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Emodiversity in social interactions. Dissecting affect, physiology and behavior

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Abstract
Experiencing an abundance of positive and negative emotions (emodiversity) can predict better outcomes than positive or negative emotions in separation. We tested whether state and trait emodiversity influence behavior in challenging social situations and whether this link is mediated by parasympathetic activation. Two hundred ten undergraduate students reported their emotions from the preceding month and were then randomly assigned to one of four movie-clip conditions: emodiverse (varied positive and negative emotions), positive emotions, negative emotions, or neutral. Afterward, participants engaged in an ultimatum game involving an uneven monetary split. They had to decide either to accept the offer, which would be a prosocial act financially benefit the proposer, or reject it, which would financially harm the proposer. Electrocardiogram, hemodynamic, and respiratory response were recorded continuously. We found that emodiversity, whether temporary or long-term, did not affect participants' social decisions or physiological responses. Contrary to the emodiversity hypothesis, we found more straightforward effects. First, inducing negative emotions adversely affected participants' affect and increased their likelihood of rejecting the offer. Second, participants with higher positive affect, greater parasympathetic activation, and faster breathing rates were more likely to accept the offer. In summary, we found little support for the proposed benefits of emodiversity. Instead, our findings highlighted well-established affective and physiological effects (i.e., parasympathetic activation), demonstrating that positive emotions were associated with increased prosocial behavior, whereas negative emotions reduced it.

Keywords Emotions · Psychophysiology · Social interaction · Parasympathetic activity · Emodiversity

Introduction

For over a century, research in psychology has aimed to examine the function of emotions in human life. Early research primarily explored the negative impact of negative emotions and the advantages of positive emotions (Fredrickson et al., 2003). More recently, researchers have highlighted the importance of experiencing a variety of positive and negative emotions as a key factor in well-being. This phenomenon, known as emodiversity, suggests that a rich emotional repertoire in emotional experience might be healthier than an abundance of only positive emotions (Quoidbach et al., 2014).

We aimed to test the emodiversity hypothesis by examining whether higher emodiversity is connected to better psychological and physiological outcomes than emotional experiences dominated by either positive or negative valence (Quoidbach et al., 2014; Wang et al., 2021). Using a social game with monetary incentives, we sought to examine whether emodiversity would lead to better physiological outcomes indicative of better emotional regulation and more prosocial actions. These findings could inform applied contexts for emotions regulation in such as conflict resolution in workplaces, education, or interpersonal relationships.

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Emodiversity definition and theoretical basis

Emodiversity refers to the variety and relative abundance of emotions that humans experience. It draws from the idea of biodiversity in natural ecosystems, suggesting that a diverse emotional life, including positive and negative emotions, can contribute to overall well-being (Quoidbach et al., 2014). This concept is intriguing because it reaches beyond the hedonic perspective, where individuals ought to seek positive emotions while minimizing negative ones. It also contradicts many studies that indicated the adverse effects of negative emotions on health (Renna, 2021).

On a theoretical level, emodiversity could allow for a richer emotional life, which can provide individuals with a broader range of emotional tools to handle life's challenges, compared to relying solely on positive emotions (Quoidbach et al., 2014). Diversity in emotions might help individuals better navigate complex emotional landscapes, improving emotional regulation and resilience (O'Toole et al., 2020).

Individuals with broader positive and negative emotions might have more nuanced and accurate information about their social environment (Grossmann et al., 2019; Hoemann et al., 2023). In contrast, when individuals experience lower emotions of either kind, they might be disengaged with their environment and thus less likely to cope effectively and succeed (Kashdan & Rottenberg, 2010).

Moreover, individuals with high levels of positive and negative emotions might be more experienced in managing emotions as they have had more general and more recent opportunities to exercise emotion regulation (Quoidbach et al., 2014). This might also include the physiological adaptation to emotional episodes necessary to cope effectively (Yeager et al., 2022). Thus, emodiverse individuals might use positive and negative emotions more effectively (Grossmann et al., 2019). This might give them an advantage in emotionally engaging scenarios such as those related to social conflict.

Empirical evidence for the emodiversity

Studies have linked emodiversity to reduced inflammation (Ong et al., 2018), better reasoning about life events (Grossmann et al., 2019), lower hospitalization rates (Quoidbach et al., 2014), improved mental health (Minusa et al., 2023; Forster & Lougheed., 2023), and greater happiness (Vuillier et al., 2018). However, some results are mixed. For example, some studies find that only positive emotional diversity correlates with well-being (Yoon & Kim, 2024), while negative emotional diversity predicts poor outcomes such as depression, anxiety, and physical health problems (Urban-Wojcik et al., 2022; Heshmati et al., 2023).

