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# **Contrast effect of emotional context on interpersonal distance with neutral social stimuli**

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**Running head:** Context effect on interpersonal distance regulation

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## **Abstract**

In social interactions, valence-based judgements are an important component of interpersonal distances regulation. Within the framework of the Range-Frequency model, we tested whether temporal presentation of an emotional context, known to produce a contrast effect on valence ratings, also influences the regulation of interpersonal distances. Two groups of participants were shown virtual characters with either a neutral facial expression (target stimuli) or an emotional facial expression (contextual stimuli) in two successive sessions (angry then happy emotional context, or vice-versa). Participants rated the valence of the characters and judged the appropriateness of various interpersonal distances. The results showed a contrast effect of the emotional context on the valence rating of neutral characters, which extended to preferred interpersonal distance, although sparingly. The findings revealed thus that the emotional context alters more perceptual-related valence-based judgments than action-related interpersonal distance judgments.

**Keywords:** Social interaction, Emotional context, Interpersonal distance, Contrast effect

## Introduction

Since Hall (1966), particular attention was paid to the different factors responsible for the natural and automatic regulation of interpersonal distances (IPD) in social contexts, which implies a subtle balance between the need to approach others for efficient social interactions, and the need to maintain a certain margin of safety from others to preserve body integrity (Lloyd, 2009; Siegman & Feldstein, 2014). Accordingly, a too large IPD would not be appropriate for efficient social interactions, and a too short IPD would trigger discomfort and defensive neurophysiological responses (Cartaud, Ott, Iachini, Honoré, & Coello, 2020; Cartaud, Ruggiero, Ott, Iachini, & Coello, 2018; Kennedy, Gläscher, Tyszka, & Adolphs, 2009; Vieira, Pierzchajlo, & Mitchell, 2020). Furthermore, IPD perception and regulation can be altered by egocentric representation of near-body action space (Coello, 2018; Quesque et al., 2017), idiosyncratic characteristics such as the level of anxiety (Givon-Benjio & Okon-Singer, 2020; Givon-Benjio, Oren-Yagoda, Aderka, & Okon-Singer, 2020; Perry, Levy-Gigi, Richter-Levin, & Shamay-Tsoory, 2015) and others' attributes such as age, gender and emotional facial expression (FE, Iachini et al., 2016; Ruggiero et al., 2017), highlighting the sensitivity of social spatial regulation to contextual information. As such, emotional FE are crucial cues in social interactions and thus in the regulation of IPD, mainly because they represent a valuable source of information with respect to the emotional state of others (Schrammel, Pannasch, Graupner, Mojzisch, & Velichkovsky, 2009). Hence, IPD increases when conspecifics display an angry FE, whereas it decreases when they display a happy FE (Ruggiero et al., 2017). The regulation of IPD thus correlates with both the strength of the neurophysiological responses triggered by a social stimulus when not complying with expected social distances, and the evaluation of its subjective valence (Cartaud et al., 2018; Ruggiero, Rapuano, Cartaud, Coello, & Iachini, 2021; Vieira et al., 2020). The processing of emotional information conveyed by others, in particular the valence dimension of their FE, seems therefore to be of paramount importance in the

regulation of IPD.

A large body of the literature on this matter has shown that judgement (or feeling) of a stimulus' emotional valence depends also on the emotional information conveyed by the context in which the stimulus is embedded (Matsumoto & Sung Hwang, 2010; Russell & Fehr, 1987; Wedell & Parducci, 1988; Wieser & Brosch, 2012). As pointed out in different domains of research, judgment of a stimulus refers broadly on relative rather than absolute information, due to the influence of the context (Clark, Frijters, & Shields, 2008; Furl, 2016; Kahneman & Tversky, 1979; Kontek & Lewandowski, 2018; Louie, Khaw, & Glimcher, 2013; Trueblood, Brown, Heathcote, & Busemeyer, 2013). The notion of context is usually defined along two dimensions: a temporal and a spatial dimension (Louie, Grattan, & Glimcher, 2011). The spatial dimension of the context refers to the set of stimuli presented simultaneously with the target, whereas the temporal dimension of the context refers to the sequence of stimuli presented across time (Louie et al., 2011). With temporal context, salient information and explicit judgment tasks usually promote contrast effects (Kobylńska & Karwowska, 2014; Martin, Seta, & Crelia, 1990), which corresponds to a negative correlation between the judgment of a defined target and the characteristics of the context (Schwarz & Bless, 2007), that nonetheless decays over time (Louie et al., 2011). As evidence, neutral faces are judged more (less) happy when presented in a context made up of negative (positive) faces (Wedell & Parducci, 1988). Among the models predicting contrast effect, the Range-Frequency (RF) model (Parducci, 1965) proved to be particularly relevant (Wedell, Hayes, & Kim, 2020; Wedell, Parducci, & Geiselman, 1987; Wedell & Parducci, 1988). The RF model is based on the range and frequency principles. According to the range-principle, judgement of a target stimulus depends on its location relative to the extreme values of the stimuli encountered so far (*i.e.*, the boundaries of the context). According to the frequency-principle, judgement of a target stimulus depends on the target rank within the distribution of the different values of the stimuli encountered so far.

It is assumed that when judging the value of a stimulus, people make a compromise between the range-principle and the frequency-principle (Parducci, 1965).

Although the manipulation of the emotional context, leading to contrast effect, has been extensively investigated in the field of emotional judgment (Wieser & Brosch, 2012), it is not yet known whether such contrast effect can also alter IPD regulation in social context. However, recent studies revealed that the sanitary context due to the COVID-19 pandemic led to IPD adjustment, suggesting that environmental information can also alter IPD regulation (Cartaud, Quesque, & Coello, 2020; Welsch, Wessels, Bernhard, Thönes, & von Castell, 2021). Our rationale was the following: if preferred IPD is primarily driven by the valence of a social stimulus, thus, altering the valence of that social stimulus by manipulating the emotional context should in turn impact IPD regulation. To address this issue, we designed an online experiment based on RF model simulation (Parducci, 1965). In this experiment, virtual characters with a neutral FE (target stimuli) were presented singly within a temporal social context made up of characters displaying an emotional FE (happy or angry, contextual stimuli). Contrast effect was assessed by testing the effect of the range and frequency of the contextual emotional characters on valence ratings and preferred IPD with the neutral characters. According to the RF model, in a unimodal context (*e.g.*, negative emotional characters) the perceived valence of the neutral characters should drift towards the opposite direction than the valence of the contextual emotional characters (*e.g.*, a higher positive valence rating). However, in a multimodal context (*e.g.*, negative and positive emotional characters, equally represented across time), the valence attributed to the neutral characters should be repelled by both edges of the contexts, remaining thus close to the central position of the range of the whole set of stimuli. As a corollary, since preferred IPD depends on the subjective valence of the characters, it should be altered by context manipulation. More specifically, preferred IPD with neutral characters embedded in a negative context should be shorter than preferred IPD with neutral

characters embedded in a positive context, the effects cancelling each other out in the multimodal presentation of the context.

## **Method**

### *Participants*

Fifty-one adult volunteers completed the entire online experiment (39 women,  $M_{age} = 30.40$ ,  $SD_{age} = 9.7$ ,  $M_{study} = 4$ ,  $SD_{study} = 2.55$  after the French baccalaureate). Based on GPower (version 3.1, within-between ANOVA  $\alpha = 0.05$ , Cohen's  $F = 0.25$ ), the requested sample size was 36 participants, but we decided to increase this number because the experiment was completed online. All the participants had a normal vision or were invited to use optical correction (e.g., wear glasses), if they consented to take part in the experiment. The protocol received approval by the local institutional ethics committee (2020-426-S83).

### *Apparatus and stimuli*

The experiment was created on lab.js builder (Henninger, Shevchenko, Mertens, & Kieslich, 2019), hosted and run online on the CNRS web server. The experiment could only be performed using a computer. Advertisement was shared on social and professional networks. The stimuli consisted of 14 male and 14 female characters selected from the ATHOS database (Cartaud & Coello, 2020). Two male and two female characters had a neutral FE (targets), five males and five females had an angry FE (negative context) and the remaining five characters of each gender had a happy FE (positive context). Both the characters and the empty room in which they were presented were built on Unity (2018.2.21f1 version, Fig. 1).

Depending on the task, the characters were presented at different distances (25 to 135 cm) from the participants, who had to represent themselves being on the proximal side of the

virtual room. The distance increment was 6 cm from 25 to 85 cm and was 10 cm from 85 to 135 cm, thus resulting in a total of 16 different distances. This presentation was used in order to minimize the number of trials while keeping the increment as small as possible, allowing us to experimentally scan a reasonable range of distances, while ensuring a balanced number of “appropriate” and “inappropriate” responses in the IPD judgment task.

### *Procedure and design*

First, participants completed a short questionnaire focusing on general information (age, gender, study level). Then, in two sessions, participants performed a set of three tasks twice (stimuli presentation, stimuli evaluation and IPD judgment, detailed below and presented in Fig. 1). Each participant was randomly assigned to one of the two groups that differed only in the order of presentation of the emotional context (positive or negative). For group AH (N = 23, 6 males), the emotional context of the first session consisted of angry characters (negative unimodal context) and that of the second session consisted of happy characters (positive and multimodal context, due to previous exposition to the other emotional context). The pattern was reversed for group HA (N = 28, 6 males, the unimodal session (session 1) consisted of happy contextual characters and the multimodal session (session 2) consisted of angry contextual characters). For each participant, the pair of neutral characters (one male and one female) was randomly assigned to each session.

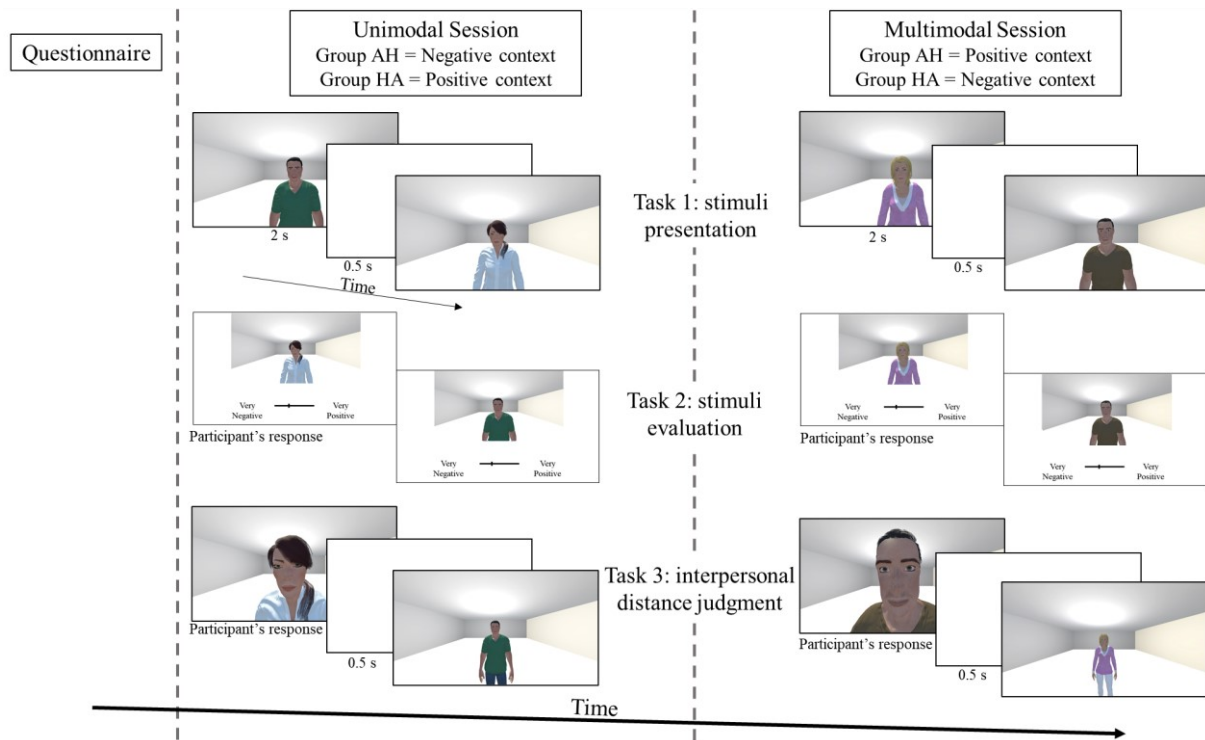


Fig. 1. Schematic representation of the experiment set up and the time course of stimuli presentation.

In the first task, the stimuli were composed of 10 emotional characters (happy or angry depending on the group and the session) and 2 neutral characters (one of each gender). During the first session, since (i) the neutral stimuli were at the edges of the range in terms of valence (neutral characters have either the minimum or the maximum valence rating depending on the context) and (ii) the distributions of the stimuli were skewed (context was either mostly negative or mostly positive), the RF model predicted a strong contrast effect (Parducci, 1965). Participants passively observed successive pictures of the characters. Each character was presented twice in a random order for 2 secs at 61 cm from the proximal side of the room in full screen mode (see Fig. 1, task 1). A white screen was displayed for 500 ms between each character presentation.

In the second task, participants sequentially evaluated the valence of the two neutral characters and two contextual emotional characters (one male and one female) which corresponded to the stimuli that received the highest positive or negative valence according to

the ATHOS database (Cartaud & Coello, 2020). The number of evaluations of contextual characters was limited in order to prevent the online experiment extending too much in time (reducing thus the number of dropouts). The characters were displayed at 61 cm from the proximal side of the room and the picture filled 60% of the computer screen. Underneath each character was positioned a slider question for the evaluation of the valence of the character. Participants had to position a cursor along the horizontal line using the computer trackpad or a mouse (10 units) with the labels “very negative” on the left side and “very positive” on the right side of the slider (see Fig. 1, task 2). No numerical feedback of their ratings was provided.

The third task consisted in judging whether the distance between the participants and each character was appropriate for social interaction or not (*i.e.*, too close, IPD judgment). The same characters as in the previous task (two neutral target characters and two contextual emotional characters) were presented singly and randomly at a distance varying from 25 to 135 cm (see Fig.1 task 3). Participants had to respond as fast and as spontaneously as possible by pressing the “L” (appropriate, not too close) or “S” (inappropriate, too close) keys of their keyboard. The characters remained on the screen until the participant’s response was provided, then followed by a white screen lasting 500 ms. Each character pseudo-randomly appeared four times at each distance (Character’s gender [2] \* FE [2] \* Distance [16] \* Repetition [4]), using the method of constant stimuli and leading to a total of 256 trials. A break was possible following the completion of the first 128 trials. Participants started with a 6-trials training session with (neutral and emotional) characters that were not used in the main experiment, in order to operationalize the association between responses and computer keys.

Following the first (unimodal) session, a break was proposed before launching the second (multimodal) session, which consisted of the same three tasks, but with the other emotional context and two new characters displaying a neutral FE. Thus, during the multimodal session, the contextual characters had a happy FE for group AH and an angry FE for group HA.

The entire experiment lasted about 20 minutes.

### *Control task*

A control task was designed to quantify the contextless rating of the neutral characters in terms of valence. During this task, another group of 20 participants performed a valence rating of the neutral characters used in the main experiment. One of them was discarded because he/she didn't move the sliders while completing the evaluation ( $N=19$ , 9 women,  $M_{age} = 26.16$ ,  $SD_{age} = 8.62$ ,  $M_{study} = 4$ ,  $SD_{study} = 2.59$  after the French baccalaureate). The characters assessed consisted of the four target characters with the neutral FE (two males and two females). As in the main experiment, the characters were first sequentially presented, then participants rated their valence as in task 2 (varying from very negative to very positive).

### *Data analysis*

Statistical analyses were carried out using Bayesian linear mixed models' regressions (Bürkner, 2017; Gelman, Lee, & Guo, 2015), with R (version 4.0.2) and R Studio software (version 1.3.1056). The main independent variables of interest were the Stimulus FE (angry, happy, neutral), the Context (negative, positive), the Session (unimodal, multimodal), and their combinations. We mainly focused on the contrast between eight combinations: angry negative unimodal (or multimodal), happy positive unimodal (or multimodal), neutral negative unimodal (or multimodal), and neutral positive unimodal (or multimodal). More specifically for every task, we analyzed the contrasts between:

- Neutral negative unimodal – neutral positive unimodal (*unimodal* context effect)
- Neutral negative multimodal – neutral positive multimodal (*multimodal* context effect)
- Neutral negative (positive) unimodal – neutral negative (positive) multimodal (context effect *across* the sessions)

In addition, we compared the valence ratings of neutral stimuli (negative and positive context, unimodal and multimodal session) to that in the control group in order to quantify the effect of the *Emotional context*. Finally, we tested for the *Characters' Gender* effect in the data analysis and controlled for the effect of *Participant's Gender* in each regression.

