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Tears of joy, aesthetic chills and heartwarming feelings: Physiological correlates of Kama Muta

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Abstract

Situations involving increased closeness or exceptional kindness are often labeled as *moving* or *touching* and individuals often report bodily symptoms, including tears, goosebumps, and warmth in the body. Recently, the *kama muta* framework has been proposed as a cross-cultural conceptualization of these experiences. Prior research on kama muta has mostly relied on subjective reports. Thus, our main goal of the present project was to examine the pattern of physiological responses to kama muta inducing videos and compare it to the patterns for the similar, though distinct emotions of *sadness* and *awe*. One hundred forty-four Portuguese and Norwegian participants were individually exposed to all three emotion conditions. Several psychophysiological indexes of the autonomic nervous system were collected continuously during exposure, including cardiovascular, respiratory, and electrodermal activity, facial EMG, skin temperature, as well as piloerection and lachrymation using cameras. Overall, the results partly replicated previous findings on *being moved* experiences and self-report studies. Strong self-reported experiences of kama muta were associated with increased phasic skin conductance, skin temperature, piloerection, and zygomaticus activity, while they were associated with reduced heart rate, respiration rate, and tonic skin conductance. The physiological profile of kama muta was successfully distinguished from sadness and awe, partly corroborating self-report evidence. We obtained no clear evidence of a kama muta association with the occurrence of lachrymation or heart rate variability. Our findings provide a systematic overview of psychophysiological response to experiences of kama muta, and help to inform future research on this emotion and positive emotions in general.

KEYWORDS

ANS, being moved, goosebumps, kama muta, psychophysiology, tears

1 | INTRODUCTION

People often say that they are *moved* or *touched*, sometimes even to tears. A number of theories have recently conceptualized such *being moved* experiences, discussing, and exploring its antecedents, motivations, and its physiological responses (Cova & Deonna, 2014; Haidt, 2003; Menninghaus et al., 2015). One particular framework accounting for emotional experiences often labeled as *moving* is the concept of *kama muta* (Fiske, Seibt, & Schubert, 2019). According to kama muta theory, appraising sudden increases in communality and closeness (communal sharing) evokes a distinctive positive social relational emotion that motivates devotion to communal relationships. The emotion is often accompanied by tears, chills, and feelings of warmth, and is denoted with terms such as *moving*, *touching*, or *heartwarming* in English vernacular (e.g., Zickfeld, Schubert, Seibt, Blomster, et al., 2019).

Recent studies on *being moved* commonly explored its co-occurrence with tears and goosebumps, and have observed increases in autonomic nervous system (ANS) responses for peak moments of *being moved*, including increased heart rate (HR), respiration rate (RR), or depth (RD), and continuous phasic skin conductance responses (SCRs; e.g., Benedek & Kaernbach, 2011; Wassiliwizky, Jacobsen, Heinrich, Schneiderbauer, & Menninghaus, 2017). However, no study has systematically explored the psychophysiology of kama muta and compared it to other emotional experiences.

The present study tests the physiological correlates of kama muta and compares them to two similar, though distinct emotions: *sadness* and *awe*. In order to enhance the cross-cultural validity of our findings, the studies were conducted using Norwegian and Portuguese participants.

1.1 | Being moved

Experiences of *being moved* have been subsumed under various psychological concepts (see Zickfeld, Schubert, Seibt, & Fiske, 2019 for a review). Already mentioned by Darwin (1872) and McDougall (1919) as the *tender* emotion, experiences of feeling *moved* were later explored under the concept of *empathic concern* (Batson, Fultz, & Schoenrade, 1987) and *elevation* (Haidt, 2003). Empathic concern is argued to occur when observing another person in need, while the emotion of elevation occurs when observing morally superior actions. In addition, recent theorizations have provided more philosophical (Cova & Deonna, 2014; Deonna, 2018) and aesthetic perspectives (Hanich, Wagner, Shah, Jacobsen, & Menninghaus, 2014; Konečni, 2005; Menninghaus et al., 2015, 2017) on the phenomena of *being moved*. Cova and Deonna conceptualize *being moved* as a positive emotion that occurs when positive core values arise against a backdrop of negativity (see Strick & Van Soolingen, 2017). Menninghaus and colleagues (2015, 2017; see also Kuehnast, Wagner, Wassiliwizky, Jacobsen, & Menninghaus, 2014) regard *being moved* as a mixed emotion, that often occurs in response to art reception but also as a more general response to highly moral situations that are compatible with self-ideals or prosocial norms, and significant aspects in relationships.

1.2 | Kama Muta—Being moved by love

The present study uses kama muta theory, which argues that the typical *being moved* experience is an instance of the theorized emotion *kama muta* (Sanskrit for *moved by* love). Based on Relational Models Theory (RMT; Fiske, 2004), the theory assumes that kama muta is evoked by observing or experiencing *sudden intensifications of communal sharing* (Fiske et al., 2019). In communal sharing relationships, resources are shared according to need and ability, and relational partners believe they share essential characteristics. Communal sharing relations are indexed by touch, commensalism or synchrony (Fiske, 2004). Intensification of communal sharing means that agents are perceived as coming closer together, getting more connected and forming a unit. Additionally, the aspect of suddenness refers to a temporal contrast (a shift in salience) that strengthens the emotion. Although it often co-occurs with other emotions, including negative ones (e.g., sadness), kama muta itself is experienced as positive (Fiske et al., 2019). In addition, kama muta is assumed to motivate communal action such as hugging, taking care, or helping others and it is often labeled with terms such as *moved*, *touched*, or *heartwarming* in English vernacular (Fiske et al., 2019). The kama muta framework has been supported by several empirical studies in various cultures (Blomster Lyshol, Seibt, & Thomsen, 2020; Schubert, Zickfeld, Seibt, & Fiske, 2018; Seibt, Schubert, Zickfeld, & Fiske, 2017; Seibt et al., 2018; Steinnes, Blomster, Seibt, Zickfeld, & Fiske, 2019; Zickfeld, Schubert, Seibt, Blomster, et al., 2019; Zickfeld, Schubert, Seibt, & Fiske, 2017).

There is a high degree of overlap between kama muta and other conceptualizations of *being moved* experiences, especially with regard to sensations and physiology (Zickfeld, Schubert, Seibt, & Fiske, 2019). Thus, previous studies targeting self-report or actual physiological responses of *being moved* are informative for kama muta, and the present research is informative for research on *being moved*. We will, therefore, refer to studies exploring other conceptualizations of *being moved*, when discussing the physiological responses to kama muta.

However, we note that *being moved* and kama muta are not the same. Other conceptualizations consider everything that is linguistically labeled as *moving* (e.g., Menninghaus et al., 2015), or everything that is labeled as *moving* and experienced as positive (e.g., Cova & Deonna, 2014), as part of the respective *being moved* concept. In contrast, there is no definite lexeme denoting kama muta, as no label has a one-to-one overlap across languages, situations, or historical time periods (Schubert, Seibt, Zickfeld, Blomster, & Fiske, 2017). *Moved* often denotes states of kama muta, but does not always (see Schubert et al., 2017; Zickfeld, Schubert, Seibt, & Fiske, 2019). In fact, the emotion of kama muta is defined by the interplay of the appraisal (i.e., sudden communal sharing intensification), valence, motivation, sensations, and label components. In order to avoid mistaking lexical categories for psychological ones (a lexical fallacy, Fiske, 2019), we, therefore, refer to a scientific term, kama muta.

1.3 | The physiology of Kama Muta

Several studies have provided self-report evidence that individuals experience physiological sensations within their body when they are *moved* or feeling kama muta, and these findings are largely undisputed across different theorizations (Zickfeld, Schubert, Seibt, & Fiske, 2019).

First, claims that individuals get moist eyes or shed tears in response to *being moved* (Cova & Deonna, 2014; Fiske et al., 2019; Fiske, Schubert, & Seibt, 2017; Gračanin, Bylsma, & Vingerhoets, 2018; Haidt, 2003; Konečni, 2005; Menninghaus et al., 2015; Miceli & Castelfranchi, 2003; Pohling & Diessner, 2016; Tan, 2009; Tan & Frijda, 1999; Thomson & Siegel, 2016) have been supported by self-report evidence (e.g., Landmann, Cova, & Hess, 2019; Mori & Iwanaga, 2017; Schubert et al., 2018; Wassiliwizky, Jacobsen, et al., 2017; Zickfeld, Schubert, Seibt, Blomster, et al., 2019). Relatedly, a feeling of being choked up or having a lump in the throat, which might be accompanied by intense crying has been identified (Cova & Deonna, 2014; Fiske et al., 2019; Konečni, 2005).

Second, the experience of goosebumps or chills has been mentioned frequently (Benedek & Kaernbach, 2011; Fiske et al., 2019; Menninghaus et al., 2015; Panksepp, 1995) and is supported by self-report evidence (Bannister, 2018; Landmann et al., 2019; Panksepp, 1995; Schubert et al., 2018; Wassiliwizky, Wagner, Jacobsen, & Menninghaus, 2015; Zickfeld, Schubert, Seibt, Blomster, et al., 2019). These findings include objective evidence assessing piloerection with the use of a recording device (Benedek & Kaernbach, 2011; Wassiliwizky, Jacobsen, et al., 2017).

Third, experiences of warmth in the body, especially in the center of the chest, have been reported (Cova & Deonna, 2014; Landmann et al., 2019; Pohling & Diessner, 2016; Schnall, Roper, & Fessler, 2010; Schubert et al., 2018; Tan & Frijda, 1999; Thomson & Siegel, 2016; Zickfeld, 2015). All these findings have been obtained using self-report evaluation, and there exist no studies objectively measuring whether body or skin temperature increases during episodes of kama muta.

1.3.1 | Autonomic nervous system activity of Kama Muta

There have been few studies testing ANS responses and other objective psychophysiological measures related to *being moved* experiences. Importantly, to our knowledge only four of these studies were directly related to *being moved* (i.e., by measuring it through self-report; Benedek & Kaernbach, 2011; Kimura, Haramizu, Sanada, & Oshida, 2019; Wassiliwizky, Jacobsen, et al., 2017; Wassiliwizky, Koelsch, Wagner, Jacobsen, & Menninghaus, 2017),[1] while the remaining studies focused mostly on responses typical (though not exclusive) of *being moved* experiences, including (aesthetic) chills or tears. From most of these studies it is not clear to what extent kama muta is evoked by the specific stimuli, especially as they are sometimes framed to induce a different emotion (i.e., *sadness*, *attachment love*). Those studies, therefore, provide mostly indirect evidence for the ANS response of kama muta. An overview of the identified studies and their outcomes is provided in Table 1. We will briefly summarize the general pattern of empirical findings regarding the different ANS systems and take into consideration theoretical predictions with regard to kama muta.

Cardiovascular activity

Direct and indirect evidence for cardiovascular activity suggests an acceleration of heart rate (HR) activity in response to *moving* stimuli. Studies targeting being moved (Wassiliwizky, Jacobsen, et al., 2017), chills (Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009), and tears (Gross, Fredrickson, & Levenson, 1994) found an increase in HR for strong emotional reactions (compared to a control condition). Consistently, pulse volume amplitude decreases (Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011). However, two studies focusing on being moved reported no differences in HR activity in response to *moving* stimuli (Benedek & Kaernbach, 2011; Kimura et al., 2019). From a theoretical viewpoint, it is not immediately obvious what cardiovascular reaction strong episodes of kama muta should elicit.

Empirical findings on heart rate variability (HRV) have been mixed. On the one hand, a study comparing the

[1] As mentioned earlier, although these studies are not directly targeting kama muta they are relevant as evidence for it, since a person labelling her affective state as *being moved* is one of the indicators for diagnosing a kama muta experience (though not a sufficient nor necessary one; Fiske, Seibt, & Schubert, 2019).

