Effects of jointly recalling emotions in dyads on emotional valence and arousal: A preregistered study using Light Detection and Ranging (LiDAR)

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Abstract

Emotions play a crucial role in social interactions, yet little is known about the effects of experiencing emotions together with others on expressed emotional valence and arousal. We compared changes in adults' body posture when recalling experiences of positive and negative basic emotions (happiness & sadness) and social emotions (pride & shame), either jointly (dyadic condition) or by themselves (individual condition). To capture the dynamic unfolding of the emotional experience, we used a novel depth sensor imaging technique based on LiDAR-technology integrated in a commercial tablet. Adults (N = 80) displayed greater postural chest-height elevation and upper-body chest expansion (measuring valence) following positive compared to negative emotion recalls. Furthermore, participants showed more overall movement (measuring arousal) after positive compared to negative emotions, especially in the dyadic condition. These results suggest that recalling emotions together affects non-verbal expression of emotions, and we discuss our findings in light of recent advances in emotion science.

Keywords: social emotions, joint emotion recall, body posture, computer vision

Introduction

Emotions are an integral part of human social life. The experience and expression of emotions regulate interactions with others and give meaning to our relationships in ways written or spoken language do not (van Kleef et al., 2016). Emotions can be broadly classified into two categories: Basic emotions include anger, happiness, disgust, sadness, and fear while social, or self-conscious, emotions include guilt, pride, shame and embarrassment (APA dictionary of Psychology, 2025). In contrast to basic emotions, social emotions can serve important interpersonal functions to maintain and repair relationships. For example, the *experience* of guilt or shame motivates individuals to repair relationships and to conform to social norms. Likewise, the *expression* of guilt after transgressions or of shame following non-conforming behavior motivates observers to punish such behaviors less (Vaish & Hepach, 2020).

Emotions thus regulate behavior in social interactions, and they are also often experienced together with others (Crivelli & Fridlund, 2018). Emotions experienced jointly often result in stronger and longer-lasting experiences (Goldenberg, 2024) than individually experienced emotions. Emotions recalled together are also rated to be more positive in valence, both when experienced in dyads (Moreland, 2010) and in groups (Pizarro et al., 2022; for a recent meta-analysis see Chung et al., 2024).

Despite the importance of emotions for regulating social interactions, most studies measured experienced or expressed emotions in individual participants (cf., Goldenberg, 2024). However, by not considering the effects of the actual or imagined presence of others (a key feature of defining social

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psychology, see Aronson et al., 2018) we may limit our understanding of the nature of especially social emotions which crucially regulate interactions between people. Research on joint emotional experiences, in turn, has mainly relied on participants' self-reports (Chung et al., 2024), which provide only an indirect assessment, and they lack a more objective, physiological measurement (cf., Chung et al., 2024). Self-reports are also subject to biases such as social desirability concerns (Reisenzein, 2022; Hepach & Vaish, 2020).

A feasible alternative to self-reports is to capture emotional experience non-verbally through studying changes in participants' body posture. Individuals can infer emotions from posture (Ross et al., 2012; Zieber et al., 2014; Missana et al., 2015), and facial emotional expressions that are accompanied by congruent postural expressions are identified more readily than emotions displayed in one modality only (Mondloch, 2012; Rajhans et al., 2016; Hock et al., 2017). Moreover, posture can be observed from a distance and is hence easier to identify in others compared to facial expressions (Walk & Walters, 1988; as cited in McHugh et al., 2010).

In one recent line of work, body posture is often recorded during a walking sequence after an emotion induction. Such studies use emotional recall procedures, for example, to induce emotions in participants (Suchodoletz & Hepach, 2021). Hepach and colleagues found that a slumped posture is indicative of negative emotional valence while a more upright posture reflects positive emotional valence, in both children and adults (Hepach, Vaish & Tomasello, 2015; Hepach & Tomasello, 2020; Suchodoletz & Hepach, 2021; Gerdemann, Vaish & Hepach, 2025). Försterling et al. (2024) found more upper-body posture expansion as measured via the angle under the shoulders in children when they experienced more positively valenced emotions compared to more negative emotions. Other studies with adult participants found a relation between experienced emotions and the speed of walking, with slower walking in conditions that elicited sadness (Gross et al., 2012; Barliya et al., 2013; Kang & Gross, 2015; for a review see Xu et al., 2022), and individuals with a diagnosis of depression showed slower speeds of walking than a control group (Lemke et al., 2000; Michalak et al., 2009; Gross, 2012). In a similar vein, happiness was associated with faster walking speed (Gross, 2012) and larger arm swing (Jianwattanapaisarn, 2022).