For every model, we considered interindividual variability by adding the Subject level random effect. We specified a mildly informative normal distribution on the fixed effects (constraining the magnitude of the effects to reasonable values without specific direction) and used the default brms priors for the random effects when applicable. The approximation of the posterior distribution was obtained through 8000 Markov chain Monte Carlo (4 chains of each 2000 warm-up samples), whose convergence was validated through visual inspection and by computing the Rhat statistic. The Credible Intervals (CI) were fixed at 95% to judge contrasts between estimates of the parameters of the posterior distribution as probable. We performed linear regressions with a normal distribution for the analyses of the valence ratings and a logistic regression with a binomial distribution likelihood for the analysis of IPD. For each condition, the preferred IPD were determined from the participants' appropriate/inappropriate responses at each distance using the following equation:

$$y = \frac{1}{1 + e^{-(\alpha + \beta X)}} \quad (1)$$

where  $y$  is the participants' probability to answer "appropriate" (not too close), and  $X$  is the distance. From this equation, we computed the ratio  $-\alpha/\beta$  giving the critical value of  $X$  corresponding to the transition between the appropriate and inappropriate responses (*i.e.*, the inflection point of the logistic function). This value was interpreted as the preferred IPD. The slope at the vicinity of the inflection point was retrieved from  $\beta/4$ . Data and statistical analysis are available on the OSF platform at: (<https://osf.io/dur4k>; Cartaud, Lenglin, & Coello, 2020).

## Results

For every task, estimates and their 95% CI are reported in Table 1 and the contrasts of interest listed in the data analysis section are reported in Table 2. The Bayes  $R^2$  of each fit (*i.e.*, the estimate of the expected variance of the posterior distribution; Gelman, Goodrich, Gabry, & Vehtari, 2019) was computed using the function `bayes_R2`. The slopes of the logistic regressions were not statistically different across the conditions suggesting that the different conditions tested had the same level of difficulty (slope difference between the neutral characters from the negative and the positive context in the unimodal session: 0.02 [-0.51; 0.54] and in the multimodal session: -0.22 [-0.74; 0.31]).

Table 1. Posterior estimates (standard deviation, SD) and 95% CI for the dependent variables analyzed: valence ratings (0-10 scale) in the experimental and control groups, preferred IPD (cm) and its slope (at IPD threshold) as a function of Stimulus FE, Context, Session, and Characters' Gender.

<b>Dependent variable</b>	<b>Stimulus</b>	<b>Context</b>	<b>Session</b>	<b>Mean (SD)</b>	<b>95% CI</b>
<b>Experimental group</b>					
Valence ratings	Angry	Negative	Unimodal	0.85 (0.18)	[0.51; 1.2]
	Angry	Negative	Multimodal	1.51 (0.25)	[1; 1.99]
	Happy	Positive	Unimodal	7.63 (0.21)	[7.21; 8.05]
	Happy	Positive	Multimodal	7.95 (0.33)	[7.27; 8.61]
	Neutral	Negative	Unimodal	6.41 (0.28)	[5.85; 6.96]
	Neutral	Negative	Multimodal	5.31 (0.2)	[4.93; 5.7]
	Neutral	Positive	Unimodal	2.81 (0.29)	[2.25; 3.38]
	Neutral	Positive	Multimodal	4.56 (0.27)	[4.02; 5.1]
Male Characters				4.67 (0.11)	[4.45; 4.89]
Female Characters				4.53 (0.11)	[4.32; 4.76]
<b>Control group</b>					
Valence ratings	Neutral	Control		4.59 (0.29)	[4.04; 5.15]
<b>Preferred IPD</b>					
	Angry	Negative	Unimodal	58.51 (4.17)	[50.95; 67.36]
	Angry	Negative	Multimodal	60.75 (5.35)	[51.39; 72.4]
	Happy	Positive	Unimodal	47.78 (3.15)	[42.13; 54.53]
	Happy	Positive	Multimodal	44.38 (3.39)	[38.22; 51.67]
	Neutral	Negative	Unimodal	48.39 (4.17)	[40.71; 57.19]
	Neutral	Negative	Multimodal	46.95 (3.66)	[40.54; 54.65]
	Neutral	Positive	Unimodal	53.33 (3.72)	[46.67; 61.17]
	Neutral	Positive	Multimodal	50.44 (4.01)	[43.09; 59.02]
Male Characters				52.09 (3.25)	[46.39; 59.03]
Female Characters				50.72 (3.05)	[45.32; 57.17]
<b>Slope of preferred IPD</b>					
	Angry	Negative	Unimodal	3.9	[3.31; 4.47]
	Angry	Negative	Multimodal	3.64	[2.98; 4.29]
	Happy	Positive	Unimodal	4.44	[3.82; 5.04]
	Happy	Positive	Multimodal	4.79	[4.12; 5.45]
	Neutral	Negative	Unimodal	4.16	[3.53; 4.82]
	Neutral	Negative	Multimodal	4.16	[3.53; 4.8]
	Neutral	Positive	Unimodal	4.15	[3.54; 4.75]
	Neutral	Positive	Multimodal	4.38	[3.74; 5.04]

Table 2. Context effects between the estimates and 95% CI for every dependent variable evaluated: valence ratings (experimental group, control group) and preferred IPD (cm). Post-hoc analysis is also reported for preferred IPD (Emotion effect).

<b>Dependent variable</b>	<b>Effect</b>	<b>Estimate 1</b>	<b>Estimate 2</b>	<b>Contrast</b>	<b>95% CI</b>
Experimental group Valence ratings	Unimodal	<i>Neutral</i>	<i>Neutral</i>		
		<i>Negative</i>	<i>Positive</i>		
	Multimodal	<i>Unimodal</i>	<i>Unimodal</i>	3.6	<i>[2.81; 4.39]</i>
		<i>Neutral</i>	<i>Neutral</i>		
	Across sessions	<i>Negative</i>	<i>Positive</i>		
		<i>Unimodal</i>	<i>Multimodal</i>	1.1	<i>[0.42; 1.77]</i>
	Characters' gender	<i>Neutral Positive</i>	<i>Neutral Positive</i>		
<i>Unimodal</i>		<i>Multimodal</i>	-1.75	<i>[-2.52; -0.96]</i>	
Control group Valence ratings	Emotional context	<i>Neutral</i>			
		<i>Negative</i>	<i>Neutral Control</i>	1.81	<i>[1.01; 2.61]</i>
	Multimodal	<i>Neutral</i>	<i>Neutral Control</i>	0.64	<i>[-0.1; 1.39]</i>
		<i>Negative</i>	<i>Neutral Control</i>		
	Multimodal	<i>Neutral Positive</i>	<i>Neutral Control</i>	-1.74	<i>[-2.58; -0.94]</i>
		<i>Unimodal</i>	<i>Neutral Control</i>		
	Multimodal	<i>Neutral Positive</i>	<i>Neutral Control</i>	-0.02	<i>[-0.83; 0.8]</i>
<i>Multimodal</i>		<i>Neutral Control</i>			
Preferred IPD	Unimodal	<i>Neutral</i>	<i>Neutral</i>		
		<i>Negative</i>	<i>Positive</i>		
	Multimodal	<i>Unimodal</i>	<i>Unimodal</i>	-4.94	<i>[-13.26; 3.44]</i>
		<i>Neutral</i>	<i>Neutral Positive</i>		
	Across sessions	<i>Negative</i>	<i>Neutral Positive</i>		
		<i>Unimodal</i>	<i>Multimodal</i>	-3.49	<i>[-11.61; 4.53]</i>
	Characters' gender	<i>Neutral Negative</i>	<i>Neutral Negative</i>		
		<i>Unimodal</i>	<i>Multimodal</i>	1.44	<i>[-6.85; 9.98]</i>
	Emotion (post-hoc)	<i>Neutral Positive</i>	<i>Neutral Positive</i>		
		<i>Unimodal</i>	<i>Multimodal</i>	2.89	<i>[-5.16; 10.76]</i>
	Emotion (post-hoc)	<i>Male</i>	<i>Female</i>		
		<i>Characters</i>	<i>Characters</i>	1.37	<i>[0.67; 2.14]</i>
	Emotion (post-hoc)	<i>Angry Negative</i>	<i>Neutral Negative</i>		
		<i>Unimodal</i>	<i>Unimodal</i>	10.13	<i>[3.98; 16.19]</i>
	Emotion (post-hoc)	<i>Happy Positive</i>	<i>Neutral Positive</i>		
<i>Unimodal</i>		<i>Unimodal</i>	-5.55	<i>[-9.16; -2.12]</i>	
Emotion (post-hoc)	<i>Angry Negative</i>	<i>Neutral Positive</i>			
	<i>Unimodal</i>	<i>Unimodal</i>	5.18	<i>[-2.17; 12.68]</i>	
Emotion (post-hoc)	<i>Happy Positive</i>	<i>Neutral Negative</i>			
	<i>Unimodal</i>	<i>Unimodal</i>	-0.61	<i>[-8.73; 7.39]</i>	
<i>Valence</i>				-0.82	<i>[-1.23; -0.43]</i>

Note: Contrasts with CIs that do not overlap with zero are in italics (*i.e.*, robust estimate with 95% CI).

## Valence ratings

The main effects observed on valence ratings during the experiment are represented in Fig. 2. Contrast effects were observed: during the unimodal session, the neutral characters embedded in the negative context were judged as more positive than the neutral characters embedded in the positive context (+3.6 [2.81; 4.39], Bayes  $R^2 = 0.85$  [0.83; 0.87]). This effect was much smaller during the multimodal session (+0.75 [0.09; 1.42]). In line with these results, valence ratings of the neutral characters in the unimodal session were more pronounced than in the multimodal session (difference in negative context: 1.1 [0.42; 1.77]; difference in positive context: -1.75 [-2.52; -0.96]).

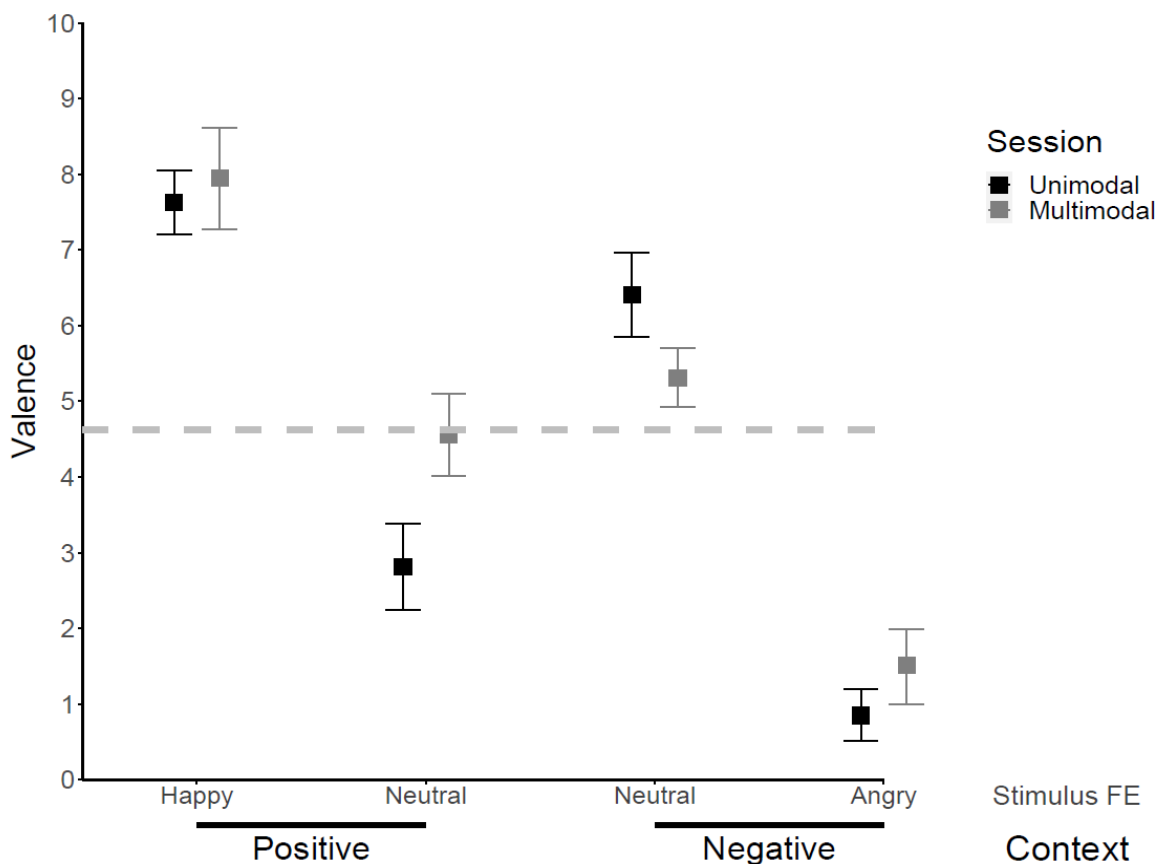
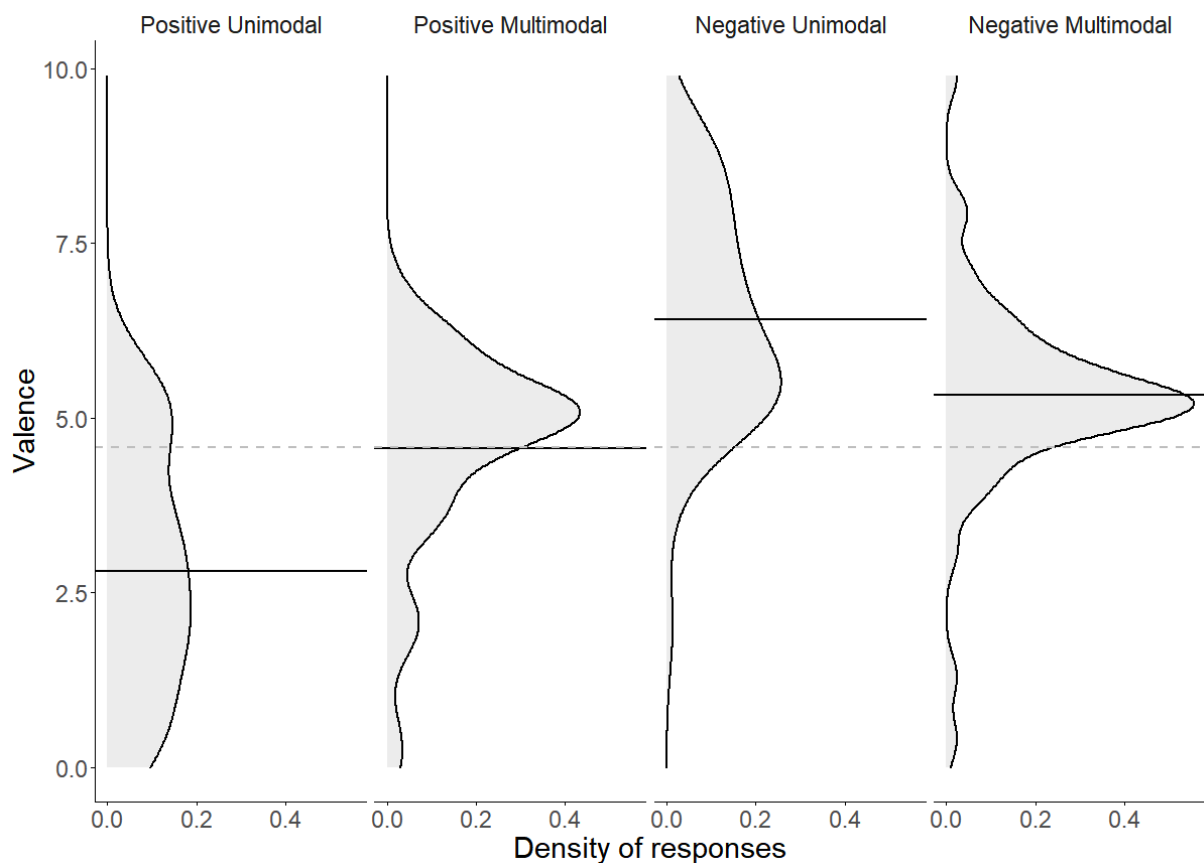


Fig. 2. Graphical representation of the posterior mean valence and the 95% CI as a function of Stimulus FE, Context and Session. Grey horizontal line represents the average rating of neutral targets obtained by the control group.

Then, we compared the valence ratings obtained for neutral characters during the experiment to those obtained in the control group (Fig. 3, Bayes  $R^2 = 0.54$  [0.45; 0.6]). As presented in Table 2 (control group valence ratings section), only valence ratings performed in the unimodal session differed from valence ratings provided by the control group; the neutral characters were rated +1.81 [1.01; 2.61] higher when embedded in the negative context during the unimodal session and -1.74 [-2.58; -0.94] lower when embedded in the positive context. Finally, no difference emerged when comparing the valence ratings of male and female characters 0.13 [-0.08; 0.35].



*Fig. 3. Density of responses relating to valence ratings for the neutral characters in the experimental group in each condition. The black horizontal lines represent the average valence ratings. The dashed horizontal grey line represents the average valence ratings obtained by the control group.*

## Interpersonal distances

Concerning the analysis of IPD judgments and as reported in Table 2, valence ratings drove preferred IPD since each 1-point increase in valence ratings led to a decrease in preferred IPD of almost 1 cm (-0.82 cm [-1.23; -0.43], Bayes  $R^2 = 0.91$  [0.90; 0.91]). However, and as presented in Fig. 4, no contrast effect emerged when comparing preferred IPD with the neutral characters embedded in the positive context with those with the neutral characters embedded in the negative context, neither in the unimodal nor in the multimodal session.

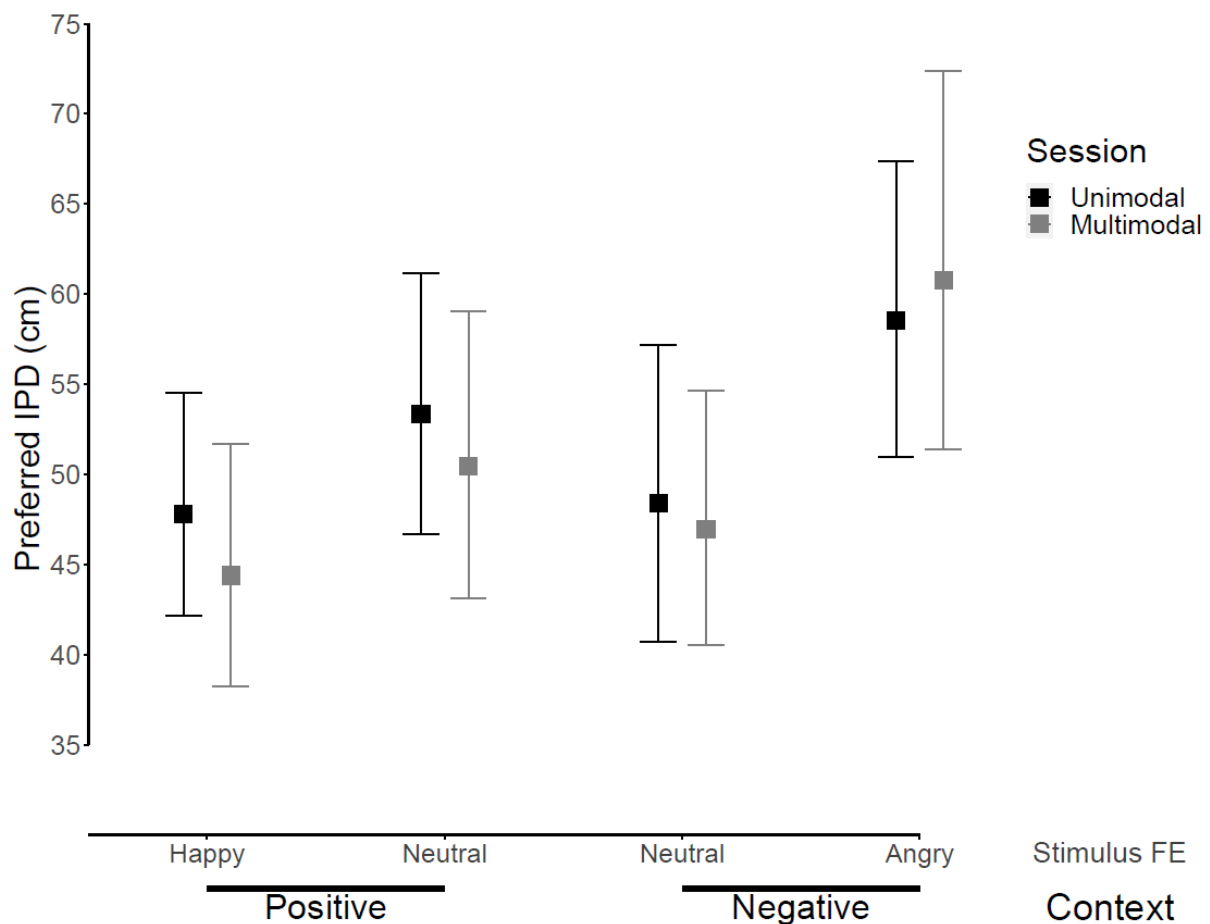


Fig. 4. Mean prediction and 95% CI of posterior distribution of preferred IPD per stimulus, context and session.

## *Post-hoc analysis*

To further analyze the contrast effect of the context on IPD regulation, we conducted a post-hoc analysis for the unimodal session only. More precisely, we investigated whether the contrast effect would emerge when comparing preferred IPD with the neutral characters to preferred IPD with the emotional characters in each context (Table 2, see *Emotion* effect for preferred IPD). First, we observed that preferred IPD with the neutral characters differed from preferred IPD with the contextual emotional characters when belonging to the same context. Preferred IPD was larger with angry characters than with neutral characters embedded in the same negative context (+ 10.13 cm, [3.98; 16.19]), whereas preferred IPD was shorter with happy characters than with neutral characters embedded in the same positive context (-5.55 cm [-9.16; -2.12]). Second and appealingly, preferred IPD with the neutral characters did not differ from preferred IPD with the contextual emotional characters when belonging to different contexts. More precisely, preferred IPD with angry characters was not different from that with neutral characters embedded in the positive context (+5.18 cm [-2.17; 12.68]). Similarly, preferred IPD with happy characters was not different from preferred IPD with neutral characters embedded in the negative context (-0.61 cm [-8.73; 7.39]). Therefore, even though the contrast effect was not directly observed on IPD regulation when comparing preferred IPD with the neutral characters of each context, the above analysis revealed that the emotional context specifically altered preferred IPD with the neutral characters although sparingly.

## **Discussion**

In social context, facial expressions serve as social signals that provide information about the emotional state of others (Hess, Banse, & Kappas, 1995), that helps to coordinate and facilitate interpersonal interaction and communication (Niedenthal & Brauer, 2012; Parkinson,

Fischer, & Manstead, 2005). Accordingly, IPD regulation is dependent on the emotion perceived in others' facial expression: the more conspecifics appear positive, the shorter the preferred IPD; conversely the more conspecifics appear negative, the larger the preferred IPD (Coello & Cartaud, 2021; Ruggiero et al., 2017, 2021). However, it has been highlighted that judging the affective dimension in others through their FE also depends on the emotional context (Hess & Hareli, 2016; Wedell & Parducci, 1988), which can be altered by the simple presence of other people (Kafetsios & Hess, 2013; Masuda et al., 2008). More precisely, a contrast effect (*i.e.*, a negative correlation between the valence ratings of a neutral target and the valence of the context), which can be formalized by the RF model, has been often reported when presenting successive faces with various emotional FE (Wedell & Parducci, 1988). The aim of the present study was to establish whether the valence of a neutral character, when influenced by an emotional context (using positive and negative emotional characters), leads also to congruent IPD regulation.

On the one hand, and in line with the previous studies, we observed a contrast effect on the valence ratings of neutral characters when presented in the unimodal emotional context condition. Thus, neutral characters were judged more positively when presented in a context made up with angry characters than when presented in a context made up with happy characters (Wedell & Parducci, 1988). This finding outlines the crucial role of contextual information in the processing of emotional stimuli (Hess & Hareli, 2016). On the other hand, when participants were exposed to an initial emotional context (*e.g.*, positive), then to a contrasting emotional context (*e.g.*, negative), valence ratings of the neutral characters were influenced by both contexts (Parducci, 1965). Indeed, the average valence ratings was 2.81 (or 6.41) for the neutral characters embedded in the positive (or negative) context of the unimodal session, whereas it was 4.56 (or 5.31) for the neutral characters embedded in the positive (or negative) context of the multimodal session, which did not differ from the control group (4.59, a value close to the

central position of the range of the whole set of stimuli). This suggests that the same emotional context did not have the same impact on valence ratings of the neutral characters depending on whether or not it was preceded by a contrasting emotional context. Accordingly, valence ratings of the neutral characters embedded in a negative multimodal context differed only slightly from those of the neutral characters embedded in a positive multimodal context. This indicates that both contexts influenced neutral characters judgments, nearly cancelling each other, and suggests the presence of a small temporal decay of the influence of previously encountered contextual stimuli on valence ratings, which was not predicted by the RF model (Parducci, 1965).

With respect to the effect of emotional context on IPD regulation in the unimodal session, preferred IPD with neutral characters was specifically altered by the emotional context in the direction predicted by the contrast effect. Indeed, while preferred IPD with neutral characters (in either the negative or positive context) deviated from preferred IPD with the emotional characters within the same context (angry or happy characters respectively), it did not differ from preferred IPD with the emotional characters of the other context (happy or angry characters respectively). Preferred IPD with the neutral characters in the positive context (53.33 cm) shifted towards and eventually became not different from the preferred IPD with the angry characters (58.51 cm), while being larger than preferred IPD with the happy characters (47.78 cm). A mirror pattern of results was observed when considering the neutral characters in the negative context. Preferred IPD with these neutral characters (48.39 cm) was shorter than preferred IPD with the angry characters but not from preferred IPD with the happy ones. Therefore, the contrast effect produced by the emotional context, which was observed on valence ratings, extended to IPD regulation, suggesting that IPD regulation is also permeable to the influence of the emotional context. Consistent with our hypothesis, as valence ratings of neutral characters increased (or decreased) in the negative (or positive) emotional context,

preferred IPD decreased (or increased) with respect to the same neutral characters. These results confirmed, thus, the dependency of IPD regulation on the subjective valence attributed to social stimuli (Coello & Cartaud, 2021), although going deeper into the underlying processes by highlighting that the emotional context also impacts IPD regulation in social interactions.

The contrast effect was however not significant enough to be observed when directly comparing the neutral characters embedded in the positive and negative contexts, as this was observed for the valence rating task. This differential effect of the emotional context did not seem to be accounted for by a large difference in variability in the participants responses in the two tasks: the coefficients of variation were of 4.36% and 10.32% for the neutral characters embedded in the negative and positive context respectively for the valence rating task and of 8.62% and 6.97% for the IPD judgment task. More likely, the weaker contrast effect on preferred IPD indicates that changes in valence produced by the context altered preferred IPD sparingly. This weaker effect might result from multiple factors. First, in the IPD judgment task, participants were asked to judge whether the distance was “appropriate” rather than “comfortable” to interact with the characters. This former concept might be more associated to social conventions than personal feelings, which can lead to differential effects in social judgments (Kennedy et al., 2009). Second, this weaker effect might be due to the different nature of the tasks used in the present study. Indeed, the valence rating task can be considered as a perceptual task that do not imply physical interaction with the social stimulus. By contrast, although based on the computation of spatial distance, IPD judgment also required action-related decision-making processes. This differential effect of the emotional context on valence ratings and IPD judgments would thus echo the classical dissociation reported between perception and action, based on compelling evidence that perception and action compute different aspects of the visual environment, in particular with respect to contextual information (Goodale & Milner, 1992). This latter possibility suggesting a specific processing of visual

information depending on the nature of the task is also reinforced by the differential effect of characters' gender. Indeed, whereas a classical gender effect of the characters was observed on preferred IPD as in previous studies (Iachini et al., 2016), this was not the case for valence ratings. However, further research would be required in the future to provide conclusive evidence for this interpretation.

Overall, the data confirm the well-known contrast effect of emotional context on valence-based judgments. As a corollary, changing valence judgments of a neutral social stimulus through the emotional context alters preferred IPD with the same neutral social stimulus, although sparingly. While the present study highlighted a differential effect of the emotional context on valence perception and IPD regulation, the findings nonetheless suggest that in everyday social interaction, the (temporal) social context contributes to the regulation of IPD when interacting with conspecifics. They also pave the way for more in-depth investigations into the effect of contextual information on IPD regulation. In particular, it would be interesting to investigate the contrast effect on clinical populations considering for instance individuals with social anxiety that shows specific sensitivity to the valence of emotional contextual stimuli (Delchau, Christensen, Lipp, & Goodhew, 2020) and alteration of IPD regulation (Givon-Benjio & Okon-Singer, 2020; Givon-Benjio et al., 2020).

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## Authors Contribution

All authors contributed to the study design, data collection and interpretation. A.C. programmed the online experiment and performed the data analysis. All authors contributed to drafting the manuscript and provided critical revisions. All authors approved the final version of the manuscript for submission.

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