TABLE 1 Review of physiological findings on being moved and similar responses (chills, tears)

					Type of system											
					Cardiovascular			Respiratory		Electrodermal		fEMG		Other		
Study	n (n females)	Construct	Stimuli	Comparison	HR	PVA/ BVP	HRV (IBI/RSA)	RR	RD	SCL	SCR	Zyg	Corr	ST	Goose	Tears[g]
Direct evidence for being moved																
Benedek and Kaernbach (2011)	50 (43)	Being moved	Audio from music and film	Piloerection versus no piloerection	o	–		o	+	o	+				+[f]	
Wassiliwizky, Jacobsen, et al. (2017)	25 (22)	Being moved	Film clips	Goosetears versus control	+			+			+	+	+		+[f]	
Wassiliwizky, Koelsch, et al. (2017)	27 (19)	Being moved	Audio from poems	Piloerection versus control	+						+	o	+		+[f]	
Kimura et al. (2019)	28 (16)	Being moved	Film clips	Being moved versus neutral	o						+	o	o[c]			
Indirect evidence for being moved																
Kraemer and Hastrup (1988)	48	Tears	Film clip	Criers versus non-criers	+						+					
Gross et al. (1994)	150	Tears	Film clip	Criers versus non-criers	+			+[e]	o	+				–[d]		
Rottenberg, Gross, Wilhelm, Najmi, and Gotlib (2002)	33[a] (23)	Tears	Film clips	Criers versus non-criers	+			o		o	+			o[d]		
Rottenberg et al. (2003)	31[a]	Tears	Film clip	Criers versus non-criers	+		+	–	+							
Hendriks et al. (2007)	60	Tears	Film clip	Criers versus non-criers[h]	+		+	–		o						
Salimpoor et al. (2009)	32 (17)	Chills	Music	Pleasurable versus neutral songs	+	–		+		+				–[d]		
Salimpoor et al. (2011)	10 (5)	Chills	Music	Pleasurable versus neutral songs	+	–		+		+				–[d]		
Shiota et al. (2011)	37	Attachment/ nurturant love	Film clips	Attachment/nurturant love versus neutral			–	o[b]			o					
Mori and Iwanaga (2014)	32 (18)	Chills	Music	Self-selected versus control songs							+					
Sumpf, Jentschke, and Koelsch (2015)	58 (34)	Chills	Music, film clips	Piloerection versus no piloerection	+			o							+[f]	

(Continues)

TABLE 1 (Continued)

					Type of system											
					Cardiovascular			Respiratory		Electrodermal		fEMG		Other		
Study	n (n females)	Construct	Stimuli	Comparison	HR	PVA/ BVP	HRV (IBI/RSA)	RR	RD	SCL	SCR	Zyg	Corr	ST	Goose	Tears[g]
Mori and Iwanagi (2017)	66 (39)	Chills, tears	Music	Self-selected versus control songs	+			o	+	+						

Abbreviations: –, decrease; +, increase; Corr, corrugator supercilia; Goose, goosebumps; HR, heart rate; HRV, heart rate variability; IBI, interbeat interval; o, no difference/mixed results; PVA, pulse volume amplitude; RD, respiratory depth; RR, respiration rate; RSA, respiratory sinus arhythmia; SCL, skin conductance level (tonic); SCR, skin conductance response (phasic); ST, skin temperature; Zyg, zygomaticus major.

[a]We focus on the non-clinical sample for the present context.

[b]Only for nurturant love.

[c]Significant difference for *high arousal* moving video but not for *low arousal* moving video.

[d]Finger skin temperature.

[e]Although respiratory rate was higher for criers than non-criers, rates were lower than the baseline level.

[f]Comparisons were made on the basis whether participants experienced visible piloerection or not so piloerection is by default higher in the experimental condition.

[g]None of the presented studies measured tears in an objective fashion (e.g., by coding videos).

[h]We inspected the differences between criers and non-criers at the crying onset.

physiological reactions of individuals crying to non-criers found an increase in respiratory sinus arrhythmia for criers (RSA; Rottenberg, Wilhelm, Gross, & Gotlib, 2003). On the other hand, a different study comparing reactions to film clips characterized as *nurturant* or *attachment love* to neutral films resulted in a decrease of RSA activity for those in the nurturant or attachment love condition (Shiota, Neufeld, Yeung, Moser, & Perea, 2011). From a theoretical viewpoint, kama muta has been found to be experienced as overall positive (Zickfeld, Schubert, Seibt, Blomster, et al., 2019) and positive emotions in general have been associated with increased HRV, as measured by specific time and frequency domains of HRV that are highly influenced by the parasympathetic system such as the time domain square root of the mean squared differences of successive heart periods (RMSSD) and the High Frequency (HF) of HRV (Duarte & Pinto-Gouveia, 2017; Oveis et al., 2009).

Respiratory activity

Direct and indirect evidence for changes in respiration rate (RR) have been mixed, ranging from findings showing an increase (Wassiliwizky, Jacobsen, et al., 2017), or no difference (Benedek & Kaernbach, 2011), to findings observing a decrease (Rottenberg et al., 2003) in RR in response to moving or similar stimuli. In addition, RR has been negatively linked to HRV (Song & Lehrer, 2003).

More specific evidence has been found for responses of respiratory depth (RD) or tidal volume. Across most studies (Benedek & Kaernbach, 2011; Mori & Iwanaga, 2017; Rottenberg et al., 2003) *being moved* or crying responses increased RD (though see Gross et al., 1994). Indeed, taking a deep breath has been argued to be typical of kama muta, which would be in line with the presented empirical findings (Fiske et al., 2019). Hence, from a theoretical and empirical view kama muta should be associated with increases in RD, while RR activity should not be affected or even show a decrease.

Electrodermal activity

Direct and indirect findings regarding electrodermal activity (EDA) are somewhat consistent. EDA has been generally divided into the tonic component (skin conductance level), referring to slower changes in arousal over time, and the phasic component (skin conductance response), referring to more immediate changes in arousal to specific stimuli (Benedek & Kaernbach, 2010). Indirect evidence starting from tears or chills has provided evidence that skin conductance level, and thereby arousal, shows an increase for tears or chills (e.g., Gross et al., 1994; Salimpoor et al., 2009). However, the only study directly targeting *being moved* reported no differences in overall tonic EDA for *moving* experiences (Benedek & Kaernbach, 2011). Moreover, (non-specific) phasic skin conductance responses (nSCR) were found to increase for *moving* responses for all studies focusing on *being moved* (Benedek & Kaernbach, 2011; Kimura et al., 2019; Wassiliwizky, Jacobsen, et al., 2017; Wassiliwizky, Koelsch, et al., 2017). From a theoretical viewpoint, kama muta theory supports the assumption that kama muta should include rapid changes in arousal but not overall increases. The theory states specifically that emotional responses occur as a response to *sudden* intensifications in communal sharing relations, the suddenness thereby can be expected to lead to a phasic EDA response (see also Menninghaus et al., 2015 who characterize *being moved* as *low to mid in arousal*).

In conclusion, the evidence regarding ANS responses of kama muta is mixed. This may be because of the considerable variation in measurement and induction methods in previous studies, or it may be that kama muta does not have a distinct ANS pattern, which would be in line with a recent meta-analysis (Siegel et al., 2018). Based on the reviewed empirical and theoretical evidence, it seems that kama muta is best described by a co-activation of sympathetic (increases in HR, nSCR) and parasympathetic (increases in RD, HRV) ANS activity (Shaffer & Ginsberg, 2017). There is less evidence for changes in SCL and RR.

1.3.2 | Facial muscle activity

Next to ANS activity, recent studies have explored facial muscle activation as measured by facial electromyography (fEMG). Such activity is generally thought to represent changes in valence, with zygomaticus major activity mapping onto positive and corrugator supercilia activity onto negative valence (Cacioppo, Petty, Losch, & Kim, 1986). Theorizations of *being moved* have generally described the emotion as positive in valence, which has been supported by some fEMG studies (Wassiliwizky, Jacobsen, et al., 2017), though not by others (Kimura et al., 2019; Wassiliwizky, Koelsch, et al., 2017). Some theories have also described *being moved* as a mixed emotion, consisting of both positive and negative valence (Menninghaus et al., 2015, 2017). Some evidence of increased corrugator activity for peaks of emotional experience supports this (Wassiliwizky, Jacobsen, et al., 2017; Wassiliwizky, Koelsch, et al., 2017).

In self-report, kama muta has been consistently found to be subjectively experienced as positive but not negative (Seibt et al., 2018; Zickfeld, Schubert, Seibt, Blomster, et al., 2019). As mentioned earlier, kama muta often occurs against a backdrop of negativity (Fiske, Seibt et al., 2017; see also Cova & Deonna, 2014; Strick & Van Soolingen, 2017) and is sometimes positively related to experiences of *sadness* (Zickfeld, Schubert, Seibt, Blomster, et al., 2019). Importantly, these more negative experiences are not part of kama muta according to the theory. Therefore, we expect kama muta to increase zygomaticus but not corrugator activity. In addition, individuals experiencing sadness should show more corrugator activity than individuals experiencing kama muta.

1.3.3 | Lachrymation, piloerection & warmth

There are few published studies examining whether the occurrence of lachrymation (or tears), piloerection (or goosebumps), and feelings of warmth as found in many self-report studies is indicative of kama muta or *being moved*.

Piloerection or goosebumps (Benedek & Kaernbach, 2011) are sometimes also referred to as chills, although some scholars have argued that chills represent a subjective component, whereas goosebumps refer to objectively quantifiable erection of the skin (Wassiliwizky, Jacobsen, et al., 2017). Studies found that piloerection (operationalized as so-called *goosetingles*) represents one aspect of the psychological concept of chills (Maruskin, Thrash, & Elliot, 2012). In line with this, we also regard studies focusing on the construct of chills as informative here. Benedek and Kaernbach (2011) found that episodes involving goosebumps, as assessed with a camera obtaining recordings of the skin (Benedek, Wilfling, Lukas-Wolfbauer, Katzur, & Kaernbach, 2010) were rated as more *moving* than the control trials. Chills or goosebumps have been described as an indicator of arousal (Laeng, Eidet, Sulutvedt, & Panksepp, 2016; Salimpoor et al., 2009), which fits the finding of increased HR and nSCRs presented in the previous section. Similarly, the piloerection response is argued to be guided by the sympathetic branch (Hellmann, 1963). There is some research indicating that subjective chill responses and objectively measured piloerection might diverge (Wassiliwizky, Koelsch, et al., 2017). The authors observed for example an increase in EDA activity for piloerection over time but a decrease for subjective chills responses (see also Maruskin et al., 2012).

Shedding emotional tears has been attributed to parasympathetic ANS activity (Ioannou et al., 2016; Rottenberg et al., 2003). The lacrimal glands controlling the crying process are also argued to be controlled by the parasympathetic branch (Werb, 1983). Crying also involves increased arousal and the sympathetic system (Gross et al., 1994; Wassiliwizky, Jacobsen, et al., 2017). Crying, thus, seems to involve a co-activation of the antagonistic branches of the ANS. Sympathetic activity might increase until the onset of the lachrymation episode, at which point it withdraws and parasympathetic activity increases (Hendriks, Rottenberg, & Vingerhoets, 2007). Wassiliwizky, Jacobsen and colleagues (2017) also found that sympathetic activation was strongest when tears co-occurred with goosebumps (so-called *goosetears*).