These mixed findings suggest that the benefits of emodiversity may depend on the balance of positive and negative emotions, with positive emotions playing a particularly critical role. This highlights the need for studies that go beyond self-report measures to include physiological data in emotionally engaging scenarios (Blascovich et al., 2011).

Emotions and social behavior

Emotions are deeply intertwined with social interactions (Blascovich et al., 2011). They arise from appraisals of goal-relevant situations and involve changes in subjective experience, behavior, and physiology (Blascovich et al., 2011). The effects of emotions on social behavior are complex. When negative emotions arise, individuals tend to exhibit fewer prosocial behaviors (Kaczmarek et al., 2021) and an increased likelihood of antisocial actions (Birkley & Eckhardt, 2015). Conversely, research has documented the "feel-good, do-good" effect, indicating that positive emotions - whether transient emotional states or enduring affective traits - promote prosocial behaviors (Li et al., 2024) and mitigate antisocial tendencies (Pond et al., 2012).

This phenomenon likely emerges because positive emotions redirect individuals' attention from self-focused concerns toward the needs of others, enhancing awareness and fostering a more favorable perception of others' intentions (Fredrickson et al., 2003). In contrast, negative emotions frequently result in inward-directed attention toward personal interests, thereby diminishing the positive appraisal of others (Fredrickson et al., 2003). Additionally, individuals experiencing positive emotions often seek to preserve their pleasurable emotional state, thus inclined to avoid social conflicts that might disrupt their hedonic experience (Fredrickson et al., 2003).

However, more nuanced studies indicate the complexity of the overall relationship between emotions and social behavior, extending beyond the notion that positive emotions boost prosocial behavior and negative emotions suppress it. For instance, a negative-state relief mechanism can lead to more prosocial behavior after experiencing negative emotions. Namely, moral emotions, such as shame, which involve the experience of intense displeasure, are likely to motivate prosocial behavior toward strangers so that the emotion could be reduced (Li et al., 2024). This shame-relief mechanism has also been observed in economic games (Ketelaar & Au, 2003).

Research on emotion regulation has predominantly concentrated on downregulating negative emotions (Webb et al., 2012). However, upregulating positive emotions can significantly enhance daily experiences. Savoring strategies such as capitalizing—communicating and celebrating positive events with others—can strengthen social bonds (Quoidbach et al., 2010). As the effects of emotions on prosocial behavior are complex, the effect of emodiversity on

social behavior might also be complex. For instance, individuals with an abundance of emotions in life can be better at differentiation and understanding of emotions. This, in turn, could lead to lower aggressive impulses when angry, indicating better emotion regulation in social conflicts (Pond et al., 2012). Moreover, a diverse emotional profile may build emotional resilience. Experiencing a variety of emotions, including negative ones, can "immunize" individuals against social stress by broadening their coping strategies (Quoidbach et al., 2014). Finally, emodiversity involves emotional granularity, i.e., distinguishing between emotional experiences (Hoemann et al., 2023; Quoidbach et al., 2014). Enhancing emotional granularity leads to increases in altruistic behavior, as measured with economy games (Ortiz Pérez, 2023).

Autonomic nervous system

The autonomic nervous system (ANS) is central to emotional and social processes (Appelhans & Luecken, 2006). It regulates involuntary functions such as heart rate, blood pressure, respiration, and sweating. The ANS has two main branches: the sympathetic branch, which activates the body for fight-or-flight responses, and the parasympathetic branch, which promotes rest and recovery through vagal activity (Blascovich et al., 2011).

Parasympathetic activation, particularly vagal tone, has been linked to beneficial outcomes such as emotion regulation (Balzarotti, 2017), and health (Kok & Fredrickson, 2015). For example, the vagus nerve may facilitate flexible responses to social challenges, enabling more moderate judgments and fostering prosocial behavior (Porges, 2007). Thus, understanding emotions and social behavior may require a broad examination of physiological responses, explicitly focusing on parasympathetic activity as a potential mediator.

The physiological responses related to emodiversity have not been addressed explicitly so far. Nevertheless, several related affective processes suggest a possible link between emodiversity and vagal tone. For instance, emotion differentiation or granularity, a concept involved in emodiversity (Quoidbach et al., 2014), is related to the parasympathetic activity (Hoemann et al., 2021). Namely, people who experience more differentiated emotions tend to have a higher vagal tone. Increased parasympathetic activity (the vagal break) could provide more physiological calm, allowing more nuanced introspection rather than being overwhelmed by escalating physiological arousal. The role of emotional granularity observed on a trait level also translates into benefits from interventions suggesting a state-like and possible causal component related to vagal tone (Hoemann et al., 2021).

The ultimatum game

To study emodiversity in a meaningful context, we used the ultimatum game, a classic paradigm for examining social dilemmas (Bearden, 2001). In this game, participants decide whether to accept a monetary offer (e.g., receiving less than an even split) or reject it, resulting in no reward for either party. The game elicits moral emotions about fairness and injustice, influencing decision-making (Bearden, 2001). Accepting an uneven offer can be seen as a prosocial act, as it leads to agreement, and both parties benefit. However, it requires overriding the immediate negative emotional response to being offered less than might be usually expected. In contrast, rejecting the offer leads to social conflict as no one financially benefits. Parasympathetic activation tends to support this type of prosocial behavior where emotion regulation is critical (Appelhans & Luecken, 2006).

Trait and state emodiversity can influence decision-making in the Ultimatum Game through several mechanisms, including enhancing emotional granularity, cognitive flexibility, and physiological regulation. Specifically, emotional granularity could enable more precise differentiation and better regulation of emotional responses to perceived unfairness, helping individuals manage impulsive retaliatory reactions (Hoemann et al., 2023; Quoidbach et al., 2014). Increased cognitive flexibility associated with emodiversity could allow individuals to reframe and re-assess an uneven monetary split leading to more acceptance and prosocial behavior (Fredrickson et al., 2003). Furthermore, individuals with higher emodiversity could benefit from greater parasympathetic activation, facilitating calmer physiological states that could mitigate immediate negative emotional arousal, thus promoting social agreement rather than conflict (Balzarotti, 2017; Porges, 2007).

The present study

We aimed to test the emodiversity theory by comparing how individuals respond under the influence of positive emotions, negative emotions, or a variable combination of both (emodiversity). We focused on a subjective, physiological, and behavioral response to a social challenge. Based on the theory and research in emodiversity (Quoidbach et al., 2014), we expected that individuals with greater emodiversity would produce a more favorable response. Namely, we expected that individuals in a more emodiverse affective state would present more prosocial behavior by accepting the uneven financial offer (Grossmann et al., 2019; Hoemann et al., 2023). We also expected that individuals with more emodiverse experience (trait-like measurement based on emotions experienced during the last month) would be more prosocial and accept the offer. Moreover, we expected

that emodiversity (on a state-like and trait-like level) would be related to higher parasympathetic activity in the social situation and that parasympathetic activity would mediate between emodiversity and the prosocial outcome (Appelhans & Luecken, 2006; Balzarotti, 2017). Based on prior concurrent research and theory, we also expected that positive emotions would elicit favorable behavioral (accepting the offer) and physiological (higher vagal tone) responses (Fredrickson et al., 2003; Kok & Fredrickson, 2015), whereas negative emotions would produce unfavorable responses (Birkley & Eckhardt, 2015; Kaczmarek et al., 2021), relative to neutral controls.

Method

Participants

The study involved 210 participants (51% women) between 18 and 35 (M=21.52, SD=2.65). Exclusion criteria for the study included a diagnosis of cardiovascular disease and/or a Body Mass Index greater than 30, indicating obesity. Participants volunteered in response to an invitation sent to their university e-mail accounts. Participants received a cinema voucher for participation. The Institutional Ethics Committee reviewed and approved the study. The study adhered to ethical guidelines outlined by the Declaration of Helsinki. Participants were informed explicitly about the study's objectives, procedures, confidentiality measures, potential risks, benefits, and their right to withdraw at any point. Written informed consent was obtained from all participants before their participation. All personal data collected was anonymized and securely stored to protect participant privacy.

Measures

Emodiversity induction. We selected film clips from a validated emotion-eliciting video clips database (Schaefer et al., 2010). We prepared four sets: emodiverse (a variety of positive and negative clips) (DIV), negative (NEG), positive (POS), and emotionally neutral (NEU). Each set consisted of six two-minute films (a total of 12 min) presented in a random order. Table 1 presents the contents of the clips.

Emodiversity. We used a retrospective self-report approach to the measurement of the trait emodiversity (Anderson et al., 2021; Quoidbach et al., 2014; Wang et al., 2021). We calculated the coefficient based on responses

Table 1 Movie clips descriptions

neutral movie clips		negative movie clips		positive movie clips	
emotion	contents	emotion	cotents	emotion	contents
-	*Twin Peaks.* A man in bar cleans the floor	fear	*Blair Witch Project*, movie ending, protagonists die in the abandoned house	amusement	*Benny & Joon*, a comical dancing bit
-	*Three Colors: Blue* the protagonists receive unexpected guest, entertains her with a small talk	anger	*In the Name of the Father*, a violent police interrogation with forced confessions	ramusement	*Les Visiteurs*, a knight and a squire move in time to the 20th century and confront the car
-	*Three Colors: Blue*, a protagonist wanders around the city, conduction daily matters	anger	*Man Bites Dog* Cruel assault on an elderly woman ends in her death	amusement	*When Harry Met Sally*,the protagonist plays the scene of a simulated orgasm in a cafe
-	*Three Colors: Blue*, the protagonist wanders around the city, looking for an unknown person	disgust	*American History X*, a neo-Nazi brutally kills a black man	amusement	*A Fish Called Wanda*, the owners of the house come back to find a dancing naked man
-	*The Last Emperor*, scenes from the life of the city and the imperial court	disgust	*Se7en*, the police find the decaying corpse of a mutilated man	tenderness	*Dead Poets Society* The final scene in which students show solidarity with the teacher
-	*The Last Emperor*, scenes from city life, travel by car and harbour wharf	sadness	*Dangerous Minds*, the teacher and students in the class receive news that their colleague was murdered	tenderness	*Life is beautiful*, the boy speaks to his mother through a loudspeaker in the prison camp

to *Differential Emotions Scale* (mDES; Fredrickson et al., 2003). The questionnaire consists of twenty items on experiencing positive emotions during the last month, e.g., *How often did you feel glad*, *happy*, *joyful?* and negative, e.g., *How often have you felt repentant*, *guilty*, *blameworthy?* The respondents responded to each item on a five-point scale from 1 (*never*) to 5 (*most of the time*). Using a recommended formula, we converted the responses into emotional diversity coefficients (Quoidbach et al., 2014). These coefficients were standardized and expressed as a percentage, as suggested by the authors. We calculated the overall emodiversity coefficient and coefficients for the diversity of positive and negative emotions. This retrospective self-report method provides a broad index of individuals' emotional repertoire over the past month, capturing not only the frequency but also the richness and balance of experienced emotion.

Social interaction. Participants played the ultimatum game (Bearden, 2001). This game is presented to the participant as involving two individuals, person A (making the decision) and person B (making the division). In fact, only one person is involved, i.e., Person A. According to the cover story, Person B receives a certain amount of money from the researchers and divides it between Person A and Person B, e.g., 50/50 (a division considered fair by most people) or 80/20 (a division considered unfair by most people). Person A decides whether to accept or reject the offer of money split. If accepted, both persons receive the money. If the offer is rejected, no one gets the money. Participants were informed that they would be Player A and would never meet their counterparts face-to-face (Player B). We fixed Participant B offer at 90/10–18 PLN ($6) for Person B and 2 PLN (80 cents) for Person A (division considered unfair).

Affect. Participants continuously reported their emotions with a slider on a scale from 1 ("extremely negative") to 10 ("extremely positive), using a Response Meter (ADInstruments, New Zealand). Participants were asked to reflect on their feelings at a given moment by adjusting the scale position. The signal was sampled at 1000 Hz by PowerLab 16/35 (ADInstruments, New Zealand) and analyzed with LabChart 8.19 software (ADInstruments, New Zealand). Electronic rating scales collect reliable and valid emotion ratings (Ruef & Levenson, 2007).

Physiological measures overview. We focused on a comprehensive assessment of the emotional response in line with the social psychophysiological perspective (Blascovich et al., 2011). We measured cardiovascular responses, skin conductance, and respiration as they convey different information about the response to stress and emotions. Physiological data were collected continuously, starting with a 5-minute resting baseline before emotion induction, throughout the 12-minute film presentation, and during the subsequent three 2-minute periods surrounding the ultimatum game: before receiving the offer, immediately after receiving the offer, and after the participant's decision.

For each physiological measure, we calculated the difference between the baseline and the activity measured at the social interaction (Christenfeld et al., 2000) while controlling for the baseline in the model. The levels for each measure were averaged over the reactivity period, and the score of the baseline level was subtracted. This calculation is mathematically equivalent to computing the area between the reactivity curve and the resting level. Using difference scores is a standard strategy for studying autonomic responses to psychological factors. Such models assess the difference in post-test means while accounting for pre-test values, which provides more statistical power (Clifton & Clifton, 2019).

Cardiovascular activity. We recorded an electrocardiogram (EKG) and impedance cardiogram (ICG) using the VU-AMS (The Vrije University Ambulatory Monitoring Systems, Vrije University, The Netherlands). We used pregelled AgCl electrodes (Kendall Abro, H98SG) placed in standard a Lead II configuration for ECG and a four-spot electrode array for ICG (Sherwood et al., 1990). After R-peaks in the ECG were detected using VU-AMS Data, Analysis & Management Software (VU-DAMS 3.0), we visually checked and adjusted all R-peak markers when necessary. We calculated interbeat intervals (IBI) measured between R waves in consecutive heartbeats. Changes in cardiac vagal control were measured using RMSSD (root mean square of successive differences in IBI) following the guidelines for HRV analysis (Shaffer & Ginsberg, 2017). We calculated the pre-ejection period (PEP, time in milliseconds in the cardiac cycle from initiating ventricular depolarization to opening the aortic valve and ejection of blood), mainly under sympathetic activation (Seery, 2011). We also calculated cardiac output (CO, the amount of blood in litters pumped by the heart per minute), which reflects the influence of sympathetic and parasympathetic activity.

Hemodynamic responses. We measured systolic blood pressure (SBP), diastolic blood pressure (DBP), and total peripheral resistance (TPR) beat-by-beat using finger cuffs and Finometer model NOVA (Finapress Medical Systems, The Netherlands). Increases in systolic blood pressure are responsive to sympathetic activity. The data were analyzed with BeatScope 2.0 (Finapres Medical Systems, Netherlands).

Respiration. We measured chest circumference changes during respiration with a piezo-electric belt, Pneumotrace II (UFI, USA). The number of respiratory cycles was computed using the Cyclic Measurements module in LabChart 8.1 (ADInstruments, New Zealand). The number of respiratory cycles per minute provided the respiratory rate.

Electrodermal activity. We sampled electric skin conductance levels with the GSR Amp (ADInstruments, New Zealand) at 1000 Hz and reported in microsiemens (μS). We used electrodes with a contact area of 8 mm diameter filled with a TD-246 sodium chloride skin conductance paste. We attached them with adhesive collars and sticky tape to the left hand's medial phalanges of digits II and IV. Skin conductance measures sympathetic arousal and is related to affective processing (Nagai et al., 2004).

Procedure

The participants were asked to refrain from eating, using over-the-counter stimulants and over-the-counter drugs, and do intensive physical exercise for up to two hours before the study. Over a few days before arrival, participants completed online questionnaires measuring their emotional experience over the past month. Although recent results suggest the benefits of using experience sampling methods (Ong et al., 2018; Petagna & Wormwood, 2025), similar approaches have been employed in studies of trait-like aspects of emotionality (Grossman et al., 2016; Klonsky et al., 2019; Quoidbach et al., 2014), and their long-term stability has been demonstrated over 7 years (Watson & Walker, 1996). After a 5-minute baseline period, participants were randomly assigned to watch a 12-minute presentation of films as the most effective strategy for emotion induction (Joseph et al., 2020).

Based on previous research and theory (Quoidbach et al., 2014), we conceptualized situational emodiversity as the experience of a variety of emotions, including positive and negative emotions. Thus, in the emodiversity group, we presented a mix of validated video clips that elicited positive and negative emotions. For an extensive comparison, we formulated three comparison groups that watched only positive, only negative, or neutral clips (Table 1).

Following the affect induction, participants played the ultimatum game (Bearden, 2001). The bidder (a bogus second participant from a second lab room) formulated an offer that was considered unfair by most people ("6 USD for me and 80 cents for you"). The participant then accepted or rejected the offer.

The parameters were recorded continuously and binned into three 2-minute waiting periods: before the offer, after receiving the offer, and after deciding to accept or reject the offer.

Analytical strategy

We performed path analysis to test if the type of elicited emotions predicted physiological responses and affect, and finally, the behavioral and social decision (accept vs. reject, binary). The elicited emotional states included emodiversity (responses to the set of positive and negative clips), positive emotion, negative emotion, and a neutral state. The emotions induction was dummy-coded with neutral conditions as the reference group. We controlled for baseline levels of each variable and their auto-regressive effects so that each coefficient reflected the explained change between the two phases rather than the general level. The model also included trait emodiversity calculated as the abundance of emotions in the preceding month, entered as a continuous predictor. To account for the binary behavioral outcome, we used the WLSMV estimator.

As we measured several responses influenced by autonomic nervous system activity, we discarded measures unrelated to the model's outcomes. We excluded data from outliers above 3.29 standard deviations. We used data from 149 individuals in the model after excluding outliers above 3.29 standard deviation and missing data (measurement failure or other technical problems). The physiological variables were calculated by subtracting the average values of the last two minutes of baseline measurements and average values of the measurements made in relevant 2-minute periods. Those included the last two minutes of the movie presentation (emotional experience depending on the experimental condition) and two minutes in which the participant made the decision whether to accept the offer. Following guidelines for evaluation of model fit (Hu & Bentler, 1999), we calculated RMSEA (values <0.06 indicating a good fit) and CFI (values >0.95 indicating a good fit). We tested direct effects (a single path from a predictor to an outcome), indirect effects (products of coefficients for two or more significant paths), and total effects that represent the sum of direct and indirect effects.

Results

Table 2 presents descriptive statistics for the responses to emotion elicitation. Table 3 presents variables included in the final model (Fig. 1). The model fit the empirical data well, χ^2 $(119) = 140.04$, $p = .09$, RMSEA $= 0.03$, 90% CI [0.01, 0.06], CFI $= 0.92$. The insignificant paths did not affect the model, $\Delta\chi^2$ $(39) = 40.20$, $p = .42$, and were removed. We found that the decision in the ultimatum game was independently predicted by stronger positive affect, RMSSD, and respiratory rate increases. Neither trait emodiversity (the dummy-coded variable reflecting the experimental manipulation) nor state emodiversity (the continuous measure derived from self-reported emotions in the preceding month) was significantly related to the study outcomes. Therefore, both variables were excluded from the final model. However, we found that emodiversity induction produced better results

Table 2 Descriptive statistics for each of the experimental conditions

	condition	*N*	M	SD
emodiversity	NEU	53	0.60	0.12
	NEG	50	0.62	0.10
	POS	52	0.67	0.10
	DIV	52	0.71	0.09
positive emotions diversity	NEU	53	0.52	0.01
	NEG	50	0.52	0.01
	POS	52	0.52	0.01
	DIV	52	0.52	0.01
negative emotions diversity	NEU	53	0.55	0.01
	NEG	50	0.55	0.01
	POS	52	0.55	0.02
	DIV	52	0.56	0.02
ΔCO	NEU	47	−0.11	0.35
	NEG	42	−0.03	0.53
	POS	46	−0.10	0.46
	DIV	40	−0.11	0.54
ΔDBP	NEU	47	0.86	6.45
	NEG	43	5.56	6.61
	POS	46	3.40	6.75
	DIV	41	4.32	6.69
Δheart rate	NEU	42	−1.86	3.32
	NEG	38	−1.70	4.79
	POS	41	−3.17	3.81
	DIV	42	−2.05	3.98
ΔRMSSD	NEU	43	2.30	26.21
	NEG	37	−0.24	12.00
	POS	42	4.80	20.52
	DIV	43	3.01	14.58
ΔRR	NEU	43	1.15	2.11
	NEG	40	0.79	2.08
	POS	43	0.49	2.17
	DIV	43	0.60	2.48
ΔSCL	NEU	52	−0.06	1.01
	NEG	48	0.61	0.79
	POS	50	0.33	0.93
	DIV	48	0.61	1.19
ΔTPR	NEU	46	0.04	0.11
	NEG	42	0.08	0.10
	POS	44	0.08	0.10
	DIV	40	0.06	0.12
Δaffect	NEU	51	0.09	1.11
	NEG	49	−1.44	1.72
	POS	50	0.62	1.32
	DIV	49	−0.01	1.80

Δ change between T0 (baseline measurement) and T1 (last two minutes of the film). CO - cardiac output; DBP - diastolic blood pressure; RMSSD = root mean square of successive differences; RR - respiratory rate; SCL - skin conductance levels; TPR - total peripheral resistance

Table 3 Descriptive statistics for the model

	M	SD	*N*
emodiversity	0.82	0.08	195
positive emotions diversity	0.49	0.07	195
negative emotions diversity	0.44	0.06	195
RMSSD T0	41.22	28.75	172
RR T0	16.01	2.68	172
IBI T0	763.39	155.91	172
affect T0	5.14	0.89	206
ΔRMSSD T1-T0	−197.76	401.94	172
Δrespiratory rate T1-T0	−180.13	385.82	172
ΔIBI T1-T0	−190.45	414.15	172
Δaffect T1-T0	−42.98	202.79	206
ΔRMSSD T2-T0	1.12	18.83	167
Δrespiratory rate T2-T0	0.22	2.03	172
ΔIBI T2-T0	−16.73	48.77	166
Δaffect T2-T0	−0.73	1.78	201

Δ changes in the value of the variable between the individual measuring moments, T0 - rest measurement, T1 - last two minutes of movie clips, T2 - decision making

RMSSD = root mean square of successive differences, respiratory frequency, measured in breaths per minute; IBI - inter-beat interval, heart rate, measured in cramps per minute

than negative emotion induction. However, the effects of emodiversity induction were not more favorable than positive emotions induction or a neutral presentation. Accepting the offer was less probable among participants who watched negative films and experienced more negative emotions, as reflected in an indirect path between negative emotions induction and decision.

Discussion

We extensively tested the emodiversity theory with validated emotion inductions and comprehensive measures of outcomes, including self-reported affect, physiological responses, and behavioral, social decisions (Ong et al., 2018; Quoidbach et al., 2014; Vuillier et al., 2018). We found little support for the main assumptions of the emodiversity theory, which suggested that emodiversity predicts superior outcomes relative to positive emotions. This supports previous studies that found few emodiversity benefits (Urban-Wojcik et al., 2022; Heshmati et al., 2023). We found no benefits for the long-term emodiversity (calculated using self-reports of emotions from the preceding month) or the situational emodiversity (experiencing a variety of emotions immediately before the interaction).

Contrary to the emodiversity theory, our findings aligned with the more straightforward research and theory that emphasize the role of positive emotions (Fredrickson et al., 2003) and parasympathetic activity in social behavior regulation (Appelhans & Luecken, 2006). Namely, we found that responses in affective, cardiac, and respiratory systems were informative of subsequent monetary decisions. Moreover, we also found that after negative emotions were elicited, individuals provided more adverse responses due to their

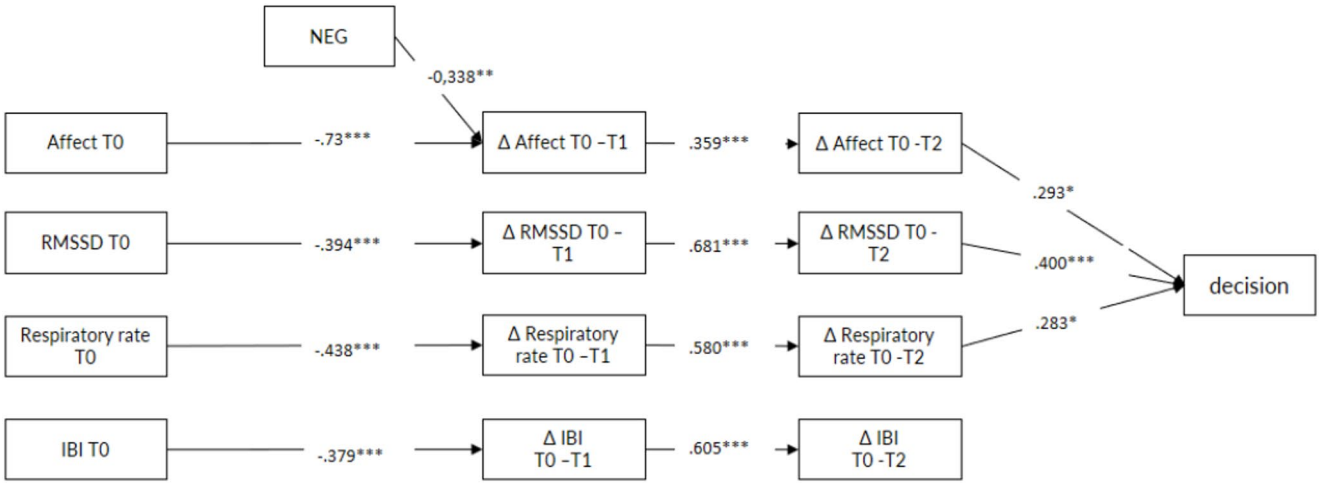

Fig. 1 A model of the relationship between physiological and psychological variables explaining the decision in an ultimatum game. For clarity, only significant paths are described. The Δ indicates the difference between relevant measurements. Coding: decision (0 = rejection, 1 = acceptance of the offer). NEG = negative emotions induction relative to neutral control. * $p < .05$, ** $p < .01$, *** $p < .001$

negative feelings. This straightforward effect is also against the emodiversity hypothesis. Instead, it aligns with previous literature indicating that negative emotions are associated with social conflict or contradiction (Bearden, 2001; Birkley & Eckhardt, 2015; Kaczmarek et al., 2021). These findings suggest that emodiversity did not contribute to the superior experience, physiological responses, or behavior relative to positive emotions or neutral states. Instead, more classical approaches that emphasize the adverse role of negative emotions and the benefits of positive emotions and parasympathetic activity are sufficient to explain the role of emotions in social behavior.

We observed a minimal benefit of emodiversity. Namely, individuals who experienced negative and positive emotions had better outcomes than individuals who experienced only negative emotions. This could suggest that the effects of negative emotions might have been neutralized when positive experiences accompanied them. Consequently, there are reasons to believe that emodiversity might provide the benefit of balancing negative and positive emotions. However, it lends limited support for the emodiversity theory as it advocates for the benefits of emodiversity over the effects of positive and negative emotions analyzed in separation (Quoidbach et al., 2014).

Our project offered several findings that are alternative to the emodiversity perspective. For instance, we found that the individuals who responded with increased positive affect, heart rate variability, and faster respiration were more likely to benefit from challenging social interactions. This supports the link between the vagal tone (reflected in RMSSD) and prosociality. As we screened out participants for several other physiological responses, the theoretically established link yielded as robust. Moreover, we found an independent contribution of respiration rate as an independent predictor of behavioral response. Individuals with more significant increases in the breathing rate were more likely to act prosocially. This is important because respiratory sinus arrhythmia is often associated with changes in respiratory patterns.

Limitations and future directions

This study had several limitations. First, participants were young adults and university students, which limits the generalizability to other groups. Second, the interpersonal conflict was simulated with an economic game. Further studies might employ other validated scenarios, including face-to-face social interactions. Third, we tested only one variant of the Ultimatum Game, with unfair offers and participants only in the role of responders. Although this allowed us to create a socially challenging situation, future studies might extend this approach by incorporating varying offer rates and roles. For instance, allowing participants to act as proposers would enable examining how emodiversity influences the initiation of social interactions, which may be particularly sensitive to individuals' willingness to initiate or mitigate social conflict. Fourth, we calculated trait emodiversity based on retrospective self-reports covering the emotional experience in the previous period. This is an established method to calculate emodiversity (Anderson et al., 2021; Quoidbach et al., 2014; Wang et al., 2021). However, more intensive methods have been introduced to measure emodiversity, including Ecological Momentary Assessment (Heshmati et al., 2023), daily diary (Urban-Wojcik et al., 2022), or day reconstruction (Grossmann et al., 2019). Fourth, we elicited emotions with movie clips. Despite the general validity of this method, some concerns remain about whether the intensity of emotions evoked with this method might be substantial enough to reflect real-life

feelings (Joseph et al., 2020). Fifth, we compared relatively short periods during the interaction. Although such block lengths are acceptable in psychophysiological research, more extended sessions might provide more reliable measurements and parameter estimations, introducing more stable indicators of physiological activity or change over time. Sixth, relatively small monetary incentives in the ultimatum game might not be large enough to evoke a vital emotional context for social interaction. Finally, we focused on conceptualizing emodiversity as the variety of positive and negative emotions. More recent studies indicated that the effects of emodiversity might be limited to the variability of positive emotions (King & Frondozo, 2022; Yoon & Kim, 2024), an aspect not covered in our project.

Practical implications

The study has several practical implications. First, we found that negative emotion induction produced adverse effects, i.e., more negative affect and, indirectly, less agreeable behavior. However, the effects of negative emotions embedded within the context of positive emotions (emodiverse experience) had no detrimental effects. This negativity-diluting effect suggests that the emodiverse experience might neutralize the impact of negative emotions that otherwise might produce decreased mood and more social conflict. Second, we identified a specific physiological response that explained the agreeable social decision. This is congruent with many applied contexts and practices where heart rate variability and respiration are targeted as the primary focus for training and improvement (Lehrer et al., 2020).

Conclusions

Our study provides insights into the role of positive and negative emotions in social behavior. By testing the emodiversity theory, we contribute to a more critical understanding of its limitations. The findings highlight that the benefits of emodiversity may be less robust than initially proposed, with classical approaches emphasizing the role of positive emotions and parasympathetic activity offering more replicable explanations. Understanding the nuanced interplay between positive and negative emotions can advance our ability to predict emotional responses and social behavior.

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Data availability The datasets generated and analyzed during the current study are available in the POPANE repository: https://doi.org/10.17605/OSF.IO/94BPX (Study 6).

Declarations

Ethical approval The study was approved by the Ethics Committee of the Institute of Psychology (now Faculty of Psychology and Cognitive Science) of Adam Mickiewicz University in Poznań.

Informed consent Each participant provided written informed consent.

Conflict of interest The authors declare no potential conflicts of interest with respect to this article.

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