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The physiological signature of sadness: A comparison between text, film and virtual reality

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ABSTRACT

Studies focused on the ubiquitous emotion of sadness demonstrate substantial variability in physiological responses during sadness elicitation, with no consensus regarding the physiological pattern of sadness. Variability in findings could be attributed to (a) the use of different induction techniques across studies or (b) the existence of subtypes of sadness with distinct physiological activation patterns. Typically, studies have used text and film to elicit sadness. However, virtual reality (VR) confers advantages over more traditional methods by allowing individuals a subjective sense of "being there" or presence. We compared participants' physiological responses to the same narrative presented via VR, Film and Story ($n = 20$ each) and collected their subjective responses to the stimuli. Results confirmed that participants in all conditions experienced the discrete emotion of sadness. Moreover, participants in the VR condition experienced the highest degree of presence. Regarding psychophysiological responses, participants in the VR condition had the lowest degree of baseline-adjusted parasympathetic activation in comparison to participants in the Film condition. Furthermore, while participants in the VR group showed diminished baseline-adjusted respiration rate and parasympathetic activation with an increase in presence, the opposite pattern was true for participants in the other conditions. The data suggest that the VR condition may elicit an activating pattern of sadness; whereas Film and Story conditions may elicit a deactivating pattern of sadness. Our results have implications for research using the discrete model of emotion, highlighting that different emotion elicitation techniques may result in differing expressions of what is considered a unitary emotion.

1. Introduction

Emotions are transient, multifaceted experiences which are evoked as a result of an internal or external cue. The saliency of emotional experience is individually determined, and unfolds through an interconnected series of physiological responses, subjective sensations and expressive behaviours (Barrett, Gendron, & Huang, 2009; Ekman, 1992; Fernández et al., 2012). Sadness, alongside other emotions, plays an adaptive role in human life by facilitating social attachment and empathic responding. Despite decades of research into the psychophysiology of emotion, there has been no consensus as to the specific physiological pattern of sadness (Mauss & Robinson, 2009; Stephens, Christie, & Friedman, 2010). Previous studies identify a variety of physiological patterns during the elicitation of sadness (Gross & Levenson, 1995; Tsai, Levenson, & Carstensen, 2000). These discrepant findings could be explained by, (a) the use of different emotion induction techniques across studies, including techniques that may not adequately elicit naturalistic emotions (McGinley & Friedman, 2017; Quigley, Lindquist, & Barrett, 2014; Uhrig et al., 2016), and (b) varying physiological activation based on subtypes of a single discrete emotion (Kreibig, 2010; Shirai & Suzuki, 2017).

1.1. Conceptualizing sadness

Sadness is typically experienced as feelings of loneliness, rejection and helplessness, which as Kreibig, Wilhelm, Roth, and Gross (2007) suggest, might reflect a neurobiological reaction that helps facilitate and maintain group attachment and may prompt empathic responses. This is consistent with Panksepp and Biven (2012) conceptualization of sadness as a characteristic of separation anxiety, loss and grief, which positions sadness as an important factor for social attachment. Furthermore, dysregulation in sadness has been associated with various conditions,

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like major depressive disorder and complex bereavement (Lokko & Stern, 2014). Although the importance of understanding the psychological and physiological constituents of sadness has been demonstrated, research has consistently struggled to develop reliable methods of emotion elicitation in laboratory settings (Kreibig, 2010; Lindquist & Barrett, 2008; Mauss & Robinson, 2009).

1.2. Different emotion elicitation methods

Numerous induction methods have been developed in an attempt to elicit naturalistic emotions within laboratory settings (Gross & Levenson, 1995; Quigley et al., 2014; Uhrig et al., 2016). These methods include the use of static images, such as those from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008), short stories (Quigley et al., 2014) and film (Gross & Levenson, 1995). Some authors describe short stories as particularly useful in prompting empathic reactions in individuals, especially in comparison with static images. Stories help participants form personal, emotional connections with the text (Zupan & Babbage, 2016). Shirai and Suzuki (2017) study revealed that the more personally relevant emotional stories are, the more intense the emotional experience is. Moreover, their study also found that narratives around loss resulted in the highest sadness ratings. However, research has remained critical of the story method, claiming that it has very little real-life generalizability (Quigley et al., 2014). As such, film is favored as the most effective method of emotion elicitation (Uhrig et al., 2016).

Films offer a more intense and vivid representation of a story than text, and are able to recreate dynamic situations with visual and auditory components (Coplan, 2006; Gross & Levenson, 1995). Zupan and Babbage (2016) demonstrated that film was more effective than text in eliciting the target emotion of sadness. Although films have been considered ecologically valid in eliciting emotion (Ray & Gross, 2007), the introduction of VR has eclipsed the benefits film confers over text.

The primary benefit of using VR to elicit emotion is related to its unique capability to imitate the complexity and variability of real-world emotional reactions without compromising experimental control (Quigley et al., 2014). Previous studies have shown that VR elevates feelings of presence, the subjective perception of "being there" (Makowski, Sperduti, Nicolas, & Piolino, 2017); and higher levels of subjective presence have been associated with enhanced emotional experiences (Lessiter, Freeman, Keogh, & Davidoff, 2001). However, this research is still relatively new and there remains limited empirical evidence to support the benefits of using VR in emotion research.

Regarding the variability in physiological responses to sadness eliciting stimuli, McGinley and Friedman (2017) posit that the main source of discrepancy between studies is the use of different emotion elicitation techniques. Factors like ecological validity, immersion, presence, and sensory engagement all vary across emotion elicitation methods and thus, might potentially generate different psychological and physiological responses (Felnhofer et al., 2015; Parsons, 2015). VR studies which have measured presence have found it to be closely associated with arousal, which stands to reason that VR paradigms would differ in physiological reactivity to paradigms with low levels of presence like short stories (Ravaja et al., 2006). Therefore, assessing the physiological and psychological differentiation between conditions may reveal important insight into whether these emotion elicitation techniques do in fact elicit predictable autonomic response patterns (McGinley & Friedman, 2017).

1.3. Emotion subtypes of sadness

A *meta*-analysis conducted by Kreibig (2010) suggests that the variability in findings across studies could also be a result of emotion subtypes. Shirai and Suzuki (2017) differentiate between sadness experienced through failure versus loss. These findings are consistent with what Kreibig (2010) terms 'deactivating' sadness, relating to parasympathetic activation, and 'activating' sadness, relating to parasympathetic withdrawal. Activating sadness is more closely associated with imminent but not inevitable loss, where the individual has a sense of agency (exceptions include crying expressions of sadness, which may or may not be associated with inevitable loss, but are characterised by high levels of arousal (Sakuragi, Sugiyama, & Takeuchi, 2002)). Whereas, deactivating sadness is more closely associated with loss that has already occurred or is inevitable. For example, Rainville, Bechara, Naqvi, and Damasio (2006) used an autobiographical recall method where participants were asked to "relive" a target emotion; this passive recollection of sad events resulted in larger Respiratory Sinus Arrhythmia (RSA), aligning with a deactivating sadness.

