she commits suicide
100	Match Point	2005	UK, Russia, Ireland, USA	04:47	1	Drama, Romance, Thriller	sadness	man shoots his lover who refuses to abort her pregnancy and cover up the affair
101	Pride and Prejudice	1995	UK	06:17	1	Drama, Romance	sadness	man confesses his love to a woman from a rival family and gets harshly rejected
102	Doctor Zhivago	1965	USA, Italy, UK	06:07	1	Drama, Romance, War	sadness	man finds his beloved in the streets, follows her but dies before he reaches her
103	Blue Valentine	2010	USA	03:18	1	Drama, Romance	sadness	montage of a couple marrying and breaking up
104	Blue Valentine	2010	USA	09:15	1	Drama, Romance	sadness	relationship between a married couple deteriorates
105	Voshoschdenje	1977	Soviet Union	04:24	1	Drama, War	sadness	soldier tries to commit suicide after he commits treason
106	Ivanovo detstvo	1962	Soviet Union	02:52	1	Drama, War	joy	two characters are reunited during war time

107	Sudba cheloveka	1959	Soviet Union	03:26	1	Drama, War	joy	orphaned child reunited with his father who supposedly died during the war
108	Dancer in the Dark	2000	Denmark et al.	06:23	2	Crime, Drama, Musical	sadness	woman is being hanged; finds solace in the fact that her sacrifice was not in vain
109	Marvin's Room	1996	USA	06:01	1	Drama	joy	two sisters bond after not having much contact over the last few years
110	The English Patient	1996	USA, UK	05:32	1	Drama, Romance, War	sadness	doctor has to leave his love interest behind to get help
111	P.S. I Love You	2007	USA	00:53	1	Drama, Romance	joy	widow finds a letter from her deceased husband, helping her to move on with her life
112	Schindler's List	1993	USA	03:17	1	Biography, Drama, History	joy	Schindler gives water to people crammed into the trains to the concentration camp on a hot day
113	Sophie's Choice	1982	UK, USA, France	05:35	1	Drama, Romance	sadness	Nazi officer forces Jewish woman to choose which of her children will have to die
115	Dancer in the Dark	2000	Denmark and others	02:34	1	Crime, Drama, Musical	sadness	woman gets fired due to her loss of eyesight
116	Emergency Room	1994–2009	USA	01:31	1	Drama	joy	grandmother reunited with her lost grandchild
117	Hachi: A Dog's Tale	2009	USA, UK	03:29	1	Drama, Family	sadness	funeral of a man; his dog is shown going to the train station and waiting for his owner

118	Aimée & Jaguar	1999	Germany	04:33	1	Biography, Drama, Romance	sadness	two women are in love; one of them is imprisoned by the Nazis because of her Jewish ancestry
119	The Green Mile	1999	USA	05:38	1	Crime, Drama, Fantasy	joy	wrongly imprisoned death-row prisoner revives pet of other inmate
120	The Green Mile	1999	USA	04:05	1	Crime, Drama, Fantasy	sadness	last conversation between a prison guard and a befriended death row inmate before the execution
121	Philadelphia	1993	USA	04:55	1	Drama	sadness	patient with AIDS tells his boyfriend that he is ready to die
122	Schindler's List	1993	USA	04:30	1	Biography, Drama, History	sadness	inmates of a concentration camp are forced to burn the corpses of other inmates
123	Schindler's List	1993	USA	02:50	1	Biography, Drama, History	joy	women are pushed into the shower room in a concentration camp; the showers are real; they are relieved
125	Brokeback Mountain	2005	USA, Canada	03:38	1	Drama, Romance	sadness	man taking clothes of his dead lover as a reminder of their relationship
126	P.S. I Love You	2007	USA	02:13	1	Drama, Romance	joy	widow receives the last letter her husband wrote
127	P.S. I Love You	2007	USA	02:54	1	Drama, Romance	joy	widow reads letter from dead husband; it describes their first chance meeting and first kiss
128	P.S. I Love You	2007	USA	02:27	1	Drama, Romance	joy	widow receives tape recorder on her birthday; husband recorded a message before his death

129	P.S. I Love You	2007	USA	01:48	1	Drama, Romance	sadness	widow brings the urn of her dead husband home
130	P.S. I Love You	2007	USA	01:43	1	Drama, Romance	sadness	widow talks to her mother and cries
131	Titanic	1997	USA	03:48	1	Drama, Romance	sadness	woman dies; is reunited with her love interest in the "afterlife"
132	Pearl Harbor	2001	USA	06:31	1	Action, Drama, Romance	sadness	soldier dies; on his deathbed he is told his wife expects a child
133	Napola	2004	Germany	05:17	1	Drama, Sport, War	sadness	young athletes forced to dive into a frozen lake; one of them commits suicide; his friend cannot save him
135	Desert Flower	2009	UK, Germany, France	05:21	1	Biography, Drama	sadness	woman recalls how she had her genitals mutilated as a child
136	Das weinende Kamel	2003	Germany, Mongolia	06:24	1	Documentary, Drama, Family	joy	camel finally accepted by its mother through a musical ceremony
137	Liebe in Gedanken	2004	Germany	02:17	1	Drama, Romance	sadness	love triangle; one of the three feels rejected and leaves

## List of Abbreviations

ACC	anterior cingulate cortex
a-Ins	anterior insula
ANS	autonomous nervous system
BOLD	blood oxygenation level dependent
df	degrees of freedom
EMG	electromyography
fMRI	functional magnetic resonance imaging
FDR	false discovery rate
FWE	family-wise error
FWHM	full width at half maximum
GLM	general linear model
M	mean
MCC	mid cingulate cortex
m-Ins	mid insula
MNI	Montreal Neurological Institute
NAcc	nucleus accumbens
OFC	orbitofrontal cortex
pEDA	phasic electrodermal activity
PET	positron emission tomography
PNS	parasympathetic nervous system
POV	point-of-view shots
RO	Rolandic operculum
ROI	region of interest
RQ	research question
SCR	skin conductance responses
SD/SE	standard deviation/standard error
SM	supplemental material
SMA	supplementary motor area
SMG	supramarginal gyrus
SNS	sympathetic nervous system



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