TABLE 2 Overview of theoretical and physiological profiles of kama muta, sadness, and awe

Aspect	Kama Muta	Sadness	Awe
Valence	Positive	Negative	Positive
Arousal	Low to medium	Low	Medium
Appraisal	Sudden intensification of communal sharing	Relationship/goal Loss	Perceptions of vastness; need for accommodation
Motivations	Devotion/commitment to communal relationship	Deliberative reasoning, withdrawal	Passive contemplation and submission, prosocial
Bodily Sensations	Tears, goosebumps, warm chest	Tears	Goosebumps, chills, deep breath
Physiology			
Cardiovascular	HR (+); HRV (+)	HR (−); RSA (+)	HR (+); RSA (+); HRV (+)
Respiratory	RR (o); RD (+)	RR (−); RD (+)	RR (+); RD (+)
Electrodermal	SCL (o); nSCRs (+)	SCL (−) nSCRs (−)	SCL (+); nSCRs (+)
fEMG	Zyg (+); Corr (o)	Zyg (−); Corr (+)	Zyg (+); Corr (o)
Main source	Fiske et al. (2017)	Kreibig et al. (2007); Lench et al. (2016)	Gordon et al. (2017); Shiota et al. (2007), Shiota et al. (2011))

Abbreviations: −, decrease; +, increase; Corr, corrugator; HR, heart rate; HRV, heart rate variability; nSCRs, phasic non-specific skin conductance responses; o: no change; RD, respiratory depth (tidal volume); RR, respiration rate; RSA, respiratory sinus arythmia; SCL, tonic skin conductance level; Zyg = zygomaticus major.

Finally, there is mixed evidence with regard to changes in actual body or skin temperature. Studies employing stimuli ostensibly evoking kama muta or targeting chills observed both decreases (Lundqvist, Carlsson, Hilmersson, & Juslin, 2009; Salimpoor et al., 2009, 2011), and increases in finger temperature (Baumgartner, Esslen, & Jäncke, 2006; Krumhansl, 1997; McFarland, 1985; Rimm-Kaufman & Kagan, 1996), and no changes in facial temperature (Rimm-Kaufman & Kagan, 1996). To our knowledge, there are no studies directly testing changes in chest temperature with regard to kama muta or *being moved* experiences. Haidt (2003) argued that heightened feelings of warmth could be attributed to an increase in vagus nerve activity, which is part of the parasympathetic nervous system. However, no empirical studies have tested such a hypothesis to date. A co-activation of sympathetic and parasympathetic activity is not unlikely (Shaffer & Ginsberg, 2017), and recent empirical research has linked positive emotionality to vagal activity (Depue & Morrone-Strupinsky, 2005; Duarte & Pinto-Gouveia, 2017; Shiota et al., 2011). Likewise, responses of compassion and sympathy correlated with increased vagal activity (Stellar, Cohen, Oveis, & Keltner, 2015). Such responses have been linked to kama muta (Zickfeld, Schubert, Seibt, Blomster, et al., 2019).

1.4 | The present study

The present study is the first to objectively identify psychophysiological correlates of kama muta. The study has two main aims: (a) to compare peak moments of kama muta with control periods and explore psychophysiological differences; (b) to compare the physiological measurements accompanying kama muta to those for the similar, though distinct, emotional experiences of *sadness,* and *awe*.[2]

We employ sadness and awe as comparisons for several reasons (see Table 2 for a comparison). First, *both* have been theoretically (Fiske et al., 2019; Koneçni, 2005; Menninghaus et al., 2015) and empirically (Seibt et al., 2017; Zickfeld, Schubert, Seibt, Blomster, et al., 2019) linked to kama muta or to *being moved*. Sadness is typically accompanied by emotional tears (Balsters, Krahmer, Swerts, & Vingerhoets, 2013; Sauter, Eisner, Ekman, & Scott, 2010) and awe has frequently been found to include chills and goosebumps responses (Quesnel & Riecke, 2018; Schurtz et al., 2012; Shiota, Keltner, & Mossman, 2007). Second, both sadness and awe have been repeatedly distinguished from kama muta (Seibt et al., 2017; Zickfeld, Schubert, Seibt, Blomster, et al., 2019) and feature different patterns. Sadness has been typically regarded as a negative low arousal emotion (Lench, Tibbett, & Bench, 2016), while awe is argued to comprise positive affect and medium arousal (Shiota et al., 2011). Thus, the two emotions allow for comparison across different degrees of valence and arousal, as well as accompanying bodily sensations such as tears and goosebumps.

We included several measurements to account for the most common physiological indicators of the ANS (cardiovascular, respiratory and electrodermal), to explore facial muscle contractions using fEMG (and thereby valence), and to provide objective ratings of tears, goosebumps, and skin

[2]In addition, we also present evidence for the continuous relationship between self-report ratings of kama muta and physiological measures in the Supporting Information (Tables S1 and S2).

temperature around the chest. In addition, we included ANS measures typically obtaining evidence for sympathetic (EDA) and parasympathetic activation (HRV domain indicators—RMSSD). Our study is thereby the most comprehensive psychophysiological investigation of *being moved* experiences to date (see overview in Table 1).

Based on previous findings regarding physiological measures, self-report evidence, and theoretical predictions, we drafted several hypotheses. For the comparison between high and low reactions of kama muta to video segments we predicted the following:

Hypothesis 1 *Emotional responses of kama muta increase HR,[3] HRV, RD, and nSCRs, while there is no change with regard to RR and SCL.*

Hypothesis 2 *Emotional responses of kama muta increase zygomaticus activity while there is no change in corrugator activity.*

Hypothesis 3 *Emotional responses of kama muta induce tears, goosebumps and higher skin temperature around the chest.*

Regarding discriminant validity by comparing responses to moving videos with responses to sad and awe-inducing videos, we predict that:

Hypothesis 4 *Physiological reactions to moving videos are similar to reactions to sad videos with regard to RD, nSCRs, and tears, while these emotions should differ on ST, HR, HRV, RR, SCL, Zyg, Corr, and goosebumps. Moving videos will evoke stronger ST, HR, HRV, RR, SCL, Zyg, and goosebumps responses, while sad videos will evoke stronger Corr responses.*

Hypothesis 5 *Physiological indicators of kama muta are similar to those of awe with regard to HR, HRV, RD, nSCRs, Zyg, Corr, and goosebumps, while these emotions should differ on ST, RR, SCL, and tears. Moving videos will evoke stronger ST and tears responses, while awe-inducing videos will evoke stronger RR and SCL responses.*

All measures, stimuli, and experimental and data files are published online at our project page (https://osf.io/rymnu/), except for data that could identify participants (e.g., video recordings). The study was approved by the internal review board of the University of Oslo and by the scientific committee of ISCTE-IUL, Lisbon. The Norwegian part of the study was also approved by the Norwegian Centre for Research Data (NSD; 54037).

[3]Note that we adapted the hypothesis with regard to HR after reviewing additional empirical studies. While this could be considered a form of *HARKing*, adjusting hypotheses in light of results, it is noteworthy to emphasize that the readjusted hypothesis deviates from the obtained results. Given the empirical findings we consider this change as sensible.

2 | METHOD

2.1 | Participants

For the final sample we recruited 105 Portuguese participants (62 females; age range: 17 to 36, $M_{age} = 21.57$, $SD_{age} = 3.03$) at ISCTE-IUL and 39 Norwegian undergraduate participants (24 females; age range: 19 to 45, $M_{age} = 21.82$, $SD_{age} = 4.62$) at the University of Oslo, resulting in a total sample of 144 participants. The limited amount of previous research complicated conducting a well-reasoned a-priori power analysis. Previous studies found in general *medium* effect sizes but also included small sample sizes (e.g., *n*s of 50, 25, 66). Recommendations for HRV analysis suggest a rule-of-thumb of 61 participants for *medium* effects (Laborde, Mosley, & Thayer, 2017). We tried to fulfill these criteria and included as many participants as possible in the present study.

2.2 | Procedure and materials

Both subsamples followed largely the same procedures. Participants were greeted and presented with written informed consent. First, the experimenters attached the physiological sensors. Then, participants were seated in an armchair about two meters away from a 55-inch LCD display (Samsung LH55EDDPLGC/EN) with a refresh rate of 50Hz in the Norwegian sample. In the Portuguese sample, participants were seated about 65 centimeters away from a 23-inch LCD display (LG Flatron W236 3D) with a refresh rate of 60Hz. Sound was presented through headphones and the room temperature was kept constant at 23 ± 1°C. Videos were presented in E-Prime 2.0 (Psychology Software Tools Inc.), which recorded self-report measures and sent triggers to the physiological recording device via a parallel port to mark video onset and offset.

After a short resting period, participants were instructed and presented with a five-minute baseline video presenting different shots of a forest during which baseline measures were obtained. Then, participants were presented with six different videos, which were chosen based on previous research to induce kama muta, sadness, and awe, two videos per emotion (Zickfeld, Schubert, Seibt, Blomster, et al., 2019). The kama muta videos depicted a doctor showing his gratitude after 30 years by rescuing one of his patients and a man performing good and altruistic deeds during his daily life. The sad videos included an animated short story of a boy losing his father in an accident and the story of a girl in a warzone that has to flee from war and is separated from her father.

TABLE 3 Overview of physiological measurements and their processing software and location

Recording equipment	Location	Country
Heart Rate (HR) and Heart Rate Variability (HRV): RMSSD & HF-HRV[k]		
ECG	Lead II chest configuration	PT
PPG	Third finger	NO
Respiration Rate (RR) and Respiration Depth (RD)[a]		
Piezoelectric transducer belt	Abdomen	PT*; NO
Skin Conductance Level (SCL) and non-specific Skin Conductance Responses (nSCRs)[a]		
EDA	Palmar Surface middle phalanges (non-dominant hand)	PT; NO
Zygomaticus major (Zyg) and Corrugator supercilii (Corr)[a]		
fEMG	Face (Fridlund & Cacioppo, 1986)	PT
Skin Temperature (ST)[a], Goosebumps (Goose)[g] and Tears		
TSD202B temperature transducer	Middle of the chest	NO
Goosecam	Left forearm	NO
Tearcam	Left eye	NO

Abbreviations: [a]AcqKnowledge 4.1/4.3/5.0; [g]Gooselab 1.12; NO, Norway; PT, Portugal; Software: [k]Kubios 3.1.

*Data for respiratory measures obtained from Portugal were not usable due to a hardware problem.

The awe videos included a climber ascending the Dawn Wall and aerial shots of mountain ranges. Three blocks of two videos, each targeting the same emotion, were presented in randomized order for each participant. The two videos within each block were also randomized. The video lengths differed between 83 and 211 s, while the length of each block was around 300 s. For the Norwegian sample, the videos were presented in English, while we included Portuguese subtitles in the Portuguese sample.

After each emotion type block, participants completed self-report measures targeting both videos. We included the sensations, valence, and labels section of the KAMMUS (Zickfeld, Schubert, Seibt, Blomster, et al., 2019), a validated self-report scale to measure kama muta in several countries, including Portugal and Norway (descriptives are presented in Table S12). The sections included 12 items on sensations (e.g., "A warm feeling in the center of the chest"), two items on valence (e.g., "I had positive feelings"), and 11 items on labels. Of these emotion labels, three items were averaged to form the kama muta label index ("I felt moved," "I felt touched," "It was heartwarming"), and one item each assessed feeling *awed* ("I felt awed") and *sad* ("I felt sad"), as a manipulation check for the awe and sadness-inducing videos (the remaining six labels were fillers). Thus, each participant completed these measures thrice. All items were completed on 7-point scales ranging from 0 ("not at all") to 6 ("very much"). We also recorded whether participants had watched the videos before. After the video presentation, physiological sensors were removed, and participants completed a short questionnaire including demographic questions and items on whether they had consumed food or beverages prior to the experiment, smoked regularly, took regular medication.[4] Finally, participants were thanked and debriefed.[5]

2.2.1 | Physiological recordings

An overview of all physiological recordings, how they were assessed, and the location of measurement is provided in Table 3. At the Portuguese site we collected an electrocardiogram (ECG), respiration, electrodermal activity (EDA), and facial electromyography (fEMG). At the Norwegian site we collected blood volume pulse via a photoplethysmograph (PPG), respiration, EDA, and skin temperature. Physiological data were recorded using BIOPAC MP150 (Biopac Systems Inc., Goleta, CA) and the AcqKnowledge 4.1 software. All measurements were recorded at a rate of 1KHz. EDA was measured on the palmar surface of the middle phalanges of the first and second fingers of the non-dominant hand. A

[4]We also tested the effect of medication on our main models. We observed an interaction effect of kama muta level (low vs. high segments of the kama muta videos) and medication for skin temperature, skin conductance level, respiratory depth, goosebumps, zygomaticus, and corrugator activity. However, at the same time we observed comparable main effects of level of kama muta. Results are reported in the Supporting Information (Table S5).

[5]In the Portuguese sample participants also completed a 7- item scale targeting the general frequency of experiencing kama muta (KAMF; Zickfeld, Schubert, Seibt, Blomster et al., 2019) and the 28 items of the Interpersonal Reactivity Index measuring different facets of empathy (Davis, 1980). To control for order effects 53 participants completed these measures prior to the main experiment, while 52 responded afterwards.

constant voltage of 0.5 V was maintained between two disposable 11mm Ag/AgCl snap electrodes filled with NaCl electrolyte paste gel. ECG was obtained using three pregelled disposable Ag/AgCl electrodes (11 mm diameter, EL503 EKG), placed in a Lead II chest configuration. Blood volume pulse was recorded using a PPG sensor attached to the third finger of the left hand. Respiration was obtained with a piezoelectric transducer belt placed around the abdomen. Skin temperature was measured using a TSD202B temperature transducer attached to the middle of the chest. Finally, fEMG was obtained at the corrugator supercilii and the zygomaticus major using disposable Ag/AgCl electrodes with 4 mm diameter, filled with gel, placed in accordance with recommendations (Fridlund & Cacioppo, 1986).

Goosebumps and tears were recorded using two camera devices in the Norwegian sample only. For piloerection measurement we employed the *goosecam*, a device based on instructions by Benedek et al. (2010), which was attached to the left forearm of the participant with a strap. In addition, participants wore a custom constructed spectacle frame that featured a camera pointing at the left eye. Videos were recorded using AcqKnowledge and Matlab 2017b.

Finally, we assessed the amount of tears or moist eyes observable, but only in the Norwegian sample. Their right eye was recorded using a video camera during the experiment. The video recorded during viewing of each video was coded by a research assistant as to whether it included no tears or moist eyes (0), moist eyes (1), little crying (2), or a lot of crying (3). One rating was given per video, thus, not resulting in a continuous score for this measure. We, therefore, only analyze lachrymation comparing emotion conditions, not within videos.

2.2.2 | Preprocessing

Most artefacts were corrected through visual inspection of the data. Four Portuguese participants were excluded from all analyses because of artefacts that could not be corrected. Therefore, the final sample for most analyses consisted of 140 participants. The respiration data in the Portuguese sample showed a considerable amount of noise possibly caused by the sensor. After consulting with the manufacturer of the hardware and software system we decided to exclude the Portuguese respiration data. Thus, the present respiration data are only based on the Norwegian participants.

The ECG and PPG[6] signals were registered to identify heart rate (HR) and two measures of vagal tone from heart rate variability (HRV): the square root of the mean squared differences of successive heart periods (RMSSD) to assess changes in the time domain, and the high frequency component (HF-HRV) using log-transformed values of absolute powers of high-frequency bands (0.15–0.40 Hz) to address changes in frequency. Both raw ECG and blood volume data of PPG were analyzed with Kubios HRV Premium Software (Version 3.1, 2018, Kubios Oy, Kuopio, Finland). In Kubios, a cubic spline interpolation was used with a rate of 4 Hz. Additional artifacts correction was made with interpolated values into the RR interval data of 58 videos (out of a total of 708 video analyses, 8.19% of the data). In these artifact corrections, the number of corrected beats was low, making a significant distortion of the results due to the correction highly unlikely ($M_{\text{peaks\_corrected}} = 0.21$). Finally, a smoothness priors detrending, with a Lambda of 500, was employed as recommended for short-term HRV analyses (Tarvainen, Lipponen, Niskanen, & Ranta-Aho, 2018).

The EDA signal was resampled to 50 Hz,[7] processed using a 50-sample median smoothing filter, and using a finite impulse response (FIR) low-pass filter at 1 Hz with a Blackman (−61 dB) window (see Braithwaite, Watson, Jones, & Rowe, 2013). Both tonic and phasic EDA were analyzed, corresponding to the SCLs and the absolute frequency of non-specific skin conductance responses (nSCRs) that emerged throughout the exposure to each video, respectively. These two components were obtained using an in-built routine in AcqKnowledge, by implementing a 0.05 Hz high pass filter, a baseline estimation window width of 0.25 s, a SCR threshold level at 0.01 μS, and a rejection rate of 10%. As the different videos had different lengths, we accounted for the duration of the video when calculating the frequency of nSCRs.

Respiration rate was registered using a respiration belt, with the data resampled to 50 Hz, then band-pass filtered between 0.05 and 1 Hz, and fixed at 4,000 coefficients with a Blackman (−61 dB) window (Lorig, 2007). Calculation was based on a peak detection algorithm implemented in AcqKnowledge. Additionally, respiration depth was extracted based on a peak to peak detection algorithm implemented in the software. Skin temperature data were resampled to 50 Hz and filtered using a FIR low-pass filter at 1 Hz.

As suggested by van Bedaf, Heesink, and Geuze (2014), the fEMG data were processed by first applying a FIR band-pass filter between 28 and 500 Hz, fixed at 1,001 coefficients (Hamming window) and second, an infinite impulse response (IIR) band-stop filter, with a frequency of 50 Hz and Q set to 30.59. Next, we computed the root mean square (RMS) with a time window interval mean of 0.3 s.

Goosecam videos were synchronized with the physiological recording and presentation by adding LED marks

[6]Note that the discrepancy between HRV measures obtained from ECG and PPG signals is rather low (Shaffer & Ginsberg, 2017).

[7]EDA, respiration and skin temperature scores were all resampled to 50Hz. This rate represents typical ranges used in previous studies (Mori & Iwanaga, 2017; Wassiliwizky, Jacobsen, et al., 2017).

to the recordings. Goose videos were resampled at 1fps and analyzed using *Gooselab* V 1.12 in Matlab 2017b, as recommended by Benedek and Kaernbach (2011). Due to a loose contact, a minority of videos featured a black screen for some seconds, which were corrected by imputing the mean of the time series. By means of an epoch analysis, a total of 174,733 data points were extracted for all seven videos (one baseline, and two kama muta, sad, and awe videos). Measurements were retained at 1 Hz, with one measurement corresponding to one second of the video. For cardiac measurements (ECG and PPG) we employed mean scores, as our time resolution was too low to extract continuous scores (Shaffer & Ginsberg, 2017).

Scores were adjusted for interindividual differences by subtracting the mean of the individual baseline responses to the initial video from the respective measurement, resulting in a reactance or difference score (e.g., Benedek & Kaernbach, 2011; Wassiliwizky, Koelsch, et al., 2017). A positive score exemplifies a higher score, or increase, in comparison to the baseline, while a negative score reflects lower responding in contrast to the baseline. To allow comparisons across measures we then z-standardized all measures. The final score, therefore, presents a standardized difference from the baseline.[8] Measures of HRV, zygomaticus and corrugator activity were log-transformed before differencing and standardization, as recommended (Laborde et al., 2017).

3 | RESULTS AND DISCUSSION[9]

We conducted three main types of analysis: First, we compared self-reports of emotions between the different conditions, testing whether the videos evoked the intended emotions. Second, we looked at changes of physiological responses *within* the kama muta videos by comparing segments that evoked little kama muta to segments that evoked a lot of kama muta (*kama muta level*; Hypothesis 1–Hypothesis 3). Third, we tested whether physiological responses differed *between* the three different emotion conditions, by comparing kama muta to sadness and to awe videos (*emotion type*; Hypothesis 3–Hypothesis 5).

[8]Note that for the final standardized scores a deviation from zero does not provide any information about an increase or decrease from baseline. Plots presenting the unstandardized difference scores can be found in Figure S4–S5. For analyses between levels of kama muta, scores generally increased from baseline (except for RMSSD, HF, and RD where we found decreases for both levels of kama muta). For analyses across emotion types, scores also increased from baseline for all emotion types, with the exception of HR, RMSSD, HF, and RD where they decreased for all emotion types.

[9]We repeated all analyses presented in the Results sections excluding *outliers* detected using the absolute deviation from the median (Leys, Delacre, Mora, Lakens, & Ley, 2019). Results were similar to our main models and can be found in Table S8–S11.

3.1 | Preparation of analyses

For the purpose of the within-video comparisons, we identified short segments (30 s) a-priori that evoked little versus a lot of kama muta by relying on data from Schubert et al. (2018) for the same videos. In that study, several hundred participants rated several variables continuously while watching the videos (Schubert et al., 2018). We used here ratings of *being moved*, *perceived closeness*, *experienced tears, warmth,* and *goosebumps*. These ratings were made by U.S. participants and may not align perfectly with experiences of Norwegian and Portuguese participants; however, recent studies revealed little cross-cultural variations for such self-report data (Zickfeld, Schubert, Seibt, Blomster, et al., 2019). For the first video ("Thai Medicine"), we identified the segment from 130 to 160 s as most kama muta evoking, and the sequence between 40 and 70 s as the control period. For the second video ("Thai Altruism"), the strongest kama muta segment appeared from 120 to 150 s, and the sequence from 10 to 40 s was the control segment.

For the physiological measures, we retained all variables at a resolution of single seconds. To adequately account for within-subject variation, we used multilevel modeling as recommended for psychophysiological data (Judd, Westfall, & Kenny, 2012; Page-Gould, 2016; see Wassiliwizky, Jacobsen, et al., 2017 for an example). All main models were computed using linear mixed model in the lme4 package in *R* (Bates, Mächler, Bolker, & Walker, 2014). We report unstandardized effect sizes *B* and standardized effect sizes *d* based on transformations by Bowman (2012) and Lakens (2013).[9] When using mixed models, we report descriptive means and within-subjects standard errors calculated based on Morey (2008). Alpha was set to .05 for all analyses.

Correlations among the physiological measures, as well as correlations between physiological and self-report measures are provided in the Supporting Information (Table S13–S14).

3.2 | Comparing self-reported emotions between emotion conditions

We examined self-report responses across the three emotion types (kama muta vs. sadness vs. awe) using multilevel models. Country was always added as a factor. As predicted, self-reported kama muta (average of feeling *moved*, *touched*, and *heartwarming*) was highest for the kama muta videos (M = 4.63, SD = 1.22) in comparison to both the sad (M = 2.55, SD = 1.23, d = 1.70) and the awe videos

[9]Due to the z-standardization of our dependent variables and the coding of our IV, unstandardized *B*s reflect standardized *d*s for the within kama muta comparisons.

($M = 1.47$, $SD = 1.25$, $d = 2.54$).[10] Similarly, sadness ratings were highest for the sad videos ($M = 4.39$, $SD = 1.41$) in contrast to kama muta ($M = 2.77$, $SD = 1.72$, $d = 1.03$), and awe ($M = 0.54$, $SD = 0.97$, $d = 2.73$). Finally, awe ratings were highest for the awe videos ($M = 3.27$, $SD = 1.92$) in comparison to sadness ($M = 2.58$, $SD = 1.86$, $d = 0.37$) and kama muta ($M = 2.15$, $SD = 1.85$, $d = 0.59$). For the awe ratings, country and condition interacted: The difference between awe and sadness videos was stronger in the Portuguese ($d = 0.48$) than in the Norwegian sample ($d = 0.08$). No such interactions were observed for the kama muta or sadness ratings. An overview of all self-report ratings is provided in the Supporting Information (Figure S1–S3). These self-reported emotions confirm that the videos elicited the emotions as we planned.

