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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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46 processes that evaluate the emotional event, understand what caused it and assess ways of
47 coping with it. In other words, “appraisals are transformations of raw sensory input into
48 psychological representations of emotional significance” (Clore & Ortony, 2000). Scherer
49 (2005) created a tool for subjective emotional assessment, placing appraisal as a key feature of
50 his model. This tool has a specific arrangement of 16 discrete emotions placed around a circle
51 divided along two axes: valence (positive versus negative) along the horizontal line, and coping
52 potential (control/power) along the vertical line. Thus, individuals can rate the intensity of their
53 feelings on the basis of the distance from the hub of the wheel and the size of the circles. In this
54 way, the intensity of emotion can be expressed as the degree to which individuals are affected
55 by emotion (Scherer, Shuman, Fontaine, & Soriano, 2013). The present study is thus based on
56 the appraisal approaches of emotion, especially Scherer's model (2005). However, besides
57 subjective feelings, emotion also affects physiology.

58 **Emotional Assessment through Cardiac Measures**

59 In accordance with the neurovisceral integration model (Thayer & Lane, 2000; Thayer
60 & Lane, 2009) there is some evidence supporting brain connections, implicated in affective
61 processes like emotion regulation, and cardiac activity controlled by both the sympathetic and
62 parasympathetic branches of the autonomic nervous system (ANS). According to Kreibig
63 (2010), cardiac measurements, particularly heart rate (HR), defined as the number of
64 contractions of the heart per minute, and heart rate variability (HRV) which refers to the
65 variations between consecutive heartbeats are widely used to investigate the impact of emotion
66 on ANS activity. While sympathetic activity tends to increase HR in a few seconds,
67 parasympathetic activity tends to decrease HR and its response is faster (0.2-0.6 s) (Berntson et
68 al., 1997).

69 **Cardiac Measures as an Indicator of Anger**

70 According to many authors, the ANS produces specific activations in response to
71 specific emotions (Cacioppo, Klein, Berntson, & Hatfield, 1993; Levenson, Ekman, & Friesen,
72 1990; Stemmler, Aue, & Wacker, 2007). According to Kreibig's review, anger is one of the
73 most widely investigated emotions. Several studies have revealed typical variations in metrics
74 related to cardiac activity while experiencing emotions with high arousal such as anger. For
75 instance, many authors have found a significant increase in HR due to anger elicitation
76 (Fairclough & Spiridon, 2012; Fernández et al., 2012; Lobbestael, Arntz, & Wiers, 2008; Marci,
77 Glick, Loh, & Dougherty, 2007).

78 Some studies have assessed HRV to explore emotion using *time-domain* methods.
79 Among the most commonly used indexes suitable for short-term recordings, the root mean
80 square of successive NN interval¹ differences (RMSSD) appears particularly relevant, notably
81 indicating short-term variability in cardiac rhythm (Task Force of The European Society of
82 Cardiology and The North American Society of Pacing and Electrophysiology, 1996). Indeed,
83 several studies have shown that the RMSSD value decreases when participants have to carry
84 out an anger-related imagery task (Kreibig, 2010; Pauls & Stemmler, 2003). Consequently,
85 lower RMSSD values are expected when anger is experienced in the current study.

86 Furthermore, the mediation of cardiac activity by complex control systems assumes that
87 non-linear mechanisms are involved in cardiac rhythm variations (Task Force of The European
88 Society of Cardiology and The North American Society of Pacing and Electrophysiology,
89 1996). Among *non-linear* methods used to study HRV, the Poincaré plot is a popular tool
90 because of the relative ease of interpreting one of the parameters. More specifically, the SD1
91 index, describes short-term variability in cardiac rhythm (Goshvarpour, Abbasi, &

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

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

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

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

106 **Cardiac Measures as an Indicator of Cognitive Reappraisal**

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

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

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

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

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

141 **Existence of an Anger Intensity Threshold?**

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

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

157 **Emotion Elicitation**

158 According to Baldaro et al. (2001), film clips are commonly used to induce emotions
159 because of their high ecological validity and their ease of presentation. Several researchers have
160 developed databases of film clips suitable for mood induction procedures (Gross & Levenson,
161 1995; Schaefer, Nils, Sanchez, & Philippot, 2010). Prior research used the most recent database
162 to study emotion. For instance, Fernández et al. (2012) investigated the objective physiological
163 responses (skin conductance level and heart rate) and subjective emotional responses elicited
164 through a set of emotional film clips capable to induce anger, fear, sadness, disgust amusement
165 tenderness and a neutral state. In the same vein, the Schaefer's database (2010) has been used

166 to compare different types of real-life emotional elicitations: film clips eliciting anger, fear or
167 sadness and a hostile social interaction (Cabral, Tavares, Weydmann, das Neves, & de Almeida,
168 2018). However; no study focused on the ability for the film clips belonging to this database to
169 elicit different intensities of a same emotion. Moreover, no study investigated the propensity
170 for these film clips to elicit emotion blends. In the current study, the Schaefer's database (2010)
171 thus enabled us to select relevant film clips for the study's objective.

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

176 **Experiment 1**

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

185 **Method**

186 **Participants and design.** Twenty-one participants (volunteers) took part in the study,
187 12 males and 9 females, aged from 17 to 51 years ($M = 29$; $SD = 11.5$). All participants reported
188 normal or corrected-to-normal vision and audition. The experimental design consisted of a
189 counterbalanced within-subjects film-clip factor (neutral, slight anger, and strong anger). The
190 dependent variable was the subjective intensity of eight negative emotions (i.e., anger,

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

193 **Material.** We used the Schaefer's validated emotional film clip database in which we
194 selected three film clips on the basis of their propensity to elicit two different levels of anger
195 and a neutral state. For the anger-inducing film clips, the selection was based first on a set of
196 10 film clips with high anger discreteness scores (i.e., mean score obtained on the anger item
197 of the Differential Emotional Scale (DES) (Izard, Dougherty, Bloxom, & Kotsch, 1974), minus
198 mean scores obtained on all remaining items of the DES). Note that DES scale allows, through
199 the rating of groups of emotional adjectives, to assess the ability of stimuli to trigger
200 differentiated emotional feeling states. Then, two of the film clips with the highest anger
201 discreteness scores (i.e., film clips with the highest propensity to elicit anger) were selected on
202 the basis of their mean anger scores on the DES. In this way, we chose two film clips that
203 potentially elicited anger at different levels: slight (no. 30 with a score of 3.16) and strong (no. 2
204 with a score of 5.04). For neutral film clip, which was used as a control condition, we selected
205 a clip with a very low level on the anger item of DES (score of 1). Precautions were also taken
206 regarding this clip, for which no other item of DES exceeded a score of 1, thus ensuring that
207 the film clip could be considered as neutral (no. 49).

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

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

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

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

237 **Results of Experiment 1**

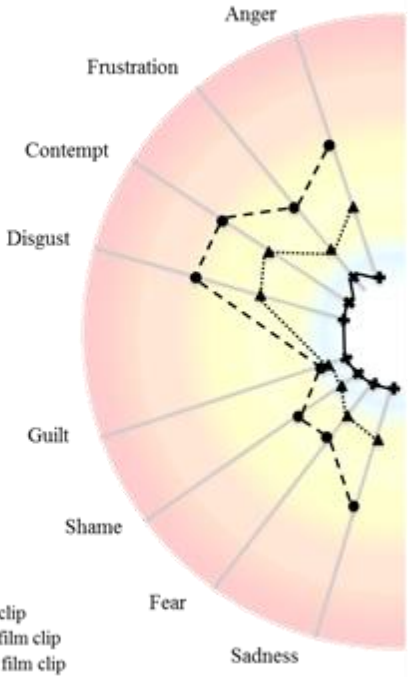
238 The assumptions underlying the ANOVAs were checked using the Kolmogorov–
239 Smirnov test for normal distribution. Then, we conducted a repeated measure analysis of
240 variance on the intensity scores, with two within-subjects factors, film clip (neutral vs. slight

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

248 Results of the ANOVAs showed significant differences between emotional assessments
249 of the three film clips ($F(2, 40) = 62.8$, $p = .001$, $\eta^2 = 0.76$) as well as significant differences
250 between assessment the items of the Emotional Wheel ($F(7, 140) = 21.16$,
251 $p = .001$, $\eta^2 = 0.51$). The interaction between film clips and items of the Emotional Wheel was
252 also significant ($F(14, 280) = 10.23$, $p = .001$, $\eta^2 = 0.34$).

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

261



262

263

Figure 1. Average emotional assessment for the three film clips

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Indeed, as can be observed in Figure 1, negative emotions other than anger also received

266

high levels of subjective intensity ratings. To gain a better understanding of the links between

267

anger and the set of negative emotions, correlation analyses were performed in order to

268

highlight emotions that could vary in the same way as anger. The results presented in Table 1

269

show that subjective intensity of anger correlated only with sadness for the neutral film clip,

270

with contempt, guilt and disgust for the slight anger film clip, and with frustration, contempt,

271

disgust, sadness, fear and shame for the strong film clip.

272

273 Table 1.

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

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

276 * $p < .05$.

277

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

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

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

$$300 \quad GI = \frac{\sum_{i=anger}^{sadness} (Correlation\ Coefficient._i \times (1 - p_i) \times Intensity_i)}{8}$$

301 The assumptions underlying the ANOVAs were checked using the Kolmogorov–
 302 Smirnov test for normal distribution. A repeated measure ANOVA was then performed on the
 303 GI values, with film clip (neutral vs. slight anger vs. strong anger) as a within subject factor.
 304 Results showed a significant effect of the three film clips on GI values ($F(2, 40) = 68.55$,
 305 $p = .001$, $\eta p^2 = 0.77$). Comparisons of means showed that GI values differed significantly
 306 between the three film clips ($p < .001$) with the lowest values ($M = 0.92$, $SD = 1.69$) for the
 307 neutral film clip, moderate values ($M = 8.81$, $SD = 4.89$) for the slight anger clip, and the
 308 highest values ($M = 16.68$, $SD = 6.49$) for the strong anger clip.

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

315 **Experiment 2**

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

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

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

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

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

340 **Method**

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

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

357 They then watched one of the three film clips on a large screen (visual angle of
358 $31^\circ \times 17^\circ$). The sound track was played through speakers positioned behind the participant in
359 order to create an immersive watching situation. Participants were randomly assigned to one of
360 the three experimental conditions. Before and after viewing the film clip, participants were
361 asked to assess the highest emotional intensities they felt throughout the baseline and the film
362 clip watching stages respectively using the EW. As for Experiment 1, they had to draw a cross,
363 on each segment of the EW indicating the highest emotional intensities they felt for each
364 emotion while watching the film clip. Participants were alone in the room, except for a short

365 interview at the end of the experiment. The total test lasted about 30 minutes. Electrocardiogram
366 (ECG) was continuously recorded and sampled at 1000 Hz from the beginning of the first
367 baseline until the end of the film clip. The ECG was analog low-pass (0.05 Hz) and high-pass
368 (35 Hz) filtered at acquisition, as approximately 5–30 Hz range covers most of the frequency
369 content of QRS complex (Pahlm & Sörnmo, 1984). Triggers were manually positioned during
370 the recording to define the beginning and the end of each baseline and film clip session.

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

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

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

394 **Results of Experiment 2**

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

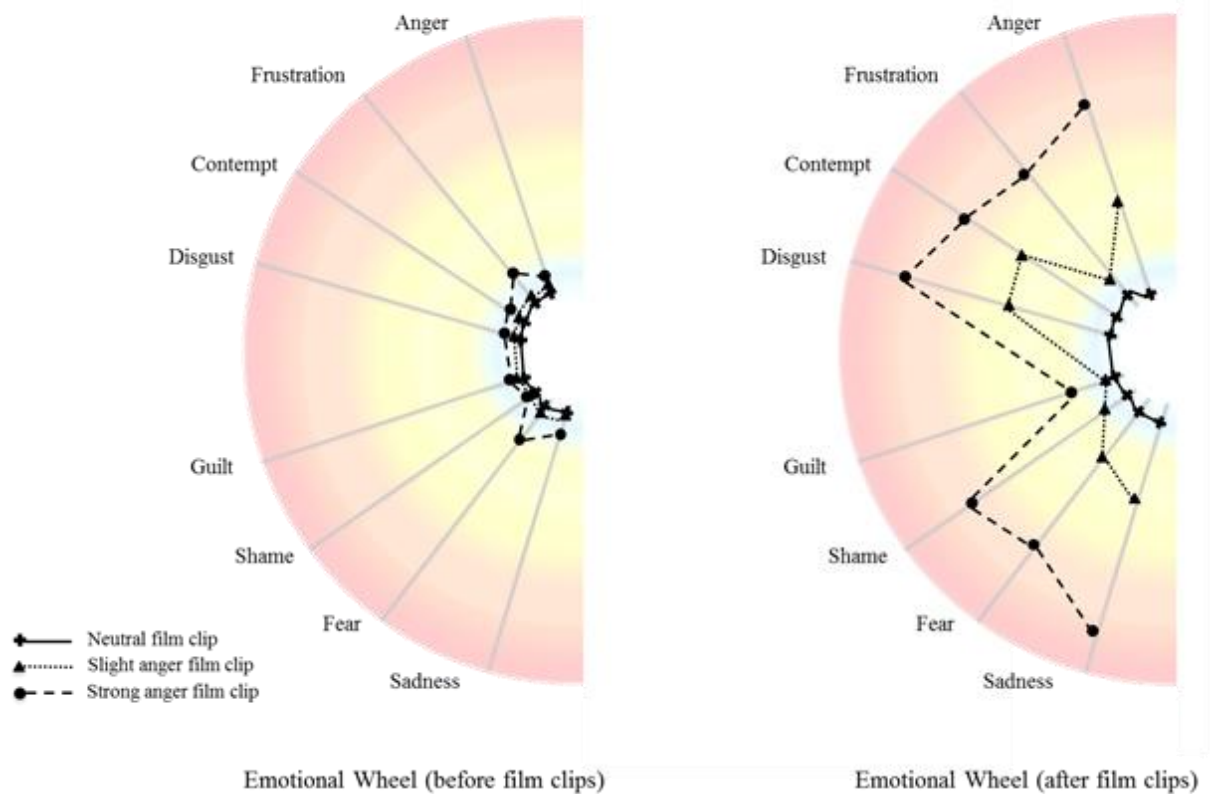
402 To study whether the film clips elicited two subjectively felt intensities of anger, we
403 conducted an ANOVA with film clip (neutral vs. slight anger vs. strong anger) as between-
404 subjects factor and Emotional Wheel item (anger vs. frustration vs. contempt vs. disgust vs.
405 guilt vs. shame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

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

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

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

416



417

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

419

420 First, results did not show any significant differences between film clip groups regarding
 421 assessment of negative emotions experienced (Emotional Wheel items) before watching the
 422 film clip: anger ($p = .72$), frustration ($p = .60$), contempt ($p = .47$), disgust ($p = .94$), guilt ($p =$
 423 $.37$), shame ($p = .74$), fear ($p = .59$) and sadness ($p = .54$) as illustrated in Figure 2. Groups were
 424 comparable for each emotion ($F_s < 1$).

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

428 between film clips and Emotional Wheel item was also significant ($F(14, 231) = 5.52$,
 429 $p = .001$, $\eta^2 = 0.25$). In addition, Newman-Keuls post hoc tests revealed that intensities of
 430 anger differed significantly between each film clip ($p < .001$). The neutral film clip triggered a
 431 very low level of anger ($M = 2.72$, $SD = 2.85$), the slight anger clip a moderate level of anger
 432 ($M = 42.92$, $SD = 19.17$), and the strong anger clip was rated with the highest intensity
 433 ($M = 70.45$, $SD = 14.22$). This result is consistent with the anger intensity pattern observed in
 434 Experiment 1.

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

440

441 Table 2.

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

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

444 * $p < .05$. ** $p < .01$.

445

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

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

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

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

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

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

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

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

483

484 Table 3.

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

<i>Film clips</i>	HR	RMSSD	SD1	SampEn
<i>Neutral</i>	$M = 74.24, SD = 12.$ 43	$M = 39.51, SD = 19.$ 73	$M = 28.05, SD = 14.$ 02	$M = 1.48, SD = .37$
<i>Slight Anger</i>	$M = 66.05, SD = 7.6$ 4	$M = 80.24, SD = 48.$ 75	$M = 56.99, SD = 34.$ 64	$M = 1.46, SD = .24$
<i>Strong Anger</i>	$M = 65.48, SD = 9.9$ 3	$M = 62.62, SD = 45.$ 15	$M = 44.46, SD = 32.$ 08	$M = 1.77, SD = .46$

487

488 Results showed a significant effect of film clip ($F(2, 33) = 5.73, p = .007, \eta^2 = 0.26,$
489 $CI = [64.04, 71.75]$) for HR, with significant differences between the neutral
490 ($M = 75.59, SD = 12.95$) and slight anger ($M = 66.12, SD = 7.19$) clips, and differences
491 between the neutral and the strong anger clips ($M = 61.97, SD = 9.32$), indicating that anger
492 elicited lower HR than a neutral situation.

493 Film clip had a significant effect on RMSSD values ($H(2, 36) = 7.59, p = .02,$
494 $CI = [41.68, 72.64]$), with significant differences between the neutral ($M = 36.72, SD = 21.89$)
495 and slight anger ($M = 65.27, SD = 33.26$) clips, and differences between neutral and strong
496 anger clips ($M = 69.48, SD = 66.20$).

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

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

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

512 **General Discussion**

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

518 clips elicited three specific negative emotion blends (i.e., low, moderate and high). Experiment
519 2 provided comparable results for the subjective emotional assessment since the anger intensity
520 ratings and the GI values both showed similar ranges to the first experiment (i.e., a low level, a
521 moderate one and high one).

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

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

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

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

556 However, why did the appraisal pattern not only appear for the film clip supposed to
557 elicit strong anger? According to Luce et al. (1999) and Yao and Lin (2015), high intensities of
558 negative emotions could be involved in the emergence of emotion-regulation strategies. In the
559 present study, the possible anger threshold predicting which cardiac pattern would be expressed
560 does not appear to be located between slight anger and strong anger intensity as expected, but
561 before our slight anger condition. Moreover, one of the key features of the reappraisal approach
562 is the immediate emergence of cognitive processes of coping strategies when faced with an
563 emotional event (Niedenthal, Krauth-Gruber, & Ric, 2006). Consequently, it is possible that
564 both anger film clips were emotionally appraised as eliciting a sufficient intensity of anger for
565 the establishment of emotion-regulation strategies. This regulatory effort interpretation of the
566 results is in line with the polyvagal theory (Porges, 1995; Porges, Doussard-Roosevelt, & Maiti,
567 1994; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996). This model postulates that

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

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

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

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

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