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Towards a Better Understanding of Emotion Blends: The Case of Anger-Related Emotion Blends Elicited Via Film Clips

Abstract

We sought to better understand the effect of film clips supposed to elicit different intensities of anger on feelings and cardiac activity among our participants. In experiment 1, we tested in 21 volunteers the ability of two film clips to elicit two intensities of anger: a slight one and strong one. In experiment 2, we used the same film clips in order to investigate, in 36 volunteers, how cardiovascular patterns may differ between the emotional states we elicited. Results suggest that the film clips produced a physiological reappraisal pattern, with a lower heart rate and higher heart rate variability values (RMSSD and SD1) during exposure to film clips that were selected to elicit anger. Results of both experiments also suggest that film clips selected to elicit anger, not only triggered anger, but also other negative emotions. Consequently, we propose a method of assessing emotions which takes emotion blends into account.

Keywords: emotion; reappraisal; heart rate variability; film clips

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"There are more than a thousand definitions of what emotion is and the only point on which everyone agrees, is that the concept is hard… to define" (Belzung, 2007). According to Kleinginna and Kleinginna, (1981) who analyzed and classified 92 definitions of emotion, it can be argued that emotion consists of four main components: a) cognitive b) subjective c) physiological d) behavioral. Although different ordering of these components could be practically all the time defended, cognitive, subjective and physiological features appear to play an upstream role in emotion emergence (Niedenthal, Krauth-Gruber, & Ric, 2006, p. 10-11; Plutchik, 2001). The present research coupled subjective and cardiac measures in order to investigate these early processes. The aim was to answer the question of what is happening throughout the processing of emotional stimuli supposed to elicit anger with different intensities. Does physiology solely vary according to the intensity of the emotion felt, or physiological variations observed during emotion elicitation could reflect other processes (e.g., emotion regulation)? With the aim of addressing this issue, let us firstly discuss about emotion, especially how can it be assessed.

Subjective Emotional Assessment

Earliest studies in psychology generally used subjective data to assess individual emotional states. Different approaches to emotion have been conceptualized in order to categorize feelings. Some are based on the view that there is a finite number of emotions (Ekman, 1984, 1992; Izard, 1977). Others are based on multidimensional models in which emotion can be defined as a function of broader features (e.g., Russell, 1980; Watson & Tellegen, 1985, Fontaine, Scherer, Roesch, & Ellsworth, 2007). Both discrete and dimensional approaches to emotion are widely used by psychologists in experimental contexts (Scherer, 2005).

Alternatively, other models have emerged from cognitive appraisal approaches of emotion (e.g., Frijda, 1986; Schachter & Singer, 1962), which assume that there are cognitive

processes that evaluate the emotional event, understand what caused it and assess ways of coping with it. In other words, “appraisals are transformations of raw sensory input into psychological representations of emotional significance” (Clore & Ortony, 2000). Scherer (2005) created a tool for subjective emotional assessment, placing appraisal as a key feature of his model. This tool has a specific arrangement of 16 discrete emotions placed around a circle divided along two axes: valence (positive versus negative) along the horizontal line, and coping potential (control/power) along the vertical line. Thus, individuals can rate the intensity of their feelings on the basis of the distance from the hub of the wheel and the size of the circles. In this way, the intensity of emotion can be expressed as the degree to which individuals are affected by emotion (Scherer, Shuman, Fontaine, & Soriano, 2013). The present study is thus based on the appraisal approaches of emotion, especially Scherer's model (2005). However, besides subjective feelings, emotion also affects physiology.

Emotional Assessment through Cardiac Measures

In accordance with the neurovisceral integration model (Thayer & Lane, 2000; Thayer & Lane, 2009) there is some evidence supporting brain connections, implicated in affective processes like emotion regulation, and cardiac activity controlled by both the sympathetic and parasympathetic branches of the autonomic nervous system (ANS). According to Kreibig (2010), cardiac measurements, particularly heart rate (HR), defined as the number of contractions of the heart per minute, and heart rate variability (HRV) which refers to the variations between consecutive heartbeats are widely used to investigate the impact of emotion on ANS activity. While sympathetic activity tends to increase HR in a few seconds, parasympathetic activity tends to decrease HR and its response is faster (0.2-0.6 s) (Berntson et al., 1997).

Cardiac Measures as an Indicator of Anger

According to many authors, the ANS produces specific activations in response to specific emotions (Cacioppo, Klein, Berntson, & Hatfield, 1993; Levenson, Ekman, & Friesen, 1990; Stemmler, Aue, & Wacker, 2007). According to Kreibig's review, anger is one of the most widely investigated emotions. Several studies have revealed typical variations in metrics related to cardiac activity while experiencing emotions with high arousal such as anger. For instance, many authors have found a significant increase in HR due to anger elicitation (Fairclough & Spiridon, 2012; Fernández et al., 2012; Lobbestael, Arntz, & Wiers, 2008; Marci, Glick, Loh, & Dougherty, 2007).

Some studies have assessed HRV to explore emotion using *time-domain* methods. Among the most commonly used indexes suitable for short-term recordings, the root mean square of successive NN interval[1] differences (RMSSD) appears particularly relevant, notably indicating short-term variability in cardiac rhythm (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). Indeed, several studies have shown that the RMSSD value decreases when participants have to carry out an anger-related imagery task (Kreibig, 2010; Pauls & Stemmler, 2003). Consequently, lower RMSSD values are expected when anger is experienced in the current study.

Furthermore, the mediation of cardiac activity by complex control systems assumes that non-linear mechanisms are involved in cardiac rhythm variations (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). Among *non-linear* methods used to study HRV, the Poincaré plot is a popular tool because of the relative ease of interpreting one of the parameters. More specifically, the SD1 index, describes short-term variability in cardiac rhythm (Goshvarpour, Abbasi, &

[1] (i.e., the interval from one R peak to the subsequent R peak)

Goshvarpour, 2017; Tarvainen, 2014). Consequently, SD1 should vary similarly to RMSSD leading to lower values when an individual experiences anger.