3.3 | Comparing physiological reactions to high versus low Kama Muta segments within Kama Muta videos

In these analyses, we compared physiological mean responses during segments eliciting little kama muta to segments eliciting a lot of kama muta within the two kama muta videos only. We used multilevel models. Units of analyses were individual physiological measures for each second. These dependent variables were z-standardized. Kama muta level (low: −0.5 vs. high: 0.5) was added as a predictor.[11] Intercepts varied randomly according to participant. Overviews of all measures are presented in Figure 1 and Table 4.

[10]To adequately differentiate kama muta from the other conditions, we also tested for differences in the sensations (tears, chills, warmth, choked up, and feeling exhilarated) and valence components. Except for feeling choked up, all these discriminated the kama muta videos from the other two videos. Due to time constraints, we were not able to assess the appraisal and motivation dimensions of the KAMMUS. However, previous studies in Norway and Portugal using the exact same videos have provided evidence that these responses differentiate from sadness and awe videos (Zickfeld, Schubert, Seibt, Blomster, et al., 2019).

[11]The analyses reported here are simplified models that report only the main effects. In addition, we also ran more complex models accounting for video (video1: Thai Medicine, −0.5 vs. video2: Thai Altruism, 0.5), order KM (Kama Muta video first −0.5 or second 0.5), order full (video block first −0.5, second 0 or third 0.5), country (Portugal, −0.5 vs. Norway, 0.5; if applicable) as factors and all interactions with level of kama muta. To account for the time course of the experiment, we added group-centered time (centered on video and level of KM) as a covariate and also its interaction with kama muta level. For the cardiac measures we repeated all models including country and video. All models provided results similar to the “main effects” reported here in the main text. Although we observed significant interaction effects for specific moderators in various models, we did not find any systematic results for the additional predictors. The results of these more complex model can be found in the Supporting Information (Tables S3 and S4; Figure S6).

3.3.1 | Cardiovascular activity

Contrary to Hypothesis 1, we found no evidence of increased heart rate during high kama muta segments. Instead, we found a significant main effect pointing at a decrease ($M = -0.16$, $SE = 0.05$) during high kama muta segments compared to low kama muta segments ($M = 0.16$, $SE = 0.05$).

Similarly, we did not observe an increase in HRV during high kama muta segments, failing to support Hypothesis 1. The time domain measure of RMSSD did not elicit a significant difference between low ($M = 0.02$, $SE = 0.05$) and high segments ($M = -0.02$, $SE = 0.05$). In addition, we found a lower HF-HRV for the high kama muta segments ($M = -0.16$, $SE = 0.06$) compared to the low kama muta segments ($M = 0.16$, $SE = 0.07$). Notably, this effect was moderated by country and stronger in the Norwegian sample ($d = 0.38$) than in the Portuguese sample ($d = 0.15$; see Table S3).

Our Hypothesis 1 was not confirmed. Our results on heart rate differ from several previous studies that observed an increase in HR (e.g., Wassiliwizky, Jacobsen, et al., 2017; Wassiliwizky, Koelsch, et al., 2017) during similar experiences. The lack of consistent effects for HRV is in line with previous studies (e.g., Shiota et al., 2011). Based on our evidence here, we cannot draw any systematic conclusions whether kama muta experiences increase or decrease HRV.

3.3.2 | Respiratory activity

High segments of kama muta videos were associated with higher RD ($M = 0.01$, $SE = 0.02$) than low segments ($M = -0.01$, $SE = 0.02$), but this effect was small ($d = 0.02$) and not statistically significant, thereby not supporting Hypothesis 1. Similarly, findings with regard to RR did not support Hypothesis 1. While we expected no differences, we found that low kama muta segments showed higher RR ($M = 0.17$, $SE = 0.03$) than high kama muta segments ($M = -0.17$, $SE = 0.02$). A similar pattern was found in some previous studies (e.g., Benedek & Kaernbach, 2011; Mori & Iwanaga, 2017), but not in others (Wassiliwizky, Jacobsen, et al., 2017) which actually reported the opposite, an increase in RR.

The present findings partly support the notion that strong experiences of kama muta induce more *deep* breathing, which might be influenced by the fact that individuals de-accelerate their breathing rate or hold their breath (Fiske et al., 2019).

3.3.3 | Electrodermal activity

Supporting Hypothesis 1, high kama muta segments showed a higher number of relative nSCRs ($M = 0.04$,

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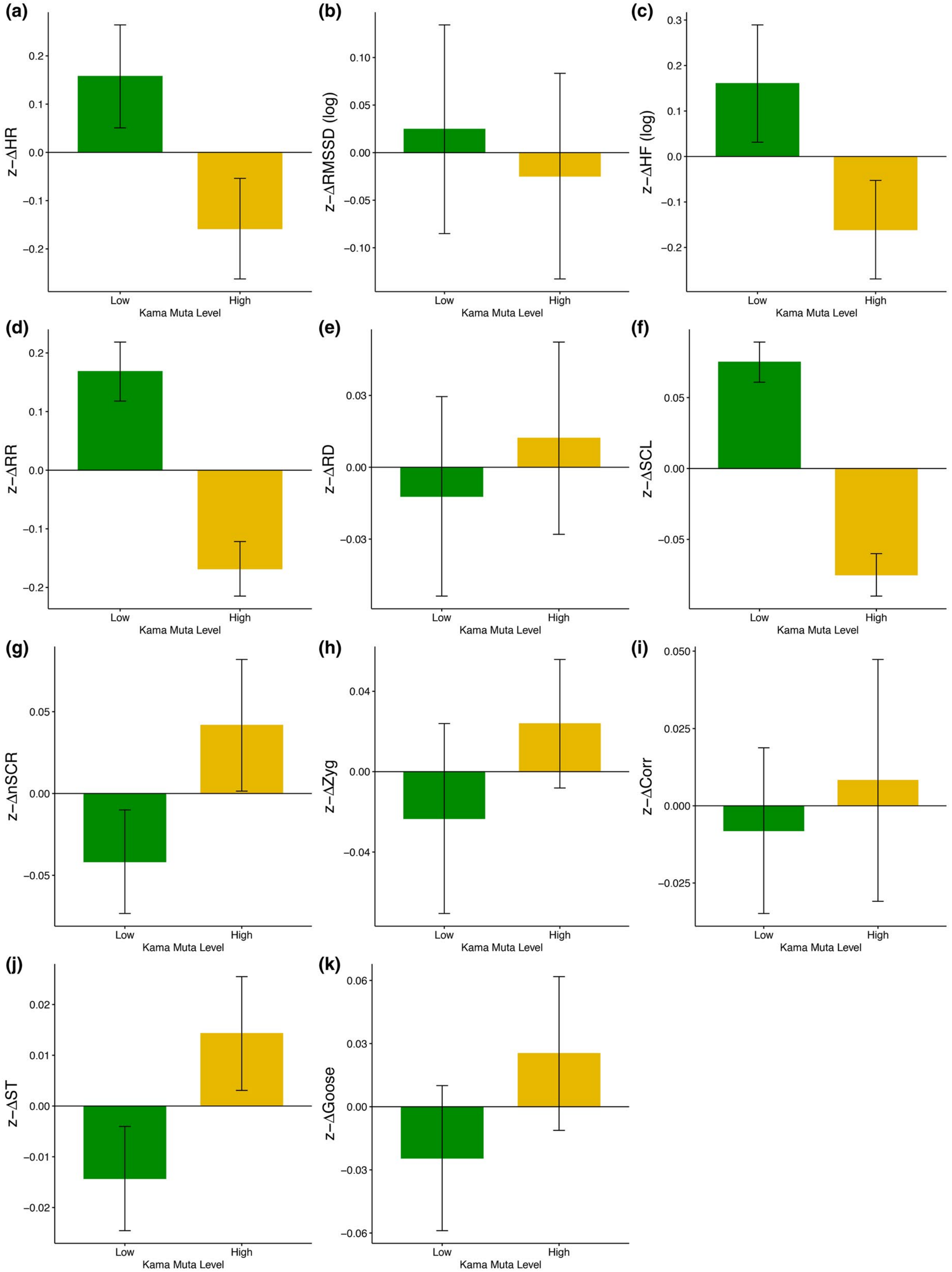

FIGURE 1 Standardized scores (difference from baseline) for each physiological recording for low and high kama muta segments. Scores are unadjusted for time or other factors. Errors bars correspond to within standard errors calculated based on Morey (2008). (a) HR, heart rate; (b) RMSSD, root mean square of successive differences (log); (c) HF, high frequency heart rate variability (log); (d) RR, respiration rate; (e) RD, respiratory depth; (f) SCL, skin conductance level; (g) nSCR, non-specific skin conductance responses; (h) Zyg, zygomaticus major; (i) Corr, corrugator supercilii; (j) ST, skin temperature; (k) Goose, goosebump activity

TABLE 4 Separate multilevel models for the physiological recordings depending on kama muta level (high vs. low)

Measure	*B*	95% CI		*t*	*df*	*p*	*d*
HR							
Intercept	0.16	0.02	0.30	2.21	207	.028	
KM	−0.32	−0.44	−0.19	−5.10	418	<.001	−0.32
RMSSD (log)							
Intercept	0.02	−0.12	0.17	0.34	212	.731	
KM	−0.05	−0.18	0.08	−0.79	418	.432	−0.05
HF-HRV (log)							
Intercept	0.16	0.03	0.29	2.38	247	.018	
KM	−0.32	−0.46	−0.18	−4.56	418	<.001	−0.32
RR							
Intercept	0.17	−0.06	0.39	1.48	39	.148	
KM	−0.34	−0.39	−0.29	−13.54	3,194	<.001	−0.34
RD							
Intercept	−0.01	−0.27	0.25	−0.1	39	.920	
KM	0.02	−0.02	0.07	1.16	3,194	.247	0.02
SCL							
Intercept	0.07	−0.08	0.23	0.95	137	.344	
KM	−0.15	−0.16	−0.14	−20.07	11,330	<.001	−0.15
nSCR							
Intercept	−0.04	−0.07	−0.01	−2.71	331	.007	
KM	0.08	0.05	0.12	4.49	11,330	<.001	0.08
Zyg							
Intercept	−0.02	−0.12	0.07	−0.48	98	.632	
KM	0.04	0.002	0.08	2.04	7,399	.042	0.04
Corr							
Intercept	−0.008	−0.15	0.13	−0.11	93	.910	
KM	0.01	−0.02	0.05	0.67	7,473	.506	0.01
ST							
Intercept	−0.01	−0.32	0.31	−0.04	38	.967	
KM	0.03	0.02	0.04	5.18	3,192	<.001	0.03
GB							
Intercept	−0.02	−0.36	0.31	−0.15	28	.886	
KM	0.06	0.03	0.1	3.49	2,364	<.001	0.06

Abbreviations: Corr = corrugator; GB = goosebumps; HF-HRV = high-frequency heart rate variability; HR, heart rate; KM = Kama Muta level (−0.5 low, 0.5 high); nSCR = non-specific skin conductance response; RD = respiration depth; RMSSD = root mean square of the successive differences;RR = respiration rate; SCL = skin conductance level; ST = skin temperature; Zyg = Zygomaticus.

SE = 0.02) than segments evoking low kama muta (*M* = −0.04, *SE* = 0.02). Importantly, we focused on the overall rate of responses, not on the intensity as previous studies. This is in line with the prediction that kama muta experiences comprise sudden, phasic changes in arousal. However, replicating Benedek and Kaernbach (2011), we did not find an increase in the average tonic level for high kama muta segments. Instead, it was even lower (*M* = −0.08, *SE* = 0.008) than during the low kama muta segments (*M* = 0.08, *SE* = 0.007).

This partly supports Hypothesis 1, as we expected no difference in SCL between the conditions. Thus, the present and previous findings point at possible abrupt fluctuations in arousal that do not increase the level on average, possibly due to top-down regulations (Nagai, Critchley, Featherstone, Trimble, & Dolan, 2004).

3.3.4 | Facial muscle activity

Supporting Hypothesis 2, we observed that strong kama muta segments were associated with higher zygomaticus activity ($M = 0.02$, $SE = 0.02$) than low kama muta segments ($M = -0.02$, $SE = 0.02$; replicating Wassiliwizky, Koelsch, et al., 2017). Interestingly, the more detailed analyses revealed that this effect was only observed for one of the two kama muta videos ("Thai Medicine," see Supporting Information). Furthermore, we found no evidence for significantly increased corrugator activity for strong kama muta segments ($M = 0.008$, $SE = 0.02$) compared to low segments ($M = -0.008$, $SE = 0.01$).

Activation of zygomaticus major has been generally associated with positive affect (e.g., Larsen, Norris, & Cacioppo, 2003), and we confirm that it can be increased during kama muta, but it may not universal. Activation of the corrugator is associated with negative affect or mental effort, and we do not find here that it is related to kama muta. This contradicts the studies by Wassiliwizky, Koelsch, et al. (2017) and Kimura et al. (2019), but is in line with Hypothesis 2 and also previous findings based on self-report.

3.3.5 | Skin temperature

Supporting Hypothesis 3, we found some evidence that strong kama muta segments featured slightly higher ST ($M = 0.014$, $SE = 0.006$) than low kama muta segments ($M = -0.014$, $SE = 0.005$; $d = 0.03$; temperature difference of 0.02°C). This replicated previous findings from a pilot study observing a comparable difference (see Supporting Information).

The association between aspects of kama muta and feelings of warmth, especially in the chest, has been most consistent across self-report studies (Seibt et al., 2018; Zickfeld, Schubert, Seibt, Blomster, et al., 2019).

3.3.6 | Goosebumps

Finally, using an objective measure of goosebumps, the *goosecam*, we observed significantly higher piloerection during the high kama muta segments ($M = 0.03$, $SE = 0.02$) in contrast to the low kama muta segments ($M = -0.03$, $SE = 0.02$). This corroborates previous self-report evidence that kama muta (if intense) is accompanied by piloerection. Notably, the occurrence of observable goosebumps was also rather low (2.6%) and not comparable to previous frequencies (about 50%; Benedek & Kaernbach, 2011; Wassiliwizky, Jacobsen, et al., 2017; Wassiliwizky, Koelsch, et al., 2017; see the Limitations section for an in-depth discussion).

3.4 | Comparing physiological differences between emotion conditions

In addition, we compared physiological mean responses across the three emotion conditions. We employed multilevel models with the *z*-scored physiological measures as the dependent variable and emotion type (Dummy coded with kama muta as the reference group) as a factor.[12] Units of analysis are individual seconds. Intercepts varied randomly for participant. An overview is provided in Figure 2 and Table 5.

3.4.1 | Cardiovascular activity

For HR, we found a main effect for emotion type, which was driven by the difference between kama muta and sad videos (Table 5). The kama muta videos elicited slightly more HR activity ($M = 0.02$, $SE = 0.06$) than sad videos did ($M = -0.14$, $SE = 0.05$), and lower HR than awe videos ($M = 0.12$, $SE = 0.06$). However, HR during the kama muta videos only differed significantly from the sad, and not from the awe videos, thereby supporting both Hypothesis 4 and Hypothesis 5.

For HRV we expected kama muta videos to induce more HRV than sad videos, while they should not differ from awe videos. Contrary to these Hypothesis 4 and Hypothesis 5, we observed no significant main effects of emotion type for RMSSD (Table 5). Descriptively, kama muta videos elicited the highest RMSSD response ($M = 0.05$, $SE = 0.05$), higher than both the sad ($M = 0.03$, $SE = 0.05$) and awe videos ($M = -0.08$, $SE = 0.05$). However, we found no significant effects for the two contrasts.

Similarly, we found no significant main effect for the HF-HRV measure (see Table 5). Measures were again highest during exposure to the kama muta videos ($M = 0.09$, $SE = 0.06$), compared to the awe ($M = -0.06$, $SE = 0.05$) and sad videos ($M = -0.03$, $SE = 0.04$). Kama muta was significantly different from awe but not from sadness. The

[12]As before, we also ran more complex models that are documented only in the Supplementary Material to ease interpretation of the main text. In a first model we also included video (−0.5 first, 0.5 s), country (if applicable; −0.5 Portugal, 0.5 Norway), and order (−0.5 first, 0 s, 0.5 third) as predictors. We also included the interaction between emotion type and order in all these models. In addition, we added time in seconds centered per individual video as a covariate and its interaction with emotion type. In the cardiac models, we added country as a factor and its interaction with emotion type. We observed similar main effects as reported in the main text when controlling for these additional predictors. While we observed several significant interactions effects, we did not find any systematic effects of these additional predictors and therefore excluded them for the sake of parsimony in the main manuscript. Results are presented in the Supporting Information (Tables S6 and S7; Figure S7).

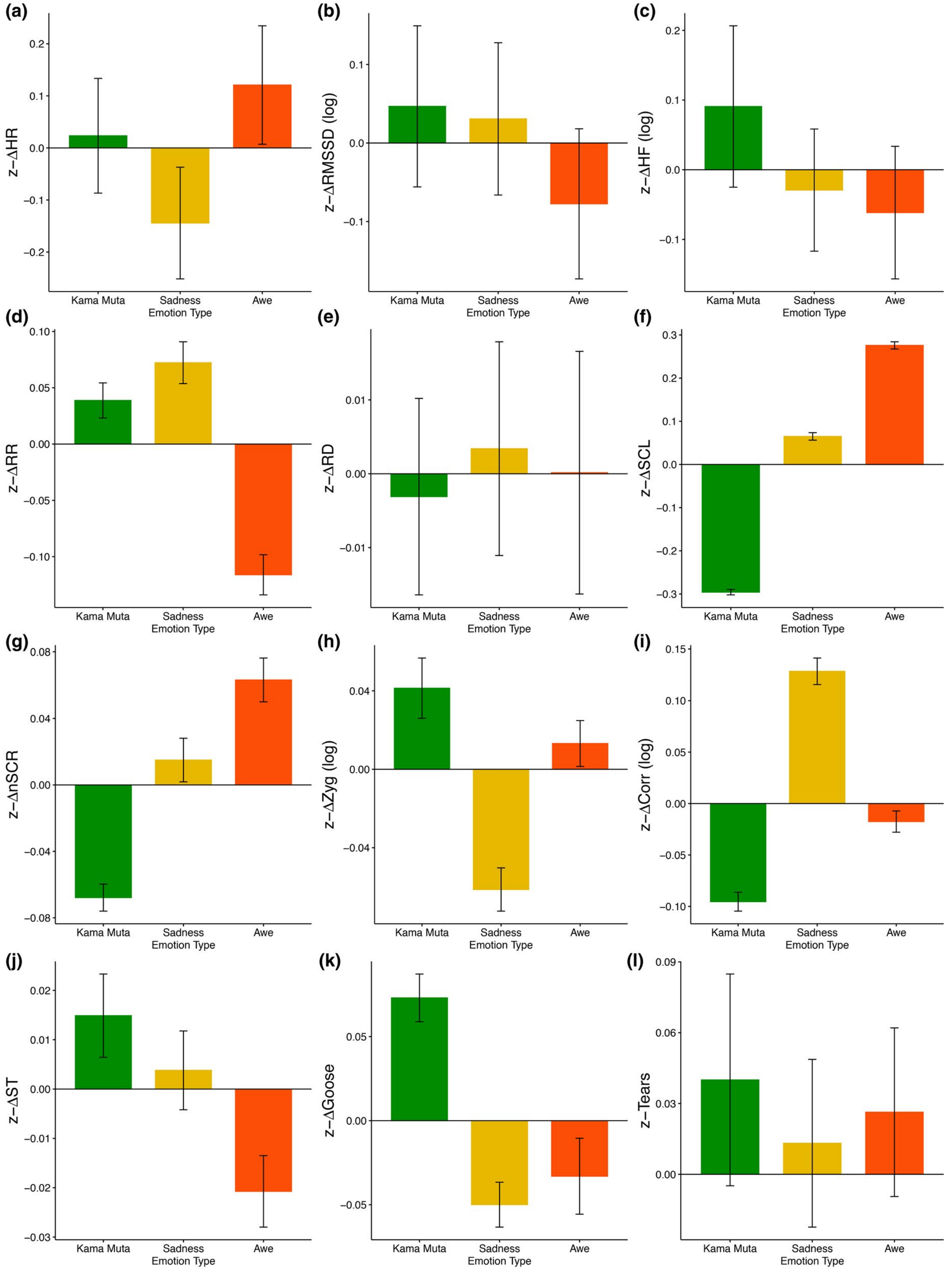

FIGURE 2 Standardized scores (differences from baseline) for each physiological recording for the three emotion conditions: kama muta versus sadness versus awe. Scores are unadjusted for time or other factors. Errors bars correspond to within standard errors calculated based on Morey (2008). (a) HR, heart rate; (b) RMSSD, root mean square of successive differences (log); (c) HF, high-frequency heart rate variability (log); (d) RR, respiration rate; (e) RD, respiratory depth; (f) SCL, skin conductance level; (g) nSCR, non-specific skin conductance responses; (h) Zyg, zygomaticus major; (i) Corr, corrugator supercilii; (j) ST, skin temperature; (k) Goose, goosebump activity; (l) Tears, Tearcam codings (no difference score)

TABLE 5 Separate multilevel models for the different physiological recordings depending on emotion condition

Measure	*B*	95% CI		*t*	*df*	*p*	*d*
HR							
Intercept	0.02	−0.14	0.19	0.28	250	.783	
Emotion type: sadness	−0.17	−0.32	−0.01	−2.12	274	.035	−0.17
Emotion type: awe	0.10	−0.06	0.25	1.23	274	.218	0.10
RMSSD (log)							
Intercept	0.05	−0.12	0.21	0.55	220	.584	
Emotion type: sadness	−0.02	−0.15	0.12	−0.23	274	.821	−0.02
Emotion type: awe	−0.12	−0.26	0.01	−1.76	274	.079	−0.12
HF-HRV (log)							
Intercept	0.09	−0.08	0.26	1.07	224	.288	
Emotion type: sadness	−0.12	−0.26	0.02	−1.67	274	.095	−0.12
Emotion type: awe	−0.15	−0.29	−0.01	−2.12	274	.035	−0.15
Stress index							
Intercept	−0.12	−0.29	0.05	−1.41	233	.159	
Emotion type: sadness	0.16	0.01	0.30	2.10	274	.037	0.16
Emotion type: awe	0.20	0.06	0.35	2.74	274	.007	0.20
RR							
Intercept	0.04	−0.16	0.23	0.38	38	.706	
Emotion type: sadness	0.04	0.02	0.06	3.57	36,920	<.001	0.08
Emotion type: awe	−0.15	−0.17	−0.13	−15.26	36,920	<.001	−0.34
RD							
Intercept	−0.00	−0.24	0.23	−0.03	38	.980	
Emotion type: sadness	0.01	−0.01	0.02	0.71	36,920	.473	0.01
Emotion type: awe	0.00	−0.01	0.02	0.39	36,920	.705	0.01
SCL							
Intercept	−0.30	−0.42	−0.18	−4.95	136	<.001	
Emotion type: sadness	0.36	0.35	0.37	80.62	130,600	<.001	0.87
Emotion type: awe	0.57	0.56	0.58	127.60	130,600	<.001	1.63
nSCR							
Intercept	−0.07	−0.08	−0.05	−8.49	215	<.001	
Emotion type: sadness	0.08	0.07	0.10	12.43	130,600	<.001	0.18
Emotion type: awe	0.13	0.12	0.14	19.68	130,600	<.001	0.29
Zyg							
Intercept	0.04	−0.04	0.12	0.46	91	.326	
Emotion type: sadness	−0.10	−0.12	−0.09	−13.35	85,030	<.001	−0.23
Emotion type: awe	−0.03	−0.04	−0.01	−8.09	85,030	<.001	−0.06
Corr							
Intercept	−0.10	−0.23	0.04	−1.45	90	.151	
Emotion type: sadness	0.22	0.21	0.24	35.67	86,020	<.001	0.51
Emotion type: awe	0.08	0.07	0.09	12.42	86,020	<.001	0.17
ST							
Intercept	0.02	−0.28	0.32	0.14	38	.890	
Emotion type: sadness	−0.02	−0.03	−0.01	−3.69	36,920	<.001	−0.04
Emotion type: awe	−0.04	−0.05	−0.03	−8.89	36,920	<.001	−0.09

(Continues)

TABLE 5 (Continued)

Measure	*B*	95% CI		*t*	*df*	*p*	*d*
GB							
Intercept	0.08	−0.19	0.35	0.58	29	.565	
Emotion type: sadness	−0.12	−0.14	−0.10	−12.43	27,340	<.001	−0.27
Emotion type: awe	−0.11	−0.13	−0.09	−10.71	27,330	<.001	−0.24

Abbrevaitions: Corr = Corrugator; HF-HRV = High-Frequency Heart Rate Variability; HR, heart rate; GB = Goosebumps; nSCR = non-specific Skin Conductance Response; RMSSD = Root Mean Square of the Successive Differences; SCL = Skin Conductance Level; ST = Skin Temperature; RR = Respiration Rate; RD = Respiration Depth; Zyg = Zygomaticus; Emotion type (Dummy coded; reference group: kama muta; contrast 1: kama muta = 0, sadness = 1; contrast 2: kama muta = 0, awe = 1).

general pattern of these findings was similar to the RMSSD measure. Therefore, we failed to find support for Hypothesis 4 and Hypothesis 5. Although kama muta videos induced the strongest HRV, they did not differ significantly from the sad videos, contrary to prediction.

Exploratorily, we tested Baevsky's *stress index* (Baevsky & Berseneva, 1997; Baevsky, Kirillov, & Kletskin, 1984) using the square root of this index as calculated by Kubios software (Tarvainen et al., 2018), and found a significant main effect for emotion type (Table 5). We recorded the lowest stress response during kama muta videos ($M = -0.06$, $SE = 0.10$) followed by sadness ($M = 0.08$, $SE = 0.10$) and awe ($M = 0.09$, $SE = 0.10$). The stress responses to kama muta videos differed significantly from the stress responses to the awe and sad videos.

The possibility that kama muta might reduce stress has not received any theoretical or empirical attention. Future studies should explore the possibility of kama muta being able to decrease stress and if so, by what mechanism. Past studies have found evidence that kama muta increases social connectedness to other individuals, which could be an important mechanism (Blomster Lyshol et al., 2020; Zickfeld, 2015; Zickfeld, Schubert, Seibt, Blomster, et al., 2019).

3.4.2 | Respiratory activity

Considering RR, we observed a significant main effect of emotion type (see Table 5). In comparison to the kama muta videos ($M = 0.04$, $SE = 0.008$), RR was significantly lower for awe videos ($M = -0.12$, $SE = 0.01$) but significantly higher for sad videos ($M = 0.07$, $SE = 0.01$). This finding failed to support Hypothesis 4 and Hypothesis 5, as we expected the exact opposite pattern with the sad videos showing lower and the awe videos higher RR compared to kama muta, as observed in previous studies (e.g., Kreibig, Wilhelm, Roth, & Gross, 2007; Shiota et al., 2011).

Supporting Hypothesis 4 and Hypothesis 5, we found no significant main effect of emotion type for RD (see Table 5). Kama muta videos evoked the lowest RD ($M = -0.003$, $SE = 0.007$) followed by awe ($M = 0.0001$, $SE = 0.008$) and sadness videos ($M = 0.003$, $SE = 0.007$), though none of these comparisons showed significant differences as predicted.

3.4.3 | Electrodermal activity

For SCL we found a significant main effect for emotion type (see Table 5). Kama muta videos elicited on average the lowest SCL ($M = -0.30$, $SE = 0.003$). SCL responses were significantly stronger for sad ($M = 0.06$, $SE = 0.004$) and awe videos ($M = 0.28$, $SE = 0.004$). These findings support the prediction that awe induces on average higher sympathetic activation (Hypothesis 5), but fail to support Hypothesis 4, the idea that kama muta features stronger overall activation than sadness.

Focusing on the rate of the nSCRs, we also found a main effect for emotion type (see Table 5). Again, the kama muta videos elicited the lowest occurrence of nSCRs ($M = -0.07$, $SE = 0.004$), while the rate of these responses was significantly higher during exposure to the sad ($M = 0.01$, $SE = 0.007$) and awe videos ($M = 0.06$, $SE = 0.007$). Findings for nSCRs fit the pattern of SCL in the present study, but fail to support Hypothesis 4 and Hypothesis 5 that expected similar phasic activation across all video types.

3.4.4 | Facial muscle activity

Focusing on zygomaticus activity, we again observed a main effect of emotion type (see Table 5). Kama muta videos evoked the strongest activity ($M = 0.04$, $SE = 0.008$), which were significantly stronger than activity for the awe ($M = 0.01$, $SE = 0.006$) and sad videos ($M = -0.06$, $SE = 0.006$).

These findings support Hypothesis 4 and previous self-report studies, predicting that kama muta is experienced as more positive than sadness. However, they fail to support the idea that kama muta and awe do not differ qualitatively on the amount of associated positivity. While both emotions have been considered as *positive* emotions (Keltner & Haidt, 2003; Zickfeld, Schubert, Seibt, Blomster, et al., 2019), it is possible that in the current study we also included stimuli that induce threat-based variants of awe, which have been argued to be experienced as less positive (Gordon et al., 2017).

For the corrugator, we also found a main effect of emotion type (see Table 5). Participants showed the lowest corrugator activity for kama muta videos ($M = -0.10$, $SE = 0.005$). Activity was significantly stronger for the awe ($M = -0.02$, $SE = 0.005$) and sad videos ($M = 0.13$, $SE = 0.007$).

Again, these findings support Hypothesis 4. Similarly, previous self-report evidence found that sadness was experienced as more negative than kama muta (Zickfeld, Schubert, Seibt, Blomster, et al., 2019). As for zygomaticus activity, we found significant differences between kama muta and awe, failing to support Hypothesis 5.

3.4.5 | Skin temperature

Testing ST, we found a significant main effect for emotion type (see Table 5). The kama muta videos elicited the strongest response ($M = 0.01$, $SE = 0.004$), while the ST was significantly lower for the sad ($M = 0.004$, $SE = 0.004$) and awe videos ($M = -0.02$, $SE = 0.004$), supporting both Hypothesis 4 and Hypothesis 5.

3.4.6 | Goosebumps

Regarding goosebumps activity, we also observed a main effect for emotion type (see Table 5). Importantly, this finding supports Hypothesis 4, predicting that kama muta videos induce stronger piloerection activity ($M = 0.07$, $SE = 0.007$) than sad videos ($M = -0.05$, $SE = 0.007$). However, contrary to our predictions in Hypothesis 5, we found that kama muta videos induced significantly stronger piloerection activity than awe ($M = -0.03$, $SE = 0.01$). Our findings resonate with a recent study failing to provide evidence that objective piloerection is a reliable indicator of awe (McPhetres & Shtulman, 2019).

3.4.7 | Lachrymation

For lachrymation, we did not code baseline videos. Therefore, the present scores do not reflect difference scores. In total, 36 participants were coded, as it was not possible to identify the LED marker for two videos and one video was corrupted during the encoding process. The occurrence of visible lachrymation was very low. Only 2.3% of total cases (6 video segments) showed moist eyes in the video. There was no indication of a full crying response in any of the participants. We observed a significant positive association between the coding and the self-report ratings for tears, $\beta = .20$, $B = 0.02$ [0.005, 0.04], $t(183) = 2.64$, $p = .009$. However, we did not find any indication of a significant difference across the three emotion types, $F(2,187) = 0.59$, $p = .558$. In line with Hypothesis 4, the occurrence of lachrymation for kama muta videos ($M = 0.04$, $SE = 0.02$) did not differ significantly from responses to sad videos ($M = -0.01$, $SE = 0.02$, $d = 0.17$). Contrary to Hypothesis 5, kama muta videos did also not differ significantly from responses to awe videos ($M = 0.03$, $SE = 0.02$, $d = 0.08$).

The amount of overall detected visual tears was very low (below 10%). One reason may have been a suboptimal position of the camera, which did not capture optimally the inner eye corner where tears often form. Future studies should try to pinpoint whether kama muta typically evokes tears by employing different methods (e.g., thermography; Ioannou et al., 2016).

4 | GENERAL DISCUSSION

Across two different populations using a total of 144 Norwegian and Portuguese participants, we explored psychophysiological changes of experiences of kama muta. We assessed cardiovascular changes including HR and HRV, respiratory activity including RR and RD, changes in the EDA including phasic and tonic skin conductance, contraction of facial muscles including zygomaticus major and corrugator supercilii, skin temperature on the chest, piloerection, and also visible lachrymation. Our findings corroborate previous self-report findings to some extent and partly replicated previous studies eliciting comparable affective states (e.g., Benedek & Kaernbach, 2011; Kimura et al., 2019; Mori & Iwanaga, 2017; Wassiliwizky, Jacobsen, et al., 2017; Wassiliwizky, Koelsch, et al., 2017), while we added physiological measures that have not yet been used to assess kama muta, including measures of lachrymation and HRV.

4.1 | The physiological profile of Kama Muta

Based on the current and previous findings, it seems that even strong reactions of kama muta are associated with only mild to moderate arousal (see also Bartsch, Kalch, & Oliver, 2014; Menninghaus et al., 2015). We observed reduced activity for strong kama muta segments in HR, SCL, and RR, typically thought to represent indicators of sympathetic activity. Importantly, we did not observe direct evidence of PNS activity by increased HRV. In addition, nSCRs were stronger for high segments of kama muta. Therefore, it seems that the physiological profile of kama muta features phasic activation during tonic parasympathetic calming. Together, these

ANS features suggest that kama muta involves the parasympathetic nervous system (PNS) to a higher degree than the sympathetic nervous system (SNS), a result that has been observed in previous studies exploring crying, which is a common response of kama muta (Hendriks et al., 2007; Ioannou et al., 2016). The pattern of phasic sympathetic activation could be attributed to the occurrence of piloerection, which also represents a common response of kama muta (Keltner & Haidt, 2003; Sumpf et al., 2015).

Considering valence, previous self-report studies have reported a consistent link between different aspects of kama muta and positivity, but not negativity (Seibt et al., 2018; Zickfeld, Schubert, Seibt, Blomster, et al., 2019). We corroborated such findings in the present study. Notably, Wassiliwizky, Jacobsen and colleagues (2017) studied responses to segments evoking strong self-reports of tears and actual goosebumps. Although self-reports for the present study also indicate some strong responses, only a minority of participants actually experienced strong responses of piloerection and lachrymation for strong kama muta experiences (see also the Limitations for a more in-depth discussion). Thus, it is possible that a full-blown response of weeping and goosebumps involves more corrugator activity than observed in the current experiment.

In the current study, we also investigated the occurrence of weeping, goosebumps, and objective changes in skin temperature in response to kama muta. The occurrence of goosebumps for strong reactions of kama muta poses implications for theories focused on why goosebumps (or chills) are experienced. On the one hand, the *separation-call* hypothesis (Benedek & Kaernbach, 2011; Panksepp, 1995) argues that piloerection or chills occur in response to sadness and coldness. On the other hand, the *peak arousal* hypothesis (Laeng et al., 2016; Salimpoor et al., 2009) emphasizes that high levels of arousal result in the occurrence of goosebumps or chills. The present findings do not provide strong evidence for either of these hypotheses. Goosebumps responses were lowest for the sad videos, providing evidence against the separation-call hypothesis, while kama muta videos included the strongest goosebumps activity, but only moderate physiological arousal contradicting the peak arousal view. Although phasic skin conductance responses were higher for strong reactions of kama muta, the strongest arousal (as indicated by HR, SCL, and nSCR) was observed for the awe videos that featured a lower occurrence of piloerection. We assume that piloerection in response to kama muta reflects a social signal and represents a motivation to approach others (Maruskin et al., 2012; Zickfeld, Schubert, Seibt, Blomster, et al., 2019). Maruskin and colleagues provided some first evidence for this notion, showing that a specific form of chills, so-called *goosetingles*, is related to approach motivations (see also Bannister, 2019).

Similarly, we observed that strong experiences of kama muta increased skin temperature on the middle of the chest (also in comparison to awe and sadness videos). Notably, the observed effect size was small. It has been discussed whether such a change is actually reflected in objective changes in temperature or rather refers to metaphorical embodiment of communality and *warmth* (IJzerman et al., 2015; Zickfeld, Schubert, Seibt, Blomster, et al., 2019). The present study seems to provide some support for the actual occurrence of ST changes. This conclusion should be made with caution as two main questions arise: first, what exact system or process would cause such a temperature difference; and second, would such a minimal difference as observed in the present study be consciously detectable as reported by a number of individuals (also in the present study).

Regarding the first point, Haidt (2003) attributed increased feelings of warmth to heightened activity of the vagus nerve, which controls parasympathetic activity. High vagus nerve activity has been found to decrease heart rate (Koizumi, Terui, & Kollai, 1985), which would fit the pattern of decreased heart rate in the current experiment. Another possible process could involve the occurrence of brown adipose tissue (BAT). BAT is primarily controlling non-shivering thermogenesis and has been located in the upper chest in adult humans (Nedergaard, Bengtsson, & Cannon, 2007). BAT is controlled by the sympathetic nervous system (Trayhurn & Ashwell, 1987), which would fit the present patterns to a lesser degree. Importantly, no systematic studies have investigated the function of BAT with regard to emotional states. Thus, this theorizing is rather speculative at the moment.

Regarding the second point, research targeting thermal sensitivity has indicated that it is possible to detect temperature differences as low as 0.02°C (Darian-Smith & Johnson, 1977). However, such experiments typically involve changes at the palmar surface and are moderated by a number of factors such as duration or suddenness of the stimulus. At the moment, it seems unlikely that such minimal bodily changes are reflected in rather strong subjective reports (e.g., Zickfeld, 2015). Future studies should use more systematic methods to disentangle the actual bodily processes. For example, studies including thermography could not only resolve the question of whether actual temperature changes occur, but also test the involvement of BAT. In addition, thermal infrared imaging has been previously used in experiments studying tears (Ioannou et al., 2016).

4.2 | Distinguishing Kama Muta from other emotional states

In the present experiment, we also compared two supposedly distinct emotional responses from kama muta: *sadness* and *awe*. It has been argued that kama muta episodes often occur against a backdrop of negativity, probably involving feelings of sadness (Cova & Deonna, 2014; Fiske et al., 2019). Still, such feelings are thought to be distinct, while also potent to evoke tears. Research has associated sadness with a passive withdrawal response, including decreased HR, RR, SCL, nSCRs, and increase in tidal volume (Kreibig et al., 2007). Awe has been attributed to experiences of vastness and need for accommodation (Keltner & Haidt, 2003). One of the few physiological experiments inducing awe found a low frequency of SCRs, suggesting a decrease in sympathetic activity, but also increased RR, which usually indicates higher sympathetic activity (Shiota et al., 2011).

For the sad videos, we replicated a deaccelerated HR and low to medium electrodermal activity compared to the other emotions. However, we also found the highest level of RR for these videos, which is at odds with some previous studies (Kreibig et al., 2007). As predicted, sadness involved the most corrugator activity and the lowest zygomaticus activity of all three emotion types, providing evidence for a distinction between *positive* and *negative* emotional states.

Regarding the awe videos, we found that they elicited a high degree of sympathetic activation, including increased cardiovascular and electrodermal activity. HR, SCL, and nSCR were strongest for the awe videos, in contrast to previous findings (Shiota et al., 2011). At the same time, the awe videos elicited a certain degree of parasympathetic activation, including the lowest RR among the three emotions. Awe videos were also perceived as less positive than kama muta videos, reflected in the lower zygomaticus and higher corrugator activity. Conversely, the kama muta videos showed the lowest activation for electrodermal activity, mid-activation of the cardiovascular and the respiratory system. Thus, it seems that the kama muta videos featured the exact opposite pattern of physiological responses from awe and included more distinct profiles than predicted. Notably, kama muta included a stronger amount of goosebumps and zygomaticus activity than the awe videos. Additionally, kama muta videos featured higher skin temperature than awe and sadness, replicating previous self-report evidence (Zickfeld, Schubert, Seibt, Blomster, et al., 2019).

Our findings indicate that the pattern of physiological responses for kama muta episodes is distinguishable from that for related emotions, such as sadness episodes and awe episodes. The general physiological pattern of kama muta seems to involve an interaction of parasympathetic and sympathetic activation, with an indication of more activation by the parasympathetic nervous system. These findings fit previous research on the physiological responses to chills (Mori & Iwanaga, 2017; Salimpoor et al., 2009, 2011) and tears (Hendriks et al., 2007; Rottenberg et al., 2003), which are often occurring for strong responses of kama muta. This general pattern of a co-activation of the parasympathetic and the sympathetic system was similar for the two comparison conditions, with sadness evoking more parasympathetic and awe more sympathetic activity. However, the concrete indicators showing these activations most pronouncedly differed for the three conditions.

4.3 | Limitations

The present experiment featured some limitations that should be considered. First, although we included a cross-cultural and well-powered sample in comparison to previous psychophysiological studies testing responses to kama muta inducing stimuli, we needed to exclude a certain number of responses and participants. While movement artefacts are hardly avoidable, we have not included respiration measures from the Portuguese sample due to a hardware issue. Nevertheless, our exclusions were not substantially large, and the final samples included a considerable number of participants.

Second, our rate of inducing (visible) goosebumps and observable weeping was considerably lower than in previous studies. Benedek and Kaernbach (2011) and Wassiliwizky, Jacobsen, et al. (2017) reported successful induction rates for goosebumps of around 40%–50%. There are two possible explanations for our low induction rate. We aimed at standardizing our experiment as much as possible by presenting participants always with the same stimuli. The previously mentioned studies actively requested participants to listen to or watch self-selected stimuli that are likely to induce piloerection. While self-report ratings of tears and goosebumps have been medium-to-strong for the chosen stimuli both in previous and the current study, we only observed a minimal number of actual occurrences. This suggests a low concordance among self-report and actual physiological responses (see Benedek & Kaernbach, 2011, for a similar conclusion). Such a low concordance may arise, for example, from people experiencing goosebumps on other parts of their skin, which we did not monitor (e.g., the neck or back). Through the lens of kama muta theory, we can think of another explanation. Kama muta is a highly social emotion, that typically (if not always) occurs in response to intensifications in communal sharing relationships (Fiske et al., 2019). Tears and goosebumps associated with kama muta might, therefore, be regarded as *social tears* (Zickfeld & Schubert, 2018) and *social goosebumps* (Schurtz et al., 2012), which more commonly occur in the (actual or imagined) presence of another social agent. Future studies could aim at measuring psychophysiological indicators in two individuals interacting and inducing kama muta in each other or observing a third party inducing kama muta in them to test this prediction.

Third, our second analysis strategy of comparing responses across whole stimulus videos contains the problem that participants only feel high degrees of the intended emotions within small parts of the video. However, even in short videos like the type we used, people can feel many different emotions in succession; in fact, many of these videos are produced for strong emotional effect rather than to target a single emotional response. For example, in the Thai medicine video, a sad middle part precedes the kama muta resolution to increase the emotional contrast. Such additional emotions can mask differences between emotional responses. Relatedly, two stimuli per emotion is a small sample. As is obvious from our supplementary analyses, video stimuli did not only differ between emotions, but also to a certain degree within the emotion category. It is, therefore, questionable how our findings generalize to other emotional stimuli. While such small samples are common in physiological studies, they risk producing response patterns that are more determined by the particular stimuli than by the emotion in general (e.g., Judd et al., 2012). This, and the fact that several of our findings did not confirm predictions, makes it important to replicate the present findings with a more varied stimulus set in the future. For instance, future studies could employ self-selected stimulus paradigms as in previous research (e.g., Mori & Iwanaga, 2017; Wassiliwizky, Jacobsen, et al., 2017), in which participant's high intensity self-selected stimuli are yoked to other participant's self-selected low intensity stimuli as a control condition. Importantly, while such designs could address the low occurrence of tears or goosebumps and introduce more variation in stimuli, our present design has the advantage of using the same standardized stimuli across participants. Therefore, it is important to consider these different designs in conjunction, in order to understand physiological changes with regard to kama muta or other emotional reactions.

Fourth, for the high versus low kama muta analyses, it has to be noted that the high kama muta segments always appeared later in the video than the low kama muta segments. Although we only observed a significant interaction effect between kama muta level and time of the video for two measures (RR and SCL), we cannot say definitively for these measures whether the observed effects are due to actual differences or a general decrease/increase of the measurement over time.

Finally, it should be noted that the Norwegian participants did not report stronger *awe* ratings for the awe videos in contrast to the other videos. There are a number of implications for these findings. First, the comparisons with the awe videos for the Norwegian participants should be interpreted with caution, as the self-report cannot confirm that they actually felt *awe* in response to them. Similarly, the question arises what *awe* constitutes in the first place. While the English vernacular term *awe* is commonly used by English speakers, its closest Norwegian translation *aerefrykt* sounds old-fashioned and is mostly used in religious situations, if at all. Possibly we were not assessing the concept of *awe* as delineated in Keltner and Haidt (2003), or such a concept is differently constructed in Norwegian language and society.

5 | CONCLUSION

Employing the kama muta framework, we have provided evidence that *being moved* experiences include a high degree of parasympathetic activation, as well as a smaller degree of sympathetic activity. Kama muta seems to be characterized by decreased cardiovascular and electrodermal activity, while increasing the tidal volume by slowing down respiration rate. In addition, this emotion is accompanied by increased zygomaticus activity reflecting its predominantly positive valence. We have also obtained some evidence that kama muta is characterized by experiencing goosebumps, possibly also tears, and increased skin temperature on the upper chest. Importantly, kama muta was successfully qualitatively differentiated from two distinct emotion categories: sadness and awe. These findings by and large confirm predictions derived from the kama muta model using objective psychophysiological indicators in a systematic fashion for the first time.

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AUTHOR CONTRIBUTIONS

All authors designed the experiment, J.H. Zickfeld, P. Arriaga, and S.V. Santos performed data collection, J.H. Zickfeld and P. Arriaga analyzed the data, J.H. Zickfeld wrote the first draft, and all authors revised the first and the final version.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.
Supplementary Material

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