Although there is some preliminary evidence supporting activating and deactivating psychophysiological subtypes of sadness, it is unknown whether different emotion induction techniques are more likely to elicit either activating or deactivating sadness. Based on the findings that VR environments tend to generate higher levels of presence and arousal, and tend to be constructed to include active engagement, it is reasonable to consider that this technique may be more likely to generate activating sadness. In contrast, film and story techniques, which are associated with lower levels of presence, arousal and agency, may be more likely to produce a deactivating pattern of sadness. There is some limited evidence in support of this hypothesis. For example, Chittaro, Sioni, Crescentini, & Fabbro, 2017 found that a VR generated funeral scene in a cemetery, in comparison to a picnic scene in a park, generated an activating sympathetic response (the authors did not measure parasympathetic responses). Comparatively, Kreibig et al. (2007) showed that two sad film clips tended to activate an increase in parasympathetic response, in contrast with two fear eliciting clips which were characterised by parasympathetic withdrawal. However, no study has conducted a direct comparison between emotion elicitation techniques regarding the induction of sadness.

The present study is, therefore, an extension of a line of research that explores the psychophysiological differentiation between emotion elicitation conditions of sadness (McGinley & Friedman, 2017). We additionally focus on how factors like presence can impact physiological responses.

2. Rationale and aims

The ambiguity in physiological responses to stimuli eliciting sadness may be explained by (a) the emotion elicitation technique, where techniques that have a higher degree of presence are associated with higher levels of physiological arousal and (b) different subtypes of sadness described as activating and deactivating. Regarding the latter, and in relation to presence, we sought to investigate whether the data supported two distinct subtypes of sadness, with our prediction being that for activating sadness a heightened sense of 'being-there' would be associated with parasympathetic withdrawal, while for a deactivating pattern of sadness immersion in the stimulus narrative would be associated with parasympathetic activation. We expect these distinct associations because activating sadness is conceptualised to include some agency in the experience of loss, while for deactivating sadness, there is little agency and loss is inevitable. To evaluate whether different emotion eliciting techniques would elicit activating versus deactivating subtypes of sadness we exposed participants to Story, Film and VR stimuli and tested the following hypotheses:

Manipulation check: For all three conditions (Story, Film and VR) participants will report sadness more frequently than other discrete emotions.

Primary hypotheses:

1) Participants experiencing the VR condition will demonstrate, in comparison to baseline, greater parasympathetic withdrawal, than participants in the Film or Story conditions.

2) Participants experiencing the VR condition will self-report higher levels of presence than participants in the Film or Story conditions.
3) Within the VR condition, participants that report higher levels of presence will experience greater parasympathetic withdrawal in comparison to participants with lower self-reported presence. In the Film and Story conditions, participants that report higher levels of presence will experience parasympathetic activation in comparison to participants with lower self-reported presence.

3. Methods

3.1. Participants

We recruited participants aged 18–25 years via a student research participation program. 190 participants responded to the online screening survey, with 110 individuals meeting criteria for participation. 30 eligible participants declined to participate in the study, 14 participants did not arrive for their scheduled appointment and 6 participants were excluded due to equipment failure. Of the final sample of 60 participants, 20 participants were allocated to each one of the three conditions: Story (Female = 14), Film (Female = 16) and VR (Female = 15).

3.2. Eligibility criteria

Participants were eligible to participate in the screening phase of the study if they were fluent in English; did not have a history of psychiatric or neurological conditions; and were not currently taking any psychiatric/chronic medication. Research suggests that depression and anxiety are associated with autonomic nervous system dysfunction which may evoke greater variability in physiological response (Fedor, Chau, Bruno, Picard, & Camprodon, 2016; Lin, Lin, Lin, & Huang, 2011). Moreover, the narrative throughout the different conditions may be particularly distressing to individuals suffering with depression (Slavich, Monroe, & Gotlib, 2011). Thus, to avoid distortion of data, individuals with depression, anxiety or PTSD were screened out of the study.

3.3. Measures

3.3.1. Screening phase. Beck depression Inventory-II (BDI-II)

The BDI-II is a widely used self-report instrument which consists of 21 questions used to assess and rate the severity of depression in individuals (Beck, Steer, & Brown, 1996). Participants were excluded from participation if they scored ≥ 21, which indicates moderate to severe depression. Research shows that clinically significant depressive symptoms fall in the moderate to severe range on the BDI-II (see e.g. Golin & Hartz, 1979; Jeong & Min, 2021).

3.3.2. State-Trait anxiety Inventory (STAI)

This STAI questionnaire comprises 20 questions, which were used to evaluate an individual's general anxiety symptoms (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). Scores ≥ 50 indicated moderate anxiety and these individuals were excluded from participation. Research shows that clinically significant symptoms of anxiety fall in the moderate to severe range on the STAI (see e.g. Valsamakis et al., 2017).

3.3.3. The 4-item primary Care Post-Traumatic Stress disorder screen (PC-PTSD)

In order to ensure that participants were not triggered by the content of the study, four yes/no questions were posed to determine whether participants had experienced any past traumas which might still be affecting them. Individuals who answered yes to three or more questions were excluded from the study (Prins et al., 2003)

3.3.4. Laboratory phase. ITC-Sense of presence Inventory (ITC-SOPI)

The ITC-SOPI is a questionnaire designed to assess presence for any stimulus medium (Lessiter et al., 2001). It comprises 44 items and is divided into Part A and Part B. There are four main factors: Spatial (19 items), Engagement (13 items), Naturalness (5 items), and Negative Effects (6 items).

3.3.5. Primary emotion Rating (PER)

Participants were asked to state their primary emotion after exposure to the emotion eliciting stimuli.

3.3.6. Physiological measures

The Biopac MP160 system was used to measure heart rate (HR), respiration rate (RR) and respiratory sinus arrhythmia (RSA) of participants during the laboratory phase of the study. Typically, and specifically in response to stimuli associated with deactivating sadness, there is a (a) decrease in HR, (b) decrease in RR and (c) an increase in RSA (Kreibig, 2010; Rainville et al., 2006). RR is often used in studies of emotion, because respiration spontaneously changes in response to emotional stimuli (Boiten, 1998; Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006), while RSA is a commonly reported measure of parasympathetic activity (Rottenberg, Wilhelm, Gross, & Gotlib, 2003).

3.3.7. Emotive stimuli

Previous research has demonstrated how narratives of loss have been most effective in eliciting sadness (Shirai & Suzuki, 2017). Therefore, we built a narrative based on the loss of a pet that was maintained across the Story, Film and VR conditions; see Supplementary Material for a more comprehensive description of each condition. The Story, Film and VR were all designed and created by the research team in order to keep the narrative as consistent as possible. While the overall narrative remained the same irrespective of the condition, the VR experience was designed in such a way as to promote interaction between the pet and the participant. Key moments of interaction included selecting one of three pets at the onset of the experience, throwing the ball that the pet would then retrieve and receiving the pet's ball from the vet at the end of the experience.

Each of the three conditions were all approximately 4 min in length.

Table 1
Sample characteristics and between-condition differences: (N = 60).

Variable	Group					
	Story	Film	VR			
	(n = 20)	(n = 20)	(n = 20)	F/χ^2	P	ESE
Age (years)				0.42	0.659	0.02
M (*SD*)	20.60 (1.27)	20.90 (1.62)	20.50 (1.40)			
Range	19–23	18–24	18–24			
Sex				0.17	0.918	0.05
Female	14 (70%)	16 (80%)	15 (75%)			
Male	6 (30%)	4 (20%)	5 (25%)			
First language				1.38	0.503	0.15
English	14 (70%)	17 (85%)	15 (75%)			
Other	6 (30%)	3 (15%)	5 (25%)			
BDI				0.02	0.979	0.00
M (*SD*)	8.15 (5.32)	8.10 (4.99)	7.85 (4.45)			
STAI				0.19	0.830	0.01
M (*SD*)	33.30 (6.26)	33.00 (7.42)	32.05 (6.66)			
PC-PTSD-4				0.67	0.517	0.02
M (*SD*)	0.75 (0.85)	0.80 (0.83)	0.55 (0.76)			

Note. For the variables *Sex* and *Home Language*, counts are presented with percentages in parentheses. *BDI* = Beck's Depression Inventory; *STAI* = State Trait Anxiety Inventory;
PC-PTSD-4 = Primary Care Post Traumatic Stress Disorder Screen; ESE = effect size estimate (in this case, η^2 for one-way ANOVA and Cramer's V for chi-squared tests of contingency).

Table 2
Univariate analysis of variance between baseline and pre-test measures across the three conditions ($N = 60$).

Variable	Condition			F	p	ESE
	Story	Film	VR			
	($n = 20$)	($n = 20$)	($n = 20$)			
Physiological Measures						
HR Baseline	83.80 (11.18)	82.92 (8.03)	82.34 (8.17)	0.13	0.881	0.00
RR Baseline	15.67 (1.30)	15 (0.99)	15.22 (1.77)	1.33	0.272	0.00
RSA Baseline	5.31 (1.22)	5.33 (1.11)	5.04 (1.46)	0.32	0.729	0.01

Note. Means are presented, with standard deviations in parentheses. ESE = effect size estimate (in this case, η^2 for one-way ANOVA). HR = heart rate; RR = respiration rate; RSA = respiratory sinus arrhythmia.

The three conditions were divided into 6 epochs of approximately 40 s in length, where epoch 3 to 6 represented the introduction of sad content (see the Supplementary Material for details of the epochs in all three conditions). For the Film and VR conditions there was no variation in the length of epochs, however, for the Story condition the epoch length was somewhat dependent on the participant's individual reading time (*SD* = 5.6). The Film and Story conditions were presented to participants via Eprime 2.0 (Psychology Software Tools, 2012, Pittsburgh, PA). Event markers sent from the E-prime programme to the Biopac denoted when a participant moved on to the next epoch in the story or film. The VR condition was presented using an Oculus Rift CV1 head mounted display (HMD). Manual event markers were used in the VR condition.

3.4. Procedure

The present study adhered to the ethical guidelines outlined by the Declaration of Helsinki. The study was granted ethical approval from the Ethics Committee in the Psychology Department at the University of Cape Town. All participants signed informed consent prior to study procedures.

After screening, each eligible participant was assigned, in consecutive order, to one of the three experimental conditions. Presentation of each condition took place in a sound and light controlled room in our laboratory. To avoid priming, participants were told that the focus of the study was on general emotions rather than sadness specifically (Lohse & Overgaard, 2017).

After familiarizing themselves with the soundproof room, participants were connected to the Biopac. In order to measure participant's electrocardiogram (ECG), three disposable electrodes (EL-500 electrodes from Biopac) were placed in a three-lead configuration as described elsewhere (Kreibig et al., 2007). The respiration belt transducer was positioned just under the sternum. After an initial few minutes that allowed physiological measures to stabilize we recorded baseline HR, RR and RSA. Participants then experienced one of the three emotion eliciting conditions. In order to maintain consistency across conditions participants remained seated for the course of the experiment. In the Story and Film conditions they were seated approximately one metre away from the computer screen, while for the VR condition this space was extended by approximately 0.5 m to allow for body movement (turning of the head, movement of arms) associated with that condition. The participants in the VR condition were equipped with the Oculus headset and a hand controller for their dominant hand. After the experiment they completed the PER and the ITC-SOPI. Before leaving the laboratory, the researcher debriefed each participant. Participants were compensated in the form of course credits relevant to their undergraduate courses.

3.5. Data management and statistical analyses

3.5.1. Data reduction of physiological measurements

All signals were sampled by a digital converter system MP150, Biopac Systems, set at 200 Hz. Aqcknowledge was used to extract data from the electrocardiogram (ECG) and RR channels to calculate HR, RR, and RSA. The ECG waveform was visually inspected for any artefacts and data was discarded if it exceeded 3 standard deviations above the mean.

3.5.2. Scoring of objective data

Baseline measures for physiological data were averaged over 3 min. Since, the different conditions were designed to be similar in length and reflect the same narrative, they all had six distinct sections/scenes (epochs). In order to establish the degree to which the emotional stimulus resulted in physiological change, we subtracted baseline

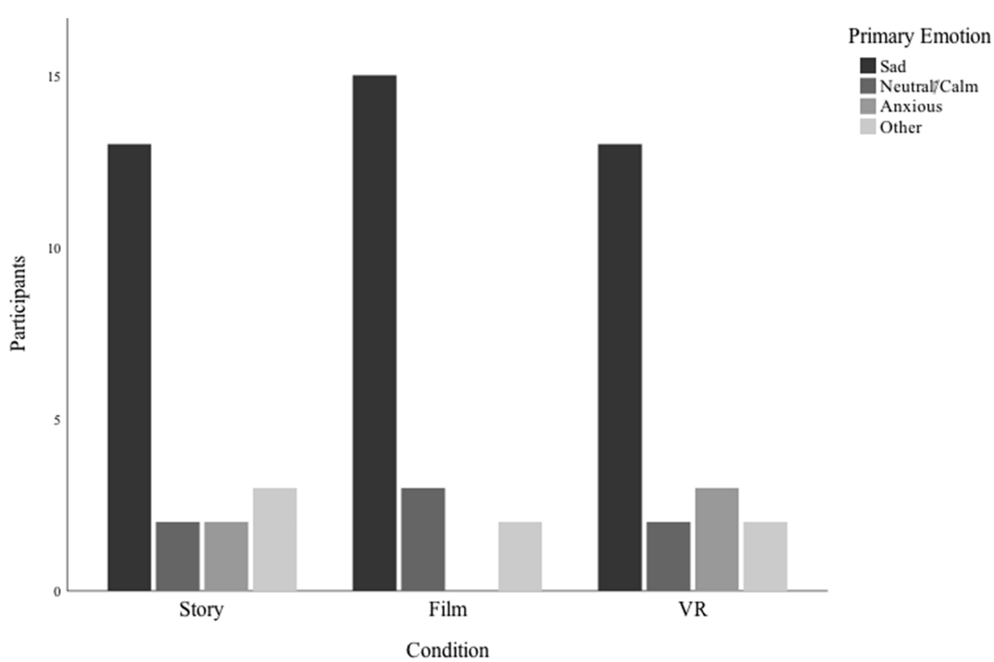

Fig. 1. The primary emotion reported on the PER. ($N = 60$).

Table 3
Between-condition comparison of physiological and subjective measures ($N = 60$).

Variable	Condition Story ($n = 20$)	Film ($n = 20$)	VR ($n = 20$)	F/H/U[b]	p	ESE
Multivariate Analysis[a]				2.95	< 0.001***	0.14
$HR_{E6\text{-}B}$	−2.15 (1.63)	−3.06 (2.97)	−1.38 (2.94)	3.86	0.145	0.07
Story versus Film				150	0.183	0.04
Story versus VR				179	0.583	0.01
Film versus VR				130	0.060	0.09
$RR_{E6\text{-}B}$	−1.78 (1.32)	−2.73 (1.95)	−0.53 (2.36)	9.08	<0.05*	0.15
Story versus Film				129	0.056	0.09
Story versus VR				143	0.127	0.06
Film versus VR				98	<0.01**	0.19
$RSA_{E6\text{-}B}$	1.54 (0.82)	2.73 (1.03)	−0.68 (2.28)	14.38	<0.001***	0.24
Story versus Film				72	<0.001***	0.30
Story versus VR				154	0.221	0.04
Film versus VR				90	<0.01**	0.22

Note. Means are presented, with standard deviations in parentheses. ESE = effect size estimate (η^2 for MANOVA and Kruskal Wallis; R^2 for Mann-Whitney). $HR_{E6\text{-}B}$ = heart rate epoch 6 – baseline; $RR_{E6\text{-}B}$ = respiration rate epoch 6 – baseline; $RSA_{E6\text{-}B}$ = respiratory sinus arrhythmia epoch 6 – baseline.
*$p < .05$. **$p < .01$. *** $p < .001$ (Bonferroni-corrected *p*-value)
[a] Because Box's M test of equality of covariance matrices was significant, Pillai's trace criterion was used
[b] Non-parametric post-hoc tests were used because homogeneity of variance was violated.

measurements of HR, RR, and RSA from the respective values measured for Epoch 6. These variables, termed $HR_{E6\text{-}B}$, $RR_{E6\text{-}B}$, and $RSA_{E6\text{-}B}$ were used for all subsequent analyses.

Inferential statistical analyses were completed using SPSS version 26, with α set at 0.05 for all decisions regarding statistical significance. We checked the assumptions underlying parametric tests and if not otherwise specified, they were upheld. Where violations to these assumptions occurred, we used nonparametric equivalent tests.

3.5.3. *Univariate analysis*

We conducted some preliminary analyses to ensure that the groups were matched on variables of mental status and demographics. Notably, three participants declared that they had not owned a pet prior to this experiment. The full statistical analysis was run with the sample excluding participants who had not owned a pet (N = 57); no significant differences were found and the original sample of 60 participants was retained. Furthermore, we also included BDI-II and STAI scores as covariates in MANOVA, ANOVA and GLM analyses, to test whether these psychiatric variables influenced the outcomes. Our findings showed no impact of these variables, and hence for reasons of parsimony, we do not include these variables in the reported analyses.

3.5.3.1. Manipulation check. Three chi-squared tests of goodness of fit (i.e. one for each condition), were used to assess whether sadness was reported significantly more frequently than the other discrete emotions from the Primary Emotion Rating (i.e. neutral, anxious, and other). Furthermore, a chi-square test of contingency was used to confirm that there were no significant differences in primary reported emotions between the Story, Film, and VR conditions.

3.5.3.2. Hypothesis 1: Comparing change in physiological arousal for Story, Film and VR. We used a one-way MANOVA to test the prediction that VR would elicit higher levels of physiological arousal in comparison to the Film and Story condition. To determine where the between-condition differences were found, we conducted Bonferroni corrected post-hoc one-way ANOVAs or non-parametric equivalents.

3.5.3.3. Hypothesis 2: Comparing self-reported presence for Story, Film and VR. To test the prediction that participants experiencing the VR condition would self-report higher levels of presence than participants in the other conditions, we conducted a one-way ANOVA or non-parametric equivalent and followed up significant results with planned orthogonal contrasts.

3.5.3.4. Hypothesis 3: Examining the interaction between condition and presence in predicting psychophysiological arousal. We ran three general linear models (GLMs) to determine whether within the VR condition a high degree of presence was associated with diminished parasympathetic activity in comparison with the Film and Story condition where a high degree of presence would be associated with parasympathetic activation. The outcome variables in these models were $HR_{E6\text{-}B}$, $RR_{E6\text{-}B}$, and $RSA_{E6\text{-}B}$. For each model the predictors were condition (Story versus Film versus VR) and self-reported presence. We examined the main effects as well as the interaction between the two variables, which was the predictor of interest.

4. Results

4.1. *Sample characteristics*

Table 1 shows that that the analyses found no significant between-condition differences in terms of age, sex, home language, BDI, STAI and PC-PTSD-4 score (all *ps* > 0.503).

4.2. *Assessment of baseline and pre-test differences.*

Table 2, shows the results of a series of one-way ANOVAs, which indicate that there were no significant differences between baseline and pre-test measures (all *ps* > 0.272).

4.3. *Manipulation checks to assess whether sadness was the primary reported emotion across conditions*

Three chi-square tests of goodness of fit showed that there was a significant within-group difference in the Story condition ($\chi^2 = 17.20$, $p < .001$), in the Film condition ($\chi^2 = 15.70$, $p < .001$), and in the VR condition ($\chi^2 = 17.20, p < .001$) for the primary reported emotion. A chi-square test of contingency confirmed that there were no significant differences ($\chi^2 = 3.57, p = .735$) between the conditions on the primary reported emotions. These results are illustrated in Fig. 1, which shows that the majority of people across conditions reported their primary emotion on the PER as sadness with very little variation across the three conditions.

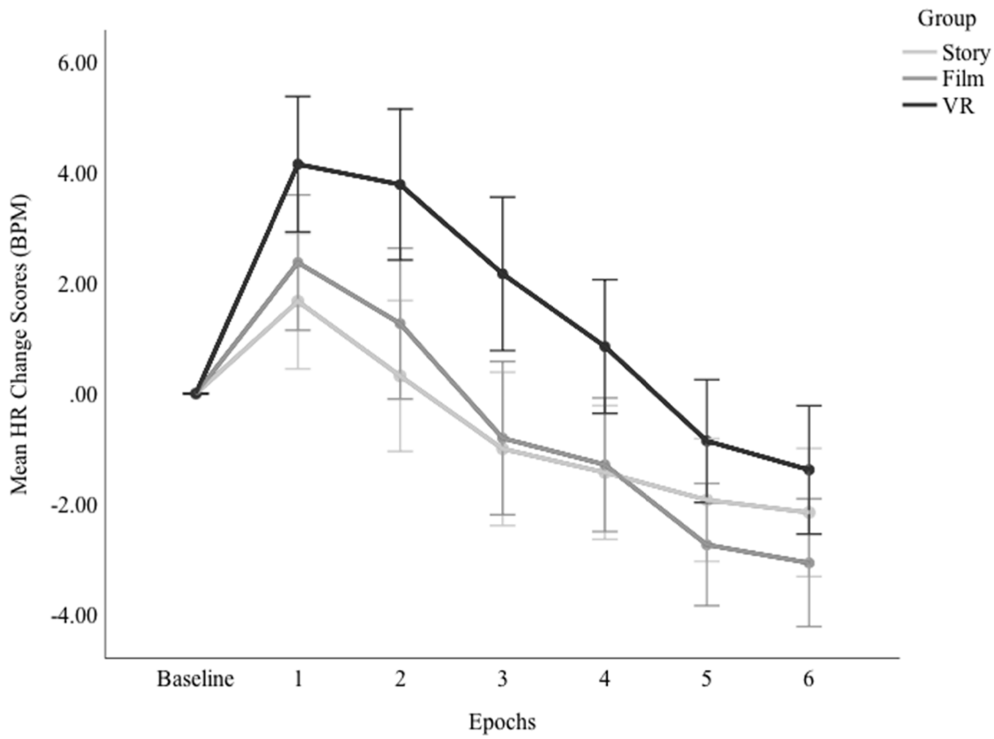

Fig. 2. Mean change scores in heart rate (HR) across the different conditions. Error bars represent the 95% confidence interval.

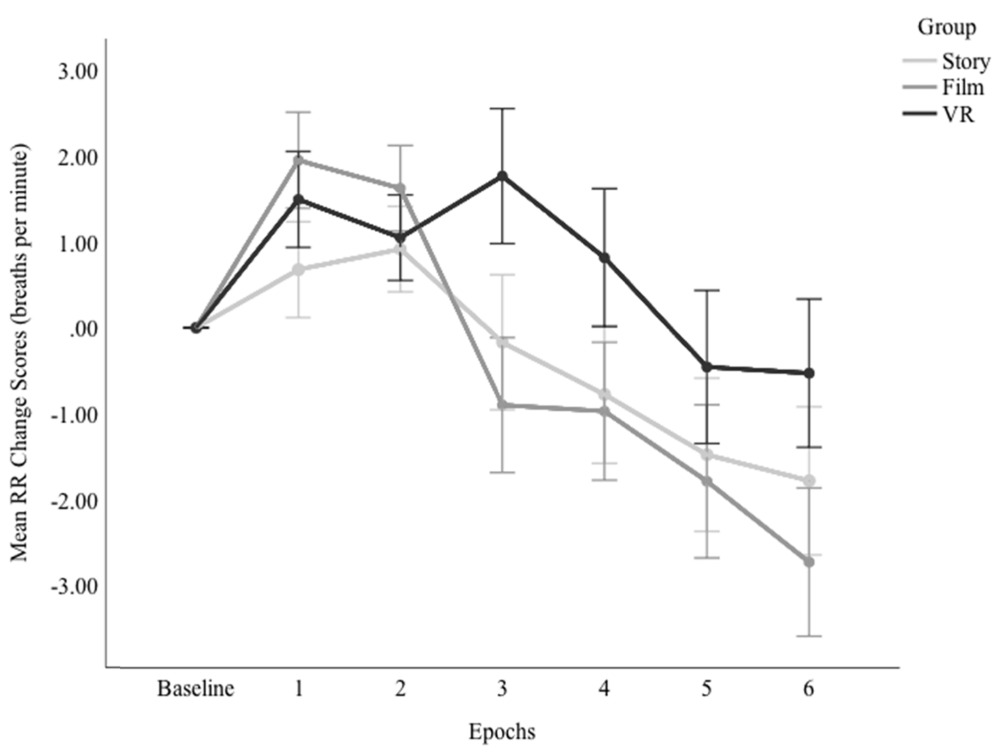

Fig. 3. Mean change scores in respiration rate (RR) across the different conditions. Error bars represent the 95% confidence interval.

4.4. Comparing change in physiological arousal for Story, Film and VR

Findings from the MANOVA analysis (Table 3) revealed that there were significant between-condition differences across the three dependent variables $HR_{E6\text{-}B}$, $RR_{E6\text{-}B}$, and $RSA_{E6\text{-}B}$.

Post hoc Kruskal Wallis tests revealed that there were significant between-condition differences for $RR_{E6\text{-}B}$ and for $RSA_{E6\text{-}B}$ but not for $HR_{E6\text{-}B}$. Bonferroni corrected post-hoc Mann-Whitney tests showed that regarding RSA: 1) participants in the VR condition had a smaller change in $RSA_{E6\text{-}B}$ than participants in the Film condition, and 2) participants in the Film condition had a larger change in $RSA_{E6\text{-}B}$ than participants in the Story condition. Regarding $RR_{E6\text{-}B}$ a similar pattern was observed as for $RSA_{E6\text{-}B}$, except that differences between the Film and Story conditions showed trend-level significance. The results indicate that

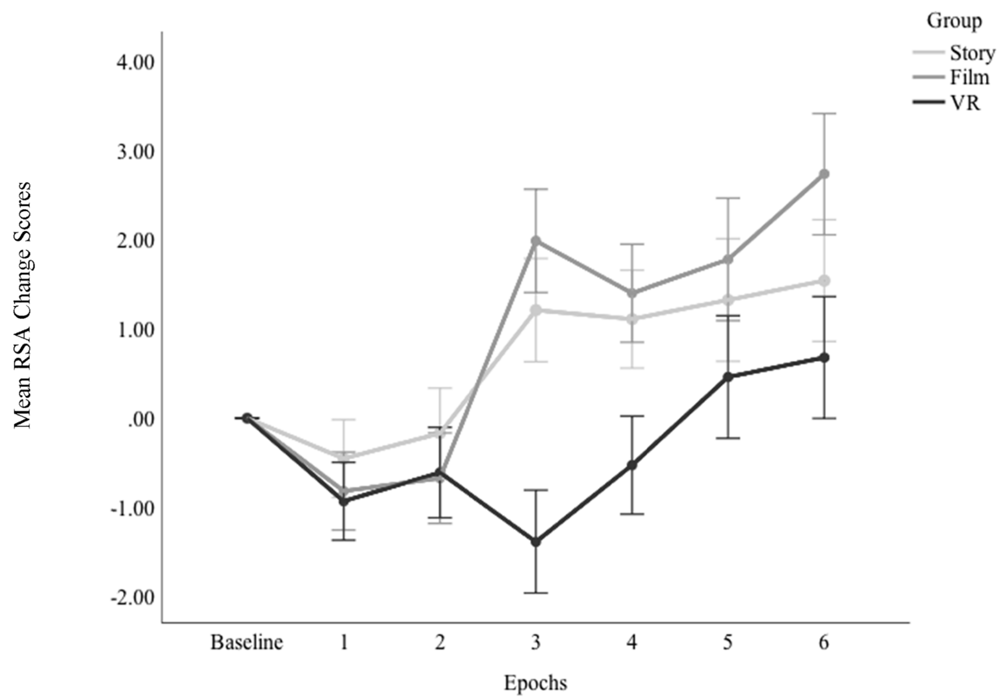

Fig. 4. Mean change scores in respiratory sinus arrhythmia (RSA) across the different conditions. Error bars represent the 95% confidence interval.

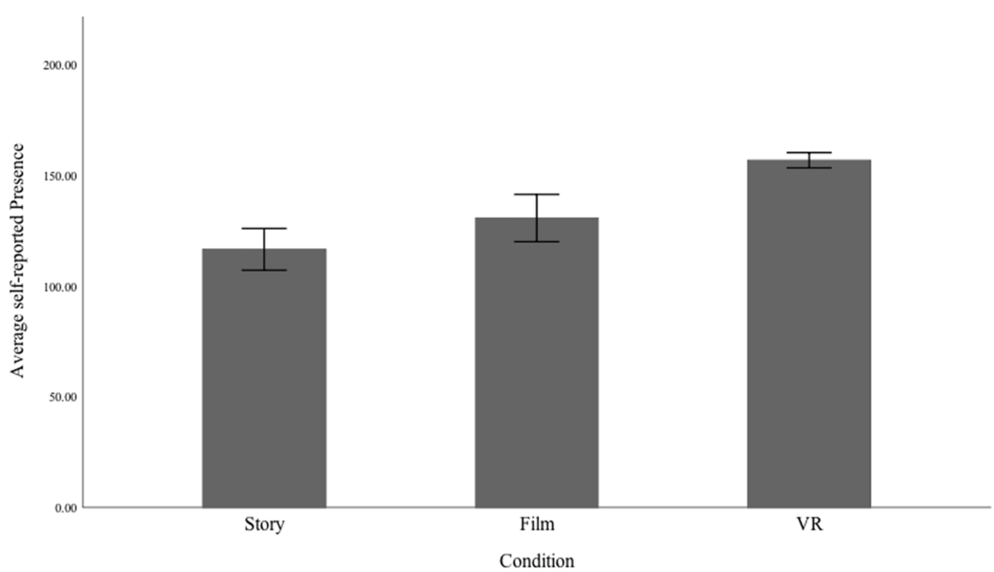

Fig. 5. The mean scores for subjective presence levels between conditions. Error bars represent the 95% confidence interval.

participants in the VR condition had the lowest degree of parasympathetic activation in relation to baseline in comparison to participants in the Film condition. The differences in physiological arousal patterns between conditions is represented graphically in Figs. 2–4.

4.5. Comparing self-reported presence for Story, Film and VR

Based on a Kruskal Wallis test that accounted for the violation of homoscedasticity we found significant differences in presence between the Story ($M = 116.6$, $SD = 20.13$), Film ($M = 130.75$, $SD = 22.84$) and VR ($M = 156.90$, $SD = 7.40$) conditions, $H\,(2) = 31.36$, $p < .001$, η^2 0,52. Follow-up Bonferroni-corrected Mann Whitney analyses showed that participants in the VR condition experienced a higher degree of presence than participants in the other conditions, (Story and VR: $U = 2$, $p < .001$, r = 0,85; Film and VR: U = 61.50, p < .001, r = 0,55), and that participants in the Film condition experienced a higher degree of presence than participants in the Story condition, ($U = 126.50$, $p = .015$, $r =$ 0,31; Fig. 5).

4.6. Predicting psychophysiological arousal using the interaction between condition and presence

We ran three GLMs to determine whether VR-experiencing participants, in contrast to the other participants, responded to the sadness protocol with an activating rather than deactivating pattern of physiological response. To this end, we evaluated the interaction between condition (Story, Film, and Story) and presence in predicting $HR_{E6\text{-}B}$, $RR_{E6\text{-}B}$, and $RSA_{E6\text{-}B}$. For $RR_{E6\text{-}B}$, and $RSA_{E6\text{-}B}$ the interaction between condition and presence was significant (Tables 4-6; Figs. 6-8). The interactions were associated with medium to large effect sizes. Figs. 7 and

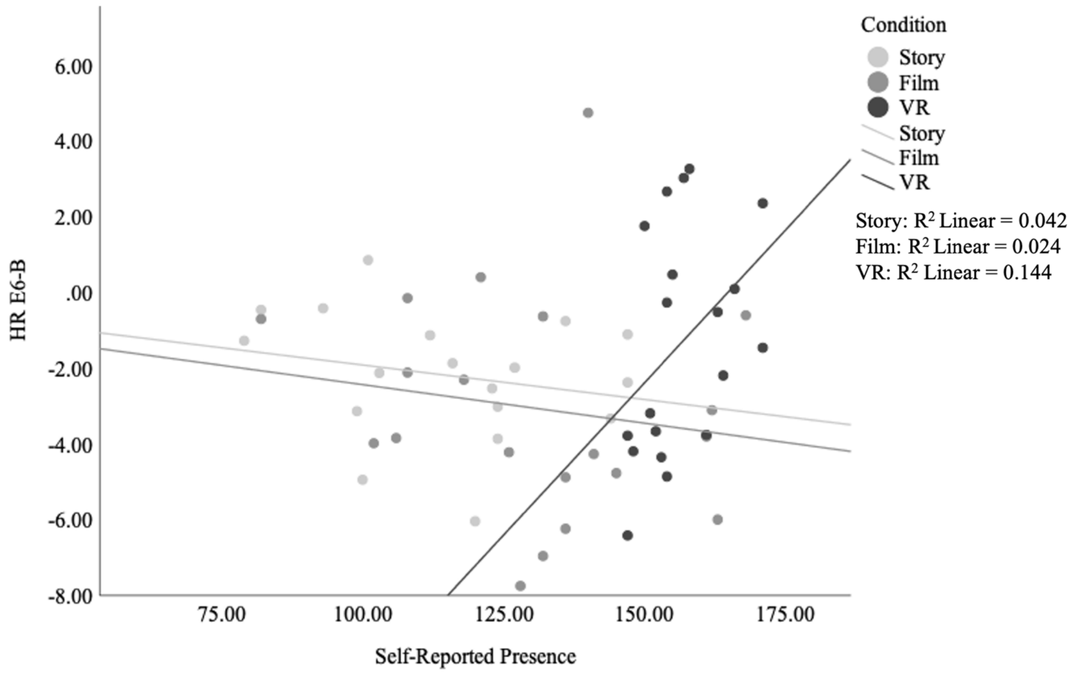

Fig. 6. Interaction between presence and the three conditions in predicting HR.

Table 4
General Linear Model: variation in $HR_{E6\text{-}B}$ predicted by condition and presence.

Variable	Type III SS	MS	F	p	ESE
Corrected Model	58.27	11.65	1.79	0.131	0.14
Condition	24.86	12.43	1.91	0.159	0.07
Presence	10.91	10.91	1.67	0.202	0.03
Condition*presence	28.28	14.14	2.17	0.124	0.07

Note. The categorical variable condition represents the Story, Film and VR conditions. SS = sum of squares; MS = mean square. ESE = effect size estimate (in this case, η^2 for one-way ANOVA). $HR_{E6\text{-}B}$ = heart rate.

Table 5
General Linear Model: variation in $RR_{E6\text{-}B}$ predicted by condition and presence.

Variable	Type III SS	MS	F	p	ESE
Corrected Model	75.48	15.10	4.41	0.002**	0.29
Condition	22.03	11.01	3.22	0.048*	0.11
Presence	10.75	10.75	3.12	0.082	0.06
Condition*presence	25.81	12.90	3.77	0.029*	0.12

Note. The categorical variable condition represents the Story, Film and VR conditions. SS = sum of squares; MS = mean square. ESE = effect size estimate (in this case, η^2 for one-way ANOVA). $RR_{E6\text{-}B}$ = respiration rate
*$p < .05$. **$p < .01$.

Table 6
General Linear Model: variation in $RSA_{E6\text{-}B}$ predicted by condition and presence.

Variable	Type III SS	MS	F	p	ESE
Corrected Model	67.86	13.57	6.88	<0.001***	0.39
Condition	23.05	11.52	5.84	0.005**	0.18
Presence	19.68	19.68	9.97	0.003**	0.16
Condition*presence	22.65	11.33	5.74	0.005**	0.18

Note. The categorical variable condition represents the Story, Film and VR condition. SS = sum of squares; MS = mean square. ESE = effect size estimate (in this case, η^2 for one-way ANOVA). $RSA_{E6\text{-}B}$ = respiration sinus arrhythmia
*$p < .05$. **$p < .01$. ***$p < .001$.

8 show that a decrease in baseline-adjusted respiration rate and parasympathetic activation was associated with an increase in the presence experienced by participants in the VR condition, while the opposite relationship was evident for participants in the Story and Film conditions. Overall, for $RR_{E6\text{-}B}$ the model accounted for 29% of the total variance, and for $RSA_{E6\text{-}B}$ the model accounted for almost 39% of the total variance (Tables 5 and 6). For $HR_{E6\text{-}B}$ while neither the interaction between condition and presence, nor the model were significant. Fig. 6 shows that the relationship between $HR_{E6\text{-}B}$ and presence followed the trend of $RR_{E6\text{-}B}$, and $RSA_{E6\text{-}B}$. While participants in the VR condition had increased baseline-adjusted HR with increased presence, participants in the other two conditions showed the opposite association.

5. Discussion

The present study set out to investigate whether different sadness eliciting stimuli evoke differential physiological responses; namely, ‘activating’ or ‘deactivating’ patterns of physiological arousal. ‘Activating’ sadness is expressed by greater sympathetic activation or parasympathetic withdrawal, whereas ‘deactivating’ sadness is characterised by greater parasympathetic activation. We aimed to determine whether these two discrete expressions of sadness were associated with specific emotion eliciting techniques. Hence, we analysed psychophysiological responses to a Story, Film, and VR experience.

First, we aimed to determine whether participants experiencing the VR condition would demonstrate a greater change, from baseline, in physiological arousal relative to participants in the Film or Story conditions. This hypothesis was partly confirmed - participants in the VR condition had a lower degree of parasympathetic activation in relation to baseline (parasympathetic withdrawal) than participants experiencing the Film condition, but not in comparison with those experiencing the Story condition. Secondly, we aimed to assess whether participants experiencing the VR condition would report higher levels of presence than participants in the Film or Story conditions. This hypothesis was confirmed. Lastly, we assessed whether participants in the VR condition would demonstrate an arousing physiological response with high levels of presence while participants in the other two conditions would show a parasympathetic dominant response pattern with high levels of presence. Our data supported this hypothesis.

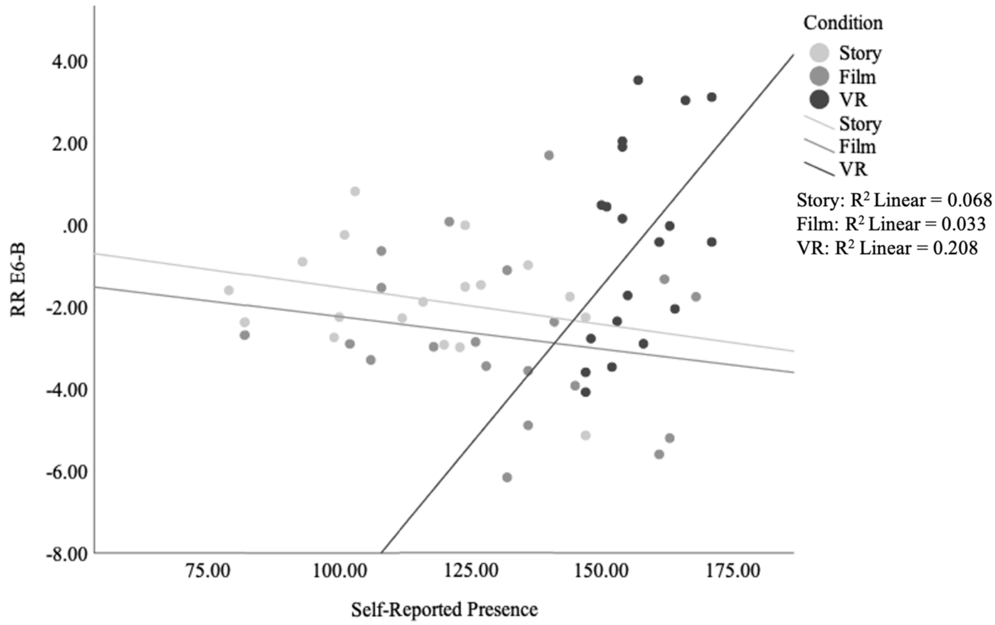

Fig. 7. Interaction between presence and the three conditions in predicting RR.

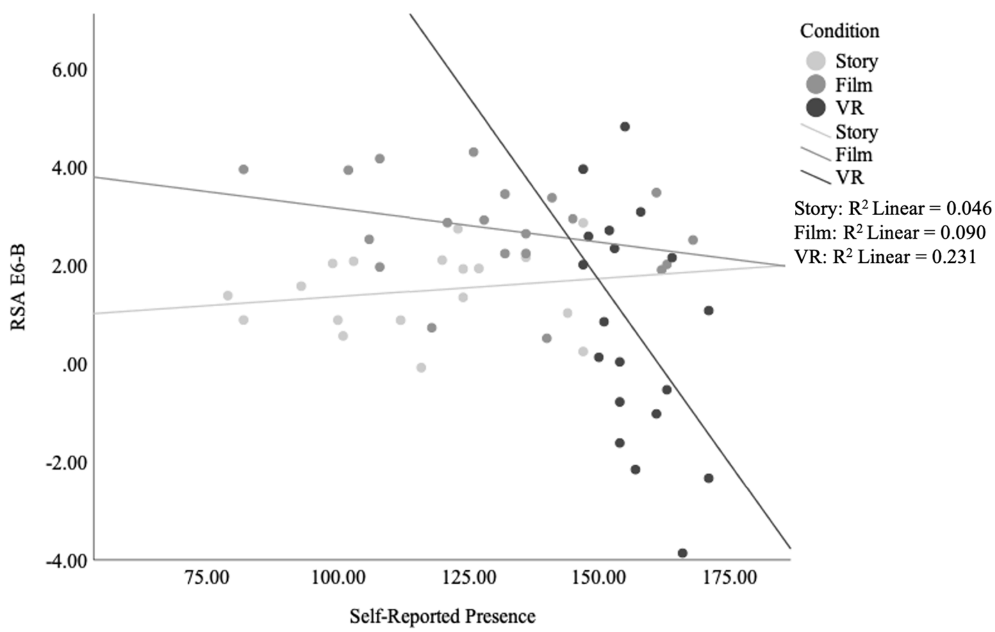

Fig. 8. Interaction between presence and the three conditions in predicting RSA.

5.1. Different techniques result in different patterns of physiological arousal

Numerous studies have looked at physiological arousal patterns elicited in response to discrete categories of emotion (Christie & Friedman, 2004; Kreibig, 2010). Within these categories, and especially regarding sadness, studies have shown discrepancies in physiological arousal (Kreibig et al., 2007). With regard to the origin of these discrepancies, very few studies have assessed whether the emotion induction method used to elicit the physiological emotion pattern contributes to the inconsistent findings (Kreibig et al., 2007; McGinley & Friedman, 2017)

Our study confirmed that different emotion eliciting techniques result in divergent physiological arousal, even when the content of each stimulus is controlled across all methods. A comparison of participants' psychophysiological reactions elicited by the VR versus Film condition showed that (a) participants in the VR condition experienced parasympathetic withdrawal and elevated respiration rates, consistent with an activating pattern of sadness, while (b) participants in the Film condition, experienced parasympathetic activation, and reduced respiration rates, consistent with a deactivating pattern of sadness. While, the Story condition did reflect a similar deactivating pattern, parasympathetic activation was not significantly elevated relative to the VR condition. Although other studies describing physiological arousal in response to sad stimuli have not directly compared different emotion eliciting techniques, studies using films clip which employ narratives of loss show a deactivating pattern of sadness with decreased HR, respiration and elevated parasympathetic activity (Shirai & Suzuki, 2017). Conversely, studies using stories and film clips that employed narratives of failure, which suggest some propensity towards agency, have been associated with an activating pattern of sadness with increased HR, respiration and parasympathetic withdrawal (Herrera, Jordan, & Vera, 2006; Kreibig, 2010).

The findings from these previous studies suggest that the elicitation of activating versus deactivating patterns of sadness may not be entirely dependent on the emotion eliciting technique used, but rather on whether individuals feel a sense of agency while experiencing sadness. Therefore, where sadness eliciting content evokes a greater degree of agency, we may expect an activating pattern of response. Our findings suggest that irrespective of the content of the stimulus (since the content remained constant throughout our study and was centred on a narrative of loss), the emotion eliciting environment strongly and differentially influences the physiological expression of sadness.

5.2. The relationship between presence and physiological responses to sad stimuli

The degree of presence may be an important explanatory factor underpinning the distinct patterns of psychophysiological response elicited by the virtual, film and text environments. We speculate that presence influences an individual's ability to effect change in a situation, that is, their agency. The Film and Story conditions were passive experiences where individuals were unable to exert agency on the unfolding situation, therefore, making loss appear inevitable. In contrast, participants in the VR condition were able to interact with the environment in a way which may have made the loss seem avoidable. For example, participants were able to follow the dog when it ran off towards the road and were able to move around at the vet, both actions associated with an ability to influence the environment. The ability to enact change and exert agency in a given context is likely to be an important factor in determining the physiological response patterns, and would, therefore, be directly connected to the levels of presence that an individual experiences. This is supported by previous studies which have identified an intimate connection between agency and presence (Herrera et al., 2006) and that this relationship is robustly evident in the VR environment (Freeman et al., 2005; Jicol et al., 2020; Sekhavat & Nomani, 2017).

A competing theory which may also explain why participants in the VR condition showed an activating pattern of sadness in comparison with participants in the other conditions, relates to the orienting response that is elicited during novel experiences (Meehan & Brooks, 2001). The orienting effect posits that individuals who experience or see something novel will experience elevated physiological arousal (Meehan & Brooks, 2001). The virtual environment is likely to have been more novel to participants than the other conditions. However, our findings demonstrate that changes in psychophysiology in all the conditions were evident from epoch three onwards (i.e., when the sad content was presented and not during the initial exposure to the environment). This suggests that although novelty may influence physiological arousal in many contexts, in our experiment the response to the emotive content was stronger than the orienting effect.

6. Limitations and future directions

The most notable limitation of this study was the lack of a measure of sympathetic activation (such as pre-ejection period or low frequency to high frequency heart-rate variability ratio), to directly gauge whether participants were experiencing an increase in sympathetic tone, which would strengthen the interpretation of an activating pattern of sadness. However, in-line with previous studies, most research eliciting sadness has measured parasympathetic activation (Kreibig et al., 2007). We wanted our research to be comparable with previous studies and, therefore, opted for this measure.

Furthermore, to maintain consistency across all the conditions, participants remained seated throughout each of the protocols. This may have blunted the immersive and interactive elements of the VR experience specifically (Meehan & Brooks, 2001; Parsons, 2015). Despite this limitation our findings demonstrated that the VR protocol still elicited the highest level of presence in comparison with the other conditions.

A promising avenue of development regarding our understanding of the subtypes of sadness lies in research that integrates participants' emotional experiences, psychophysiological expression, neural substrates and the development of psychopathology. For example, there is evidence that depression, the psychiatric disorder characterised by exaggerated sadness or depressed mood, is in the initial stages of emergence characterised by separation distress or panic, a highly aroused state mediated by increased noradrenergic activity originating in the locus coeruleus (Zellner, Watt, Solms, & Panksepp, 2011). This state may be compared to activating sadness. During this stage the individual is motivated (has agency) to resolve the distress (Watt & Panksepp, 2009). However, as depression evolves, the individual's emotional state is characterised by a withdrawal from engagement in the world mediated by decreased dopaminergic activity originating in basal forebrain regions, suggestive of a deactivating pattern of sadness (Panksepp, 2011). During this stage the feeling of loss is inevitable and there is little agency to resolve the distress. Future research should tie together these various aspects (phenomenological experience, psychophysiology and neurobiology) within a single experiment, using technological methodologies that can elicit activating and deactivating sadness reliably.

7. Conclusion

This study aids in consolidating our understanding of the discrete model of emotion, which is widely drawn upon by many investigators. Our findings show that within a single discrete category, opposing physiological patterns describe different expressions of that emotion. Specifically regarding sadness, our results demonstrated an activating and deactivating pattern of physiological arousal in response to sadness eliciting content. These differing patterns of physiological responses are accounted for by the degree of presence experienced by an individual. Moreover, the degree of presence elicited by the narratives differed according to the emotion eliciting technique. The high level of presence that the virtual environment cultivates is likely to result in an activating pattern of sadness. In comparison, the film and story condition were characterised by lower levels of presence and a deactivating pattern of sadness.

These findings have implications for research using the discrete model of emotion, highlighting, firstly, that both the emotion elicitation technique and contextual factors may result in differing expressions of what is considered a unitary emotion. Secondly, the research shows that previous discrepant findings in physiological expressions of discrete emotions can be accounted for predictably and systematically. Thirdly, our findings highlight the capacity of virtual environments as a powerful aid in both eliciting and capturing first-person immersive emotional experience. Lastly, we hope that a thoughtful interrogation of the biological underpinnings of emotion will help bridge the expanse between subjective emotional experience and physiological expression.

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CRediT authorship contribution statement

Gina Gilpin: Conceptualization, Data curation, Formal analysis, Project administration, Writing - original draft, Writing - review & editing. **James Gain:** Software, Supervision, Writing - review & editing. **Gosia Lipinska:** Conceptualization, Funding acquisition, Resources, Supervision, Visualization, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bandc.2021.105734.

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