Another interesting non-linear measure is related to entropy, which is used to quantify signal complexity and irregularity. Two entropy indexes can be calculated: Approximate entropy (ApEn) and sample entropy (SampEn). Low values for both indexes indicate greater signal regularity. However, SampEn index is more accurate than ApEn. Additionally it is preferred for short-term recordings (See Riganello, Cortese, Arcuri, Quintieri, & Dolce, 2015; Tarvainen, 2014; Valenza, Allegrini, Lanatà, & Scilingo, 2012 for further information about ApEn and SampEn). According to Valenza et al. (2012), entropy tends to decrease significantly during arousal. It is well known that anger is characterized by high arousal (see Russell, 1980). Consequently, lower values of SampEn are expected when anger is experienced.

Furthermore, cardiac measures do not only reflect a direct expression of anger. According to several authors, cardiac activity vary is affected by emotion regulation (León, Hernández, Rodríguez, & Vila, 2009; Porges, Doussard-Roosevelt, & Maiti, 1994).

Cardiac Measures as an Indicator of Cognitive Reappraisal

As briefly introduced previously, appraisal theories of emotion focus on immediate cognitive processes of evaluation of meaning, causal attribution and coping capabilities (Niedenthal et al., 2006, p. 13). Regarding the last point (i.e., coping capabilities), it suggests that a stimulus can be reappraised in order to regulate emotions felt by individuals and thus face a psychological stress. According to Gross (1998), emotion regulation depends on the individuals' ability to adjust physiological arousal on a momentary basis (see also Appelhans & Luecken, 2006). As a consequence, cognitive reappraisal could be identified through cardiac measures.

According to Wranik and Scherer (2010), anger often occurs when one's goals are obstructed. This highlights the importance of considering the cognitive appraisal step,

determining the impact of a specific event on an individual. For instance, Denson, Grisham, and Moulds (2011) asked three groups of participants to watch an anger-inducing video. In one group (control), participants just had to watch the video. In the second group (suppression), they had to try to control their facial expression and to behave in such a way that a person watching them would not know what they were feeling. In the last group (reappraisal), participants had to manage their emotional reactions; they were asked to try to maintain a neutral mood and not to be overwhelmed by the anger elicited by the video. The authors observed a significant increase in HRV (RMSSD) and decreased HR among participants in the reappraisal condition. Their results reflect a physiological correlate of adaptive emotion regulation. This physiological pattern is consistent with the notion of reappraisal as an active and adaptive means of cognitively changing our response to emotional situations. This process allows greater autonomic flexibility, and improves the ability to view anger-inducing events as non-threatening. The same kinds of pattern were observed when using pictures to induce a negative emotional state (Kuoppa, Tarvainen, Karhunen, & Narvainen, 2016; Sarlo, Palomba, Buodo, Minghetti, & Stegagno, 2005; Stemmler et al., 2007).

Furthermore, as links have been found between Poincaré's SD1 index and time-domain measures (i.e., RMSSD), higher values for SD1 can be expected when emotion-regulation strategies emerge. In addition, as parasympathetic activity is predominant when individuals reappraise emotional events (Denson et al., 2011) and entropy is higher when that branch of ANS is in control (Valenza et al., 2012), it can be assumed that SampEn values will be higher when individuals regulate their emotion.

Hence, a decrease in HR together with an increase in time and non-linear HRV indexes (RMSSD, SD1 and SampEn) could be expected when emotion-regulation strategies are implemented.

Existence of an Anger Intensity Threshold?

As previously seen, cardiac patterns may vary according to the way that individuals manage their emotions. Several studies investigating different intensities of the same negative emotion have effectively shown that emotion-regulation strategies could depend on the intensity of the elicited emotion (Luce, Payne, & Bettman, 1999; Yao & Lin, 2015). More precisely, Luce et al. (1999) found that high levels of negative emotion induce regulation strategies such as avoidance coping. This raises the question of whether the level of anger intensity produces a specific cardiac pattern, in other words an anger threshold pattern. Indeed, it could be expected that a cardiac pattern reflecting reappraisal strategies would only occur when a high intensity of anger is elicited. By contrast, a cardiac pattern reflecting direct processing of anger should emerge when a moderate intensity of anger is induced.

To our knowledge, no study has investigated different levels of anger using both HR and time and non-linear aspects of HRV. In order to see how emotional processing differs as a function of the intensity of the anger experienced, the present study combined subjective and physiological measurements to examine the specific cardiac patterns associated with different intensity levels of anger.

Emotion Elicitation

According to Baldaro et al. (2001), film clips are commonly used to induce emotions because of their high ecological validity and their ease of presentation. Several researchers have developed databases of film clips suitable for mood induction procedures (Gross & Levenson, 1995; Schaefer, Nils, Sanchez, & Philippot, 2010). Prior research used the most recent database to study emotion. For instance, Fernández et al. (2012) investigated the objective physiological responses (skin conductance level and heart rate) and subjective emotional responses elicited through a set of emotional film clips capable to induce anger, fear, sadness, disgust amusement tenderness and a neutral state. In the same vein, the Schaefer's database (2010) has been used

to compare different types of real-life emotional elicitations: film clips eliciting anger, fear or sadness and a hostile social interaction (Cabral, Tavares, Weydmann, das Neves, & de Almeida, 2018). However; no study focused on the ability for the film clips belonging to this database to elicit different intensities of a same emotion. Moreover, no study investigated the propensity for these film clips to elicit emotion blends. In the current study, the Schaefer's database (2010) thus enabled us to select relevant film clips for the study's objective.

In line with all the studies above, we expected that the chosen film clips (see below) would elicit two intensities of anger (slight and strong). In addition, we expected that the physiological patterns observed would reflect either a classic anger pattern, or could reflect a cognitive reappraisal pattern depending on the intensity of anger elicited.

Experiment 1

The goal of Experiment 1 was to study the capacity of specific film clips to elicit different intensities of anger. In addition, we sought to explore the potential presence of other emotions felt while exposed to the film clips. In this context, emotional state was assessed through the ratings of the intensities felt by the participants for eight negative emotions while exposed to specific film clips. Given the classification of Schaefer and colleagues (2010), we assumed that intensity rating of anger would be lower with the slight anger film clip than with one expected to elicit strong anger. This assumption was called the *subjective feeling hypothesis*.

Method

Participants and design. Twenty-one participants (volunteers) took part in the study, 12 males and 9 females, aged from 17 to 51 years (M = 29; SD = 11.5). All participants reported normal or corrected-to-normal vision and audition. The experimental design consisted of a counterbalanced within-subjects film-clip factor (neutral, slight anger, and strong anger). The dependent variable was the subjective intensity of eight negative emotions (i.e., anger,

frustration, contempt, disgust, guilt, shame, fear and sadness). Intensity was rated using a score varying from 0 to 100 for each emotion.

Material. We used the Schaefer's validated emotional film clip database in which we selected three film clips on the basis of their propensity to elicit two different levels of anger and a neutral state. For the anger-inducing film clips, the selection was based first on a set of 10 film clips with high anger discreetness scores (i.e., mean score obtained on the anger item of the Differential Emotional Scale (DES) (Izard, Dougherty, Bloxom, & Kotsch, 1974), minus mean scores obtained on all remaining items of the DES). Note that DES scale allows, through the rating of groups of emotional adjectives, to assess the ability of stimuli to trigger differentiated emotional feeling states. Then, two of the film clips with the highest anger discreetness scores (i.e., film clips with the highest propensity to elicit anger) were selected on the basis of their mean anger scores on the DES. In this way, we chose two film clips that potentially elicited anger at different levels: slight (no. 30 with a score of 3.16) and strong (no. 2 with a score of 5.04). For neutral film clip, which was used as a control condition, we selected a clip with a very low level on the anger item of DES (score of 1). Precautions were also taken regarding this clip, for which no other item of DES exceeded a score of 1, thus ensuring that the film clip could be considered as neutral (no. 49).

The neutral film clip showed a woman walking along the street, the one inducing slight anger showed a man undergoing intense interrogation, and the one inducing strong anger showed a man randomly shooting people from his balcony. Unfortunately, the film clips were of different length. Hence, it was necessary to make some changes to obtain three comparable videos. First, we shortened the film clip inducing slight anger by cutting some scenes that did not affect the narrative structure. Secondly, we extended the neutral film clip using a video scene that matched the rest of the clip, including color and sound, as closely as possible. In this way, we obtained three film clips of comparable length (mean length = 1 min 55 s; SD = 10 s).

To measure the dependent variable, we used the Emotional Wheel (EW) (Rogé, El Zufari, Vienne, & Ndiaye, 2015) inspired by the Geneva Emotion Wheel (Scherer, 2005), which was specifically designed to combine both discrete and dimensional approaches in self-report assessments of emotion. The EW provides both valence and intensity information about a set of 16 emotions: eight negative (i.e., anger, frustration, contempt, disgust, guilt, shame, fear and sadness) and eight positive (i.e., pride, elation, happiness, satisfaction, relief, hope interest and surprise). As two film clips were selected in order to mainly elicit anger (i.e., negative emotion), positive emotions were seen as epiphenomena. Therefore, only negative emotions were analyzed in this article (also see Rogé et al., 2015 who did the same).

Procedure. Participants were seated comfortably in a quiet room, and completed the experiment individually. They watched the three film clips, for which the presentation order has been fully counterbalanced, on a computer screen (visual angle of 32°x21°) and were asked to rate their emotional state after each clip. To this end, they had to draw a cross, on each segment (item) of the EW indicating the highest emotional intensities they felt for each emotion while watching the film clip. Data collected from this EW were the lengths (in mm), expressed as a percentage, between the beginning of each segment and the mark drawn on it by the participant. Each length corresponded to an intensity rating of the experienced emotion.

Intensity was assessed for each emotion and each film clip on the same wheel. This allowed participants to compare their own assessments while watching the clips and thus offering them the opportunity to make an accurate emotional appraisal. The total experiment lasted about 15 minutes.

Results of Experiment 1

The assumptions underlying the ANOVAs were checked using the Kolmogorov–Smirnov test for normal distribution. Then, we conducted a repeated measure analysis of variance on the intensity scores, with two within-subjects factors, film clip (neutral vs. slight

anger vs. strong anger) and Emotional Wheel item (anger vs. frustration vs. contempt vs. disgust vs. guilt vs. shame vs. fear vs. sadness), to study how the participants felt after viewing the film clips. Comparisons of means were performed using the post-hoc Newman-Keuls test, and means were considered as significantly different when the probability of a Type 1 error was less than or equal to 0.05. Pearson correlation coefficients between intensity of anger and other negative emotions were also calculated. Correlation coefficients were considered as significant when the probability of a Type 1 error was less than 0.05

Results of the ANOVAs showed significant differences between emotional assessments of the three film clips ($F(2, 40) = 62.8$, $p = .001$, $\eta p^2 = 0.76$) as well as significant differences between assessment the items of the Emotional Wheel ($F(7, 140) = 21.16$, $p = .001$, $\eta p^2 = 0.51$). The interaction between film clips and items of the Emotional Wheel was also significant ($F(14, 280) = 10.23$, $p = .001$, $\eta p^2 = 0.34$).

Regarding anger, comparisons of means showed that the intensities of anger differed significantly between the three film clips ($p < .001$). Participants rated a very low level of anger ($M = 1.96$, $SD = 1.37$) for the neutral film clip, a moderate level ($M = 39.16$, $SD = 5.39$) for the slight anger clip, and the highest level ($M = 69.05$, $SD = 5.45$) for the strong anger clip as illustrated by the average emotional assessment for the three film clips presented in Figure 1. Therefore, it can be concluded that the anger clips elicited two distinct levels of anger as compared to our control condition (i.e., neutral film clip) supporting the *subjective feelings hypothesis*. This finding is also congruent with the study conducted by Schaefer et al. (2010).

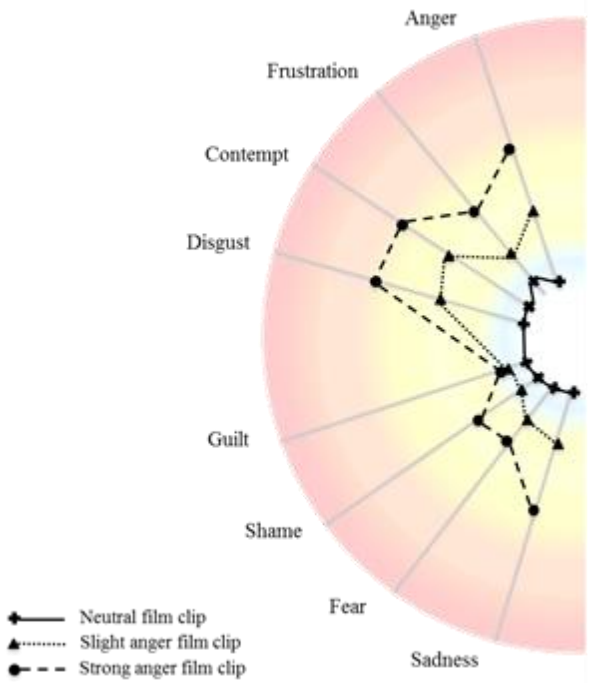

Figure 1. Average emotional assessment for the three film clips

Indeed, as can be observed in Figure 1, negative emotions other than anger also received high levels of subjective intensity ratings. To gain a better understanding of the links between anger and the set of negative emotions, correlation analyses were performed in order to highlight emotions that could vary in the same way as anger. The results presented in Table 1 show that subjective intensity of anger correlated only with sadness for the neutral film clip, with contempt, guilt and disgust for the slight anger film clip, and with frustration, contempt, disgust, sadness, fear and shame for the strong film clip.

Table 1.

Pearson correlation coefficients between anger intensity for each film clip and the intensities of other negative emotions

Film clips	**Sadness**	**Shame**	**Fear**	**Frustration**	**Contempt**	**Guilt**	**Disgust**
Neutral	**0.73***	0.10	0.02	0.32	0.05	-0.06	0.12
Slight Anger	0.13	0.25	0.35	0.37	**0.67***	**0.49***	**0.44***
Strong Anger	**0.92***	**0.48***	**0.44***	**0.58***	**0.82***	0.11	**0.81***

* $p < .05$.

Surprisingly, several significant correlations between intensity of anger and intensity of other negative emotions were observed depending on the propensity of the film clips to elicit anger. It should be noted that anger is a particular emotion which is difficult to induce in laboratories. Indeed, Harmon-Jones, Amodio and Zinner (2007) argued in a book chapter that "whereas other emotions can be induced using film clips or photographs, anger is difficult to induce using such stimuli".

On the basis of the constructed approach of emotion (Lindquist, Siegel, Quigley, & Barrett, 2013; Barrett, 2017) which suggests that mixes of emotions are possible, we proposed a new method of calculation to assess emotion blends. To this end, we developed a global emotional indicator we named *global indicator* (GI). It allows investigating the strength of the relationship between a main emotion elicited and others related to it. In the current study, two of the film clips used (i.e., slight and strong anger film clips) were previously validated as mainly eliciting anger (see Schaefer et al., 2010). As a large number of correlations between anger and other negative emotions was also observed, we decided to build an indicator in order

to take into account the relationship between anger and other negative emotions. To this end, the strength of the relationship between a given emotion and anger was weighted using the value of the correlation coefficient between the intensity ratings for both emotions. Therefore, we firstly calculated the product between the correlation coefficient with anger for the specific emotion considered, the probability of a β-type error for this correlation and the intensity collected on the EW for this emotion. Then, we made the sum of this product for all investigated emotions (i.e., eight EW's emotions). Then, we divided the result by eight. As the value of this index increases, the intensity of negative emotions felt related to anger increases too.

$$GI = \frac{\sum_{i=\,anger}^{sadness}(Correlation\ Coefficient._i \times (1 - p_i) \times Intensity_i)}{8}$$

The assumptions underlying the ANOVAs were checked using the Kolmogorov–Smirnov test for normal distribution. A repeated measure ANOVA was then performed on the GI values, with film clip (neutral vs. slight anger vs. strong anger) as a within subject factor. Results showed a significant effect of the three film clips on GI values ($F(2, 40) = 68.55$, $p = .001$, $\eta p^2 = 0.77$). Comparisons of means showed that GI values differed significantly between the three film clips ($p < .001$) with the lowest values ($M = 0.92$, $SD = 1.69$) for the neutral film clip, moderate values ($M = 8.81$, $SD = 4.89$) for the slight anger clip, and the highest values ($M = 16.68$, $SD = 6.49$) for the strong anger clip.

The analyses from Experiment 1 showed that the film clips were able to elicit two different intensities of anger and different blends of other specific negative emotions. The GI used varied together with the intensities of anger across the conditions, suggesting the following new categorization: low level emotion blend (LLEB) while exposed to the neutral film clip, moderate level emotion blend (MLEB) while exposed to the slight anger film clip and high level emotion blend (HLEB) while exposed to the strong anger film clip.

Experiment 2

Assuming the film clips used in Experiment 1 elicited two specific intensities of anger, and three different emotion blends (LLEB, MLEB and HLEB), the aim of this second experiment was to examine how cardiovascular patterns might differ between these three emotional states. In this context several hypotheses were examined.

In line with the results of Experiment 1, it was expected that subjective intensity of anger would correlate with sadness for the neutral film clip, with contempt, guilt and disgust for the slight anger clip, and with frustration, contempt, disgust, sadness, fear and shame for the strong anger clip. We named this the *comparable correlations hypothesis.*

Based on studies previously mentioned in the introduction, the specific set of negative emotions that could emerge when watching the film clips should provide an indication of the effect on cardiac measures. One possibility is that cardiac data would directly reflect how negative emotions, especially anger were processed. In this case, there would be an increase in HR and a decrease in HRV (e.g., RMSSD, SD1 and SampEn). We named this the *direct anger pattern hypothesis*.

Another possibility is that cardiac data variations reflect emotion regulation strategies. In that case, there would be a decrease in HR and an increase in HRV (e.g., RMSSD, SD1 and SampEn). We called this the *reappraisal pattern hypothesis*.

Furthermore, in view of the evidence for a link between strong negative feelings and emotion regulation strategies notably raised by Luce et al. (1999), we expected that the cardiac pattern described above, reflecting these emotion regulation strategies, would occur when the intensity of anger experienced was the highest, whereas a classic anger pattern (i.e., HR increase and a decrease RMSSD, SD1 and SampEn values) should occur for our slight anger elicitation. Consequently, it is assumed that an intensity threshold could exist between the MLEB and HLEB. We called this the *threshold hypothesis.*

Method

Participants and design. Thirty-six participants (18 males, 18 females) took part in this second experiment, aged between 20 and 43 years (*M* = 28.5; *SD* = 6.6). All participants reported normal or corrected-to-normal vision and audition. A between-subjects design was used, with film clip as between-subjects factor (neutral, slight anger, and strong anger). The dependent variables were intensity scores on each segment of the EW (i.e., eight emotions) and cardiac indices (HR, RMSSD, SD1, and SampEn).

Material and procedure. We used the same three film clips as in Experiment 1, together with the EW (see above). Three Ag-AgCl pre-gelled electrodes were attached to the participants, following a modified lead II configuration, to record their cardiac activity. Electrodes were connected to Bionomadix transmitter (BIOPAC Systems Inc.) allowing wireless connections with MP150 data recording system (BIOPAC Systems Inc.). After a few seconds of recording to ensure correct equipment functioning, participants seated comfortably and were asked to relax during five minutes in order to record cardiac baseline. This five-minute rest session was divided in two: a first rest session with eyes closed (2 min 30 s) and a second with eyes open (2 min 30 s). Closed-eye period allowed individuals to calm down, then opened-eye period was considered as cardiac baseline standard.

They then watched one of the three film clips on a large screen (visual angle of 31° x 17°). The sound track was played through speakers positioned behind the participant in order to create an immersive watching situation. Participants were randomly assigned to one of the three experimental conditions. Before and after viewing the film clip, participants were asked to assess the highest emotional intensities they felt throughout the baseline and the film clip watching stages respectively using the EW. As for Experiment 1, they had to draw a cross, on each segment of the EW indicating the highest emotional intensities they felt for each emotion while watching the film clip. Participants were alone in the room, except for a short

interview at the end of the experiment. The total test lasted about 30 minutes. Electrocardiogram (ECG) was continuously recorded and sampled at 1000 Hz from the beginning of the first baseline until the end of the film clip. The ECG was analog low-pass (0.05 Hz) and high-pass (35 Hz) filtered at acquisition, as approximately 5–30 Hz range covers most of the frequency content of QRS complex (Pahlm & Sörnmo, 1984). Triggers were manually positioned during the recording to define the beginning and the end of each baseline and film clip session.

Measures and data processing. Subjective emotional state was assessed using the EW as in Experiment 1. More precisely, data collected from this questionnaire were the lengths (in mm), expressed as a percentage, between the beginning of each segment and the mark drawn on it by the participant. Each length corresponded to an intensity rating of the experienced emotion. As for Experiment 1, only negative emotions were analyzed. For the physiological emotional state, the recorded cardiac signal was processed in order to calculate different metrics. First, each participant's filtered cardiac signal was visually checked to correct any artifacts (see Berntson et al., 1997; Berntson & Stowell, 1998 for artifact correction methods used). R peaks were detected on cardiac signal in order to calculate R-R intervals corresponding to the time between two R peaks.

Several indexes were then calculated with RR interval series using Kubios HRV software v.2.2. First, HR was computed in beats per minute (b.p.m.). HRV metrics were also computed. For HRV time domains, the square root of the mean squared differences of successive NN intervals (RMSSD) was calculated. Indeed, "in contrast to other time-domain (i.e., pNN50) and time-frequency (i.e., HF-HRV) measures, changes in breathing rate have been found to not significantly affect RMSSD" (Penttilä et al., 2001). Regarding HRV non-linear domains, the Poincaré plot provided a graphic display of the correlations between successive RR intervals (i.e., plot of RRj+1 as a function of RRj). Standard deviation of the points perpendicular to the line of identity denoted by SD1 was analyzed in order to parameterize the

shape's ellipse formed by cloud points describing short-term variability in cardiac rhythm. Finally, SampEn was computed by computing and comparing vectors derived from RR intervals series (See Tarvainen (2014) for more information about how ApEn and SampEn are calculated).

Results of Experiment 2

Subjective emotional assessment. The assumptions underlying the ANOVAs were checked using the Kolmogorov–Smirnov test for normal distribution and Levene's test for variance homogeneity for all analyses. The similarity of the three film clip groups (neutral, slight anger and strong anger) in terms of subjective emotional state at the beginning of the experiment (i.e. before watching the film clip) was checked using the Kruskal-Wallis test due to non-normal distribution of emotional intensity as illustrated by the average emotional assessment before viewing the film clip presented in Figure 2.

To study whether the film clips elicited two subjectively felt intensities of anger, we conducted an ANOVA with film clip (neutral vs. slight anger vs. strong anger) as between-subjects factor and Emotional Wheel item (anger vs. frustration vs. contempt vs. disgust vs. guilt vs. shame vs. fear vs. sadness) as within-subjects factor. Comparisons of means were conducted using a post-hoc Newman-Keuls test, and means were considered as significantly different when the probability of a Type 1 error was less than or equal to 0.05.

Pearson correlation coefficients were calculated between subjective intensity of anger and other negative emotions as in Experiment 1 in order to investigate their potential relationships (note that correlation coefficients were again considered as significant when the probability of a Type 1 error was less than 0.05).

To study whether the film clips elicited three distinct emotion blends, we conducted an ANOVA on global indicator values, with the film clips (neutral vs. slight anger vs. strong anger)

as between-subjects factor. Comparisons of means were conducted using a post-hoc Newman-Keuls test.

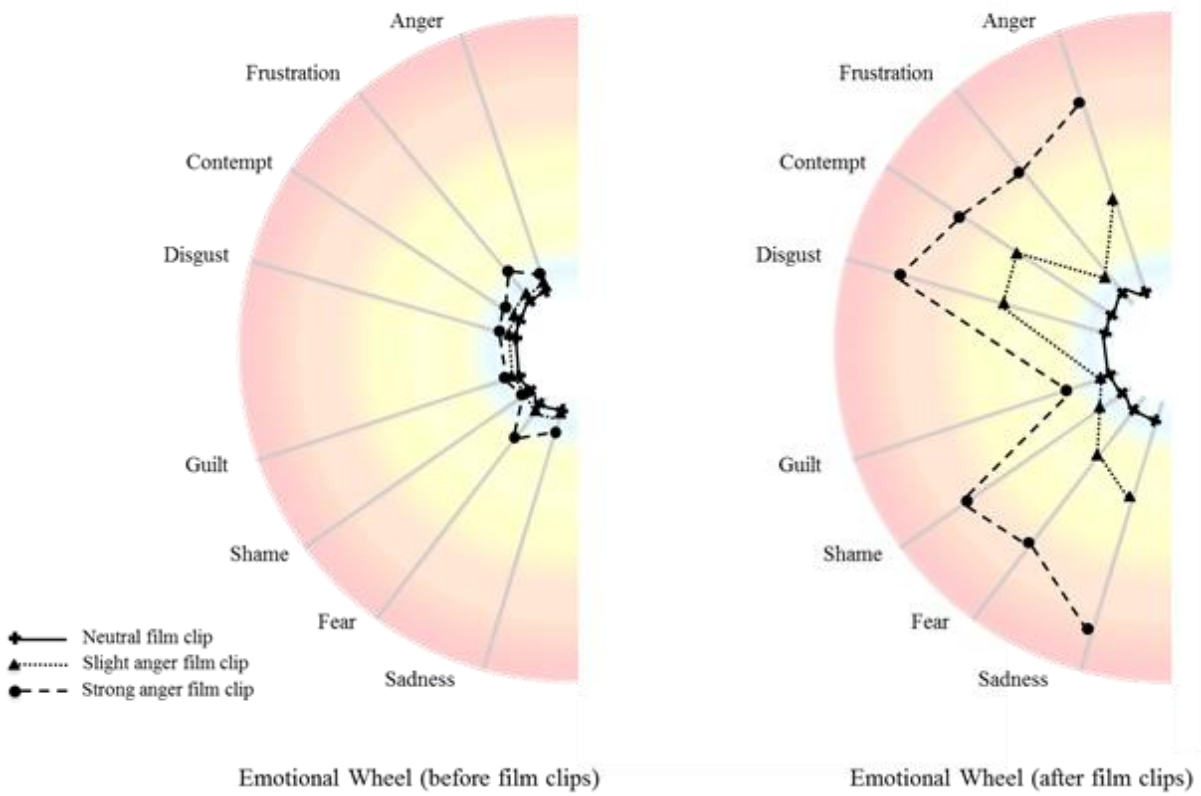

Figure 2. Average emotional assessment before and after viewing the film clip

First, results did not show any significant differences between film clip groups regarding assessment of negative emotions experienced (Emotional Wheel items) before watching the film clip: anger (p = .72), frustration (p = .60), contempt (p = .47), disgust (p = .94), guilt (p = .37), shame (p = .74), fear (p = .59) and sadness (p = .54) as illustrated in Figure 2. Groups were comparable for each emotion (Fs < 1).

Secondly, significant differences were found between emotional assessments of the three film clips ($F(2, 33) = 34.73$, $p = .001$, $\eta p^2 = 0.678$) and between assessment of negative emotions (Emotional Wheel items) ($F(7, 231) = 16.23$, $p = .001$, $\eta p^2 = 0.33$). The interaction

between film clips and Emotional Wheel item was also significant ($F(14, 231) = 5.52$, $p = .001$, $\eta p^2 = 0.25$). In addition, Newman-Keuls post hoc tests revealed that intensities of anger differed significantly between each film clip ($p < .001$). The neutral film clip triggered a very low level of anger ($M = 2.72$, $SD = 2.85$), the slight anger clip a moderate level of anger ($M = 42.92$, $SD = 19.17$), and the strong anger clip was rated with the highest intensity ($M = 70.45$, $SD = 14.22$). This result is consistent with the anger intensity pattern observed in Experiment 1.

As shown in Experiment 1, exposure to film clips elicited other negative emotions (see Figure 2, after film clips). Correlation results, which are reported in Table 2 indicated that intensity of anger correlated with sadness, shame and guilt for the neutral film clip; with shame, contempt and disgust for the slight anger film clip; and with sadness, shame, frustration, contempt, guilt and disgust for the strong anger clip.

Table 2.

Pearson correlation coefficients between anger intensity for each film clip and intensities other negative emotions

Film clips	**Sadness**	**Shame**	**Fear**	**Frustration**	**Contempt**	**Guilt**	**Disgust**
Neutral	**0.89****	**0.74****	0.55	0.04	0.27	**0.84****	0.26
Slight Anger	0.02	**0.84****	0.46	0.36	**0.70***	0.26	**0.90****
Strong Anger	**0.60***	**0.78****	0.47	**0.82****	**0.67***	**0.60***	**0.85****

** p < .05. ** p < .01.*

As in Experiment 1, the number of correlations between intensity of anger and intensity of other negative emotions increased with the propensity of the film clips to elicit anger. Once again, this suggests that watching the film clip elicited not only a varying intensity of anger, but

also a mixture of other emotions. Nevertheless, the results did not support our *comparable correlations hypothesis* since correlations between the intensity of anger and intensities of other negative emotions were not the same as Experiment 1.

Results regarding emotion blends highlighted significant differences between emotional assessments of the three film clips ($F(2, 33) = 38.58$, $p = .001$, $\eta p^2 = 0.70$). Post hoc tests revealed that GI values differed significantly following the film clip ($p < .001$) with the lowest values ($M = 1.53$, $SD = 1.50$) for the neutral film clip, moderate values ($M = 14.41$, $SD = 8.92$) for the slight anger clip, and the highest values ($M = 30.58$, $SD = 10.76$) for the strong anger clip. Emotion blend categorization provided results consistent with those observed for anger assessment.

Emotional assessment using cardiac data. The assumptions underlying the ANOVAs were checked using the Kolmogorov–Smirnov test for normal distribution and Levene's test for variance homogeneity for all analyses. The similarity of the three film clip groups (neutral, slight anger and strong anger) for all cardiac metrics investigated (i.e., HR, RMSSD, SD1 and SampEn) at baseline (i.e. open eyes) was checked using ANOVA due to the normal distribution of each cardiac metric.

In order to study whether film clips elicited different physiological emotional states, statistical analyses were conducted on the cardiac data collected while watching the film clips. For metric distributions, data normality and homogeneity were checked as previously and suitable statistical tests were then applied. Once normality had been checked (i.e., HR and SampEn), we conducted ANOVAs with film clip as between-subjects factor (neutral vs. slight anger vs. strong anger). Comparisons of means were also conducted using a post-hoc Newman-Keuls test, and means were considered as significantly different when the probability of a Type 1 error was less than or equal to 0.05. By contrast, when cardiac metric values did not follow a normal distribution (i.e., RMSSD, SD1), a Kruskal-Wallis test was performed using film clip

as between-subjects factor (neutral vs. slight anger vs. strong anger). Mann-Whitney tests were then conducted to compare groups.

Pearson correlation coefficients were also calculated between subjective intensity of anger, GI values, and cardiac indexes in order to investigate the links between subjective emotional assessment and cardiac data.

First, results at baseline did not show any significant differences between groups for any cardiac metric values ($p > .05$). These results indicate that groups were comparable regarding cardiac metrics at baseline as illustrated by the means and standard deviations for each cardiac metric at baseline in Table 3.

Table 3.

Means and standard deviations for each cardiac metric at baseline according to the experimental conditions

Film clips	**HR**	**RMSSD**	**SD1**	**SampEn**
Neutral	*M* = 74.24, SD = 12.43	*M* = 39.51, SD = 19.73	*M* = 28.05, SD = 14.02	*M* = 1.48, SD = .37
Slight Anger	*M* = 66.05, SD = 7.64	*M* = 80.24, SD = 48.75	*M* = 56.99, SD = 34.64	*M* = 1.46, SD = .24
Strong Anger	*M* = 65.48, SD = 9.93	*M* = 62.62, SD = 45.15	*M* = 44.46, SD = 32.08	*M* = 1.77, SD = .46

Results showed a significant effect of film clip ($F(2, 33) = 5.73$, $p = .007$, $\eta p^2 = 0.26$, CI = [64.04, 71.75]) for HR, with significant differences between the neutral (*M* = 75.59, SD = 12.95) and slight anger (*M* = 66.12, SD = 7.19) clips, and differences between the neutral and the strong anger clips (*M* = 61.97, SD = 9.32), indicating that anger elicited lower HR than a neutral situation.

Film clip had a significant effect on RMSSD values ($H(2, 36) = 7.59$, $p = .02$, CI = [41.68, 72.64]), with significant differences between the neutral ($M = 36.72$, $SD = 21.89$) and slight anger ($M = 65.27$, $SD = 33.26$) clips, and differences between neutral and strong anger clips ($M = 69.48$, $SD = 66.20$).

For non-linear measures, a significant effect of film clip was found on SD1 values ($H(2, 36) = 7.47$, $p = .02$, CI = [29.6, 51.61]), with significant differences between neutral (M = 26.08, $SD = 15.56$) and slight anger ($M = 46.36$, $SD = 23.64$) groups. Trends ($p = .051$) were also observed between neutral and strong anger groups ($M = 49.38$, $SD = 47.08$), and between slight anger and strong anger groups ($p = .055$).

The final indicator was *SampEn*. Results showed a significant effect of film clip ($F(2, 32) = 6.67$, $p = .004$, $\eta p^2 = .29$, CI = [-1.22, 9.99]), with significant differences between neutral ($M = 1.41$, $SD = .31$) and slight anger groups ($M = 1.89$, $SD = .37$), and between slight anger and strong anger groups ($M = 1.57$, $SD = .30$).

Considering only cardiac data, results are consistent with the *reappraisal pattern hypothesis* but not with the *direct anger pattern hypothesis.* This suggests that anger-eliciting film clips likely lead individuals to establish emotion-regulation strategies. Unexpectedly, our results did not show a cardiac reappraisal pattern only for the highest induced intensity of anger. Hence, they are not consistent with the *threshold hypothesis.* This point will be discussed in the general discussion.

General Discussion

The aim of the present research was to study the effects of specific intensities of anger on subjective and cardiac features of an individual's emotional state. The first experiment showed the ability of a set of film clips to elicit two subjective intensities of anger: a slight one and a strong one. Results suggested that film clips elicited, not only anger, but also other negative emotions. A global indicator (GI) of emotions felt allows us to highlight that films

clips elicited three specific negative emotion blends (i.e., low, moderate and high). Experiment 2 provided comparable results for the subjective emotional assessment since the anger intensity ratings and the GI values both showed similar ranges to the first experiment (i.e., a low level, a moderate one and high one).

Interestingly, the results of both experiments showed that the number of correlations between intensity of anger and intensity of other negative emotions increased with the propensity of the film clips to elicit anger. This suggests that film clips used to elicit anger have the ability to converge negative emotions toward overall negative states depending on the level of anger intensity they elicit. As the intensity of anger and other negative emotions (e.g., the emotion blends) increase, individuals may have a less accurate assessment of their own emotions. Indeed, as intensity is a concept related to the way that individuals are affected by stimuli (Scherer et al., 2013), it is possible that the overall negative states triggered by anger-inducing film clips emotionally overwhelm individuals. Consequently, they likely fail to assess their emotional state accurately.

Furthermore, cardiac data are consistent with a reappraisal pattern for both anger conditions. Indeed, anger-eliciting film clips led to lower HR than the neutral clip. This result is in line with other studies that found HR deceleration due to negative emotion elicitations (Kuoppa et al., 2016; Sarlo et al., 2005; Stemmler et al., 2007) and emotion-regulation strategies (Denson et al., 2011). In addition, higher values for RMSSD and SD1 were observed when individuals watched the anger film clips. This increase in short-term variability is associated with high frequency variations in cardiac rhythm. This testifies to the dominance of the parasympathetic branch of the ANS. It also suggests the establishment of emotion-regulation strategies (Berntson, Cacioppo, & Quigley, 1993; Butler, Wilhelm, & Gross, 2006; Denson et al., 2011; León, Hernández, Rodríguez, & Vila, 2009). Furthermore, according to Valenza et al. (2012), entropy is higher when the parasympathetic branch of ANS is in control.

Consequently, the significantly higher value for SampEn when participants were watching the slight anger film clip is congruent with an emotion-regulation strategy. Nevertheless, significant differences only appeared between the neutral and slight anger groups. An explanation could be that SampEn was influenced by specific emotions only contained in the mixture of negative emotions elicited by film clip associated with slight anger as illustrated in Table 2.

The next question is why participants seemed reappraise their feelings when watching both anger-eliciting film clips. As described above, anger intensities correlated with other negative emotions. Since the intensity of subjective anger and the number of converging negative emotions was higher following the two anger-eliciting film clips than the neutral clip, we can assume that highly negative states resulted from watching these clips. According to Luce et al. (1999), emotion-regulation strategies are established when highly intense negative emotions are experienced. Hence, it can be assumed that the highly negative states elicited by the anger-eliciting film clips triggered a greater need to reappraise the situation.

However, why did the appraisal pattern not only appear for the film clip supposed to elicit strong anger? According to Luce et al. (1999) and Yao and Lin (2015), high intensities of negative emotions could be involved in the emergence of emotion-regulation strategies. In the present study, the possible anger threshold predicting which cardiac pattern would be expressed does not appear to be located between slight anger and strong anger intensity as expected, but before our slight anger condition. Moreover, one of the key features of the reappraisal approach is the immediate emergence of cognitive processes of coping strategies when faced with an emotional event (Niedenthal, Krauth-Gruber, & Ric, 2006). Consequently, it is possible that both anger film clips were emotionally appraised as eliciting a sufficient intensity of anger for the establishment of emotion-regulation strategies. This regulatory effort interpretation of the results is in line with the polyvagal theory (Porges, 1995; Porges, Doussard-Roosevelt, & Maiti, 1994; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996). This model postulates that

the vagus nerve, which is involved in ANS parasympathetic activity, reflects active engagement with the environment in line with emotion-regulation strategies. Unfortunately, our protocol did not enable us to identify this threshold. Future studies should investigate more intensities of negative emotion to address this issue.

Our research also raises issues about how to precisely assess emotional state. As a complement to basic approaches of emotions which distinguish emotions according to specific labels and "ANS fingerprints"(e.g., Ekman, 1992; Saarimäki et al., 2016) or dimensional approaches only accounting for some dimensions like valence and arousal (e.g., Russell, 1980), our results are particularly congruent with appraisal theories of emotion (e.g., Scherer, 2009). Indeed, as attested by the cognitive reappraisal pattern we found, emotions seem to emerge after a cognitive appraisal where a stimulus is evaluated for its meaning.

Furthermore, according to Siegel et al. (2018), the classical view of emotion that consider some emotion categories having a specific autonomic nervous system (ANS) "fingerprint", has some weaknesses and need to be questioned. Indeed, for a given emotion category, ANS variations are the result of random error or epiphenomenon (e.g., the method used to elicit emotion). The work carried out by Feldman Barrett describing a new approach of emotion, called the theory of constructed emotion (Barrett, 2017), provides interesting outputs for a better understanding of the nature of emotion. It hypothesizes that emotion is a complex entity and that "an emotion category is a population of context-specific, highly variable instances that need not share an ANS fingerprint" (Siegel et al., 2018). The same authors also suggest that "ANS patterns are expected to be highly variable within an emotion category and to overlap with other categories". Therefore, we can talk about emotion as a global phenomenon consisting of many instances. In accordance with Barrett (2017); Siegel et al., (2018) we consider emotions as a complex entities and we argue that emotion would be formed by a mix of feelings related to a main emotion. The number of emerging emotions for each film clip and

the correlations observed between the intensity of anger felt and other negative emotions in this study effectively shows the difficulty to elicit an emotion in isolation. GI could offer a promising global emotional assessment of negative emotions taking into account the relationships between a main emotion and others related.

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