However, to the best of our knowledge, no prior study induced emotions in both an individual and a joint context including more than one participant while recording all participants' postural expression of their experienced emotions. Thus, it remains an open question whether jointly experiencing emotions has effects on participants' expressed emotions that are different from experiencing emotions by oneself.

Rationale for introducing a new posture tracking method

Previous studies assessing emotions via changes in body posture have typically either relied on codings by human observers, proprietary used marker-based systems or used depth-sensor imaging cameras such as Microsoft's Kinect (see review by Xu et al., 2022). However, recent advances in computer vision enable marker-free tracking on recordings taken with standard cameras, including those found on modern smartphones. For example, compared to the closed-off systems present on older tracking devices, MediaPipe (Lugaresi et al., 2019) is an open-source tracking framework developed by Google and is compatible with multiple operating systems and coding languages. Compared to methods like OpenPose (Cao et al., 2019), MediaPipe is capable of running on low-power hardware, making it much more accessible. Previous studies (Hii et al., 2023) have compared MediaPipe to traditional marker-based systems in gait analysis and have shown excellent agreement.

Because MediaPipe is designed to track participants' locations in frames, however, any recording that relies solely on an RGB camera is susceptible to changes in perspective, as a subject moving will change their relative size in the frame. To compensate, we use an RGB camera paired with a 3D-sensing LiDAR camera, eliminating perspective distortions by tracking with MediaPipe in real-world units. To develop a widely accessible system, we chose the cameras and LiDAR sensors available on Apple's iPhone and iPad. To access the data from the iPad's LiDAR sensor, Record 3D (Simonik, 2025), a commonly employed 3D recording application, was used. Apple's LiDAR sensors have previously been successfully used in numerous applications, including scanning cliffsides for topological measurements (Lutenzburg et al., 2021) and the collection of forensic evidence (Kottner et al., 2023).

The present study

We investigated the effect of recalling emotional episodes together (dyadic condition) vs. alone (individual condition) on (1) changes in adult participants' upper-body posture (to measure valence) and (2) overall movement (to measure arousal). We hypothesized that positive emotions (happiness and pride) result in greater postural elevation than negative emotions (sadness and shame), a pattern that would replicate previous findings (Suchodoletz & Hepach, 2021; *Hypothesis 1*).

In addition, based on findings by Suchodoletz & Hepach (2021), we hypothesized that recalling social emotions (pride vs. shame) results in more exaggerated upper-body postural expression compared to basic emotions (happiness vs. sadness, *Hypothesis 2*).

Furthermore, we explored whether there was an interaction of the context in which an emotion is recalled (individual versus joint), and the type of emotion recalled (basic versus social). We hypothesized that social emotions are different from basic emotions, i.e., that their expression is more pronounced when they are recalled together with another person as compared to when they are recalled in the individual condition (*Hypothesis 3*).

To test our hypotheses, we measured changes in adults' posture using an iPad LiDAR-camera which allowed us to capture posture from multiple participants simultaneously.

Method

The study was pre-registered on the Open Science Framework (https://osf.io/x7ca2/), where the analysis scripts and data are also provided.

Participants. We recruited 80 adults (52 female, 22 male, 6 diverse), aged 18 to 40 years ($M = 23.94$, $SD = 5.08$) via local databases, and invited dyads ($n = 40$) to our research institute. The majority of participants did not know one another prior to the study ($M = 1.86$, $SD = 1.28$ on rating scale from 1 [not at all] to 5 [very well]). We captured positive and negative affect (range 10-50) in daily life via PANAS (Positive and Negative Affect Schedule; Watson et al., 1988), and found a mean positive affect rating of M = 33.25, SD = 1.28, and mean negative affect rating of $M = 22$, $SD = 6.30$. Participants received either a book voucher of 10 pounds or course credit. The study was approved by the ethics committee of the University of Oxford.

Design. The study was based on a within-subjects design in which we varied the independent factors 'Level of Social Interaction', i.e., whether participants recalled emotion individually or in a dyad, and 'Type of Emotion', with the conditions happiness, pride, sadness, and shame. The procedure encompassed three phases, first an individual condition for participant 1, then a dyadic condition with both participants, and lastly an individual condition for participant 2 (see Fig. 1). Each phase began with four baseline walks followed by eight emotion induction walks, i.e., four sets of two back-to-back walks for each emotion. Within each phase, we counterbalanced the order of the first emotion and randomized the order of the subsequent emotions. For each participant, the resulting order of emotion sets was kept constant for the individual and the dyadic conditions.

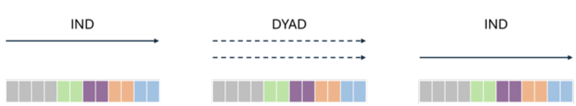

Fig. 1. Example sequence of conditions and emotion sets. One participant first completed the individual condition (IND) before the joint condition (DYAD) while the second participant completed the individual condition (IND) after the dyadic condition. Each condition consisted of a baseline set (grey) and four emotion inductions (here displayed in different colors, order counterbalanced).

Furthermore, we counterbalanced the position of where the first and second participant started their walk (left or right), as well as whether the first or the second participant shared their story first in the dyadic condition.

Procedure. We arranged the study visit for each participant within a dyad separately, such that the choice of study partners was mostly dependent on participants' availabilities (and not on whether they know one another). The study was run by a single experimenter (either male or female). Participants received an information sheet, and the experimenter explained the purpose and broad aims of the study to participants without stating the study's hypotheses. Written informed consent was obtained prior to the beginning of the study. Participants filled out questionnaires (see *Measures*) while the other person took part in the individual condition.

The individual condition began with the four baseline walks in which the participant was instructed to walk a distance across a hallway toward a camera and subsequently returned to the starting position. Following the baseline walks, the experimenter introduced the individual condition:

> "Now we will do the emotion walks. Remember I will ask you to recall an emotional experience that you are willing to share with someone else later. Next, I will ask you to walk again from here (experimenter pointed to the starting position marked by a cross on the floor) to there (experimenter pointed toward the camera on the opposite side of the starting position). During these walks you can express your emotions freely!"

Next, we gave the participant the following prompt:

> "The emotion to be displayed is happiness (sadness, pride, shame). Can you recall an event that made you feel happy (sad, proud, ashamed)? Try to vividly recall that feeling. Imagine a specific situation and the surroundings. Take your time until you experience the emotion happiness (sadness, pride, shame). When you feel happy (sad, pride, ashamed) you can start walking."

After each set of emotion walks, participants noted the specific emotional episode they recalled on paper.

Analogous to the individual condition, in the dyadic condition participants first walked toward the camera four times to complete the baseline phase. Participants walked side by side. The emotion sets were introduced as follows:

> "The emotion to be displayed is happiness (sadness, pride, shame). *[Participant 1]*, *[Participant 2]*, can you recall an event that made you feel happy (sad, proud, ashamed)? Try to vividly recall that feeling. Imagine a specific situation and the surroundings. Please

> tell *[Participant 1], [Participant 2]* about this experience. Please both take your time until you experience the emotion happiness (sadness, pride, shame). When you both feel really happy (pride, sad, ashamed) you can start walking together."

After completing the dyadic condition, we presented the second participant with the individual condition.

Data processing Data was recorded using an iPad Pro (11-inch, 3rd generation, OS version 17.4), which was primarily chosen for its inclusion of a Time-of-Flight LiDAR-sensor on the rear camera. Data were recorded with Record3D (Simonik, 2025), in a RGBD-format. This format places the standard RGB video and a Depth Map (see Fig. 2) side by side, allowing for easy separation and processing while keeping all of the data in a single MP4 video file. When two participants were part of the video (dyadic condition), the recording was s split into a "left" and "right" video.

The RGB and depth information was then separated into separate frames, and MediaPipe Pose (Lugaresi et al., 2019) was used to track participant's posture (see Fig. 2). MediaPipe outputs pixel coordinates for each landmark, which were translated to the depth video to extract the 3D information for each landmark. These data were then exported as a CSV-file at which point it was loaded into *R* (R Core Team, 2023, version 4.2.3) for post-processing.

Ratings of emotion strength. Participants rated how strongly they felt the emotion after every set of walks, on a Likert scale ranging from one to seven, with one indicating 'not at all' and seven 'very much', for example.

Upper-body chest height. As a measure of emotional valence, we calculated the change in participants' chest height, following previously established analyses routines (Gerdemann et al., 2022c; Hepach et al., 2020; Sivertsen et al., 2024). For each walk, we captured the height (in cm) of the participant's chest point (see Fig. 2) and between the distance of 4 and 2 meters (from the camera) we estimated this height within each of 20 distance bins of 10 cm each (based on the depth information provided). This resulted in 24 data rows consisting of 20 chest height data points for each walk per participant (*individual* condition: 4 baseline, 2 happiness, 2 sadness, 2 pride, and 2 shame; *dyadic* condition: 4 baseline, 2 happiness, 2, sadness, 2 pride, and 2 shame). In a subsequent step we averaged the data across all 4 baseline walks within each condition (per participant) and subtracted this average set of 20 bins from the data of each emotion set (both data rows per emotion were average) resulting in 4 baseline-corrected data rows (1 for each emotion set) for each condition, for each participant.

Upper-body chest expansion. As a measure of upper body expansion, based on a previous study (Försterling et al., 2024), we calculated the angle under the shoulders, with larger angles indicating more expansion. Specifically, we calculated the angle Hip – Shoulder – Elbow, averaged for the left and right side of the body. The data were run through the same script as the chest height, resulting in the same data structure with 20 distance bins.

Movement calculation. As a measure of overall movement, we calculated the sum of the absolute (frame-by-frame) differences between 8 angles, averaged across the number of frames (based on a previous study, Försterling et al., 2024):

$$\frac{1}{N_\theta}\frac{1}{N_{Frames}}\left(\Sigma_i^{N(Frames)-1}\Sigma_j^{N(\theta)} abs(\theta_{i,j}-\theta_{i+1,j})\right)$$

The data was run through the same scripts as above.

Fig. 2. An illustration of how the skeleton was mapped onto the participant while they were walking toward the camera (left panel), and an illustration of the depth information (indicated by standard rainbow colourmap, with red being closest to the camera) taken from Record 3D (right panel).

Statistical modelling. To test our hypotheses, we fitted linear mixed models with the lme4-package (Bates et al., 2014) in *R* (version 4.2.3). The structure of the main model was:

> lmer(Change ~ Distance + Emotion*Condition + Sex + Trial + Block + (1+ Distance.zscore + Trial.zscore || Subject) + (0+Emotion.code1| Subject) + (0+Emotion.code2 | Subject) + (0+Emotion.code3 | Subject) + (0+Condition.code1|Subject) + (1 | Side) + (1 | SharedFirst)

where *Change* was the baseline-corrected value for each distance bin depending on the dependent measures (i.e., chest expansion, or chest height). *Distance* was the number of the distance bins between 4 and 2 meters aways from the camera (1 to 20), *Emotion* (happiness, sadness, pride, shame) and *Condition* (individual, dyad) were the independent factors varied within subjects, *Sex* referred to the gender provided by the participant (female, male, diverse), *Trial* (1 to 4) was the numerical value identifying each emotion set within each block, and *Block* referred to the order of the condition within each dyad (1 to 3). In addition, each model

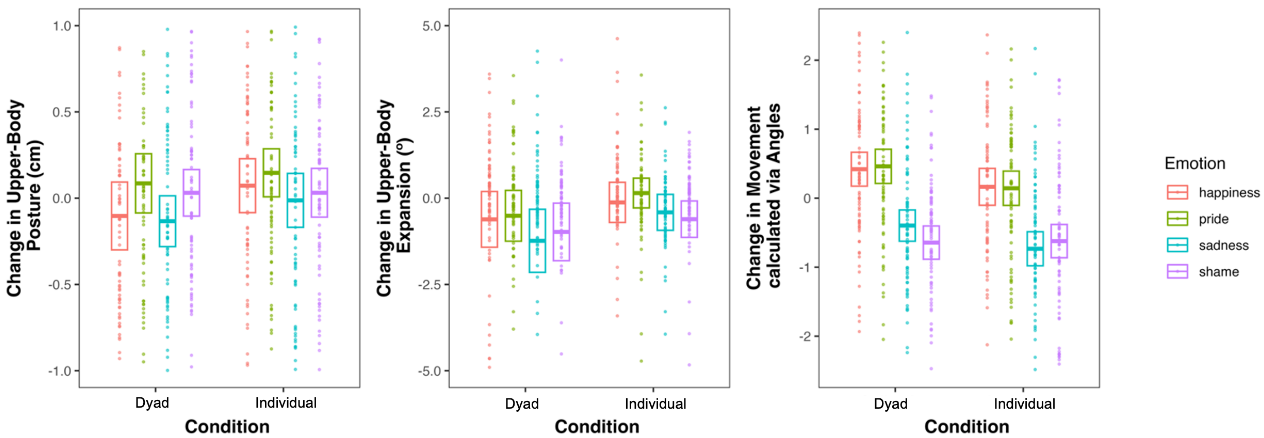

Fig. 3. Change in baseline-corrected chest height, expansion angle and movement mapped across conditions and emotions, with boxes representing 95% confidence intervals. Note that a few datapoints are not displayed to increase the scaling of the boxes but these values were included in the statistical analyses

included random intercepts for *Subject*, *Side* (left or right), and *SharedFirst* (whether the participant shared each emotional episode first during the dyadic condition (yes or no) as well as random slopes for *Distance.zscore* on *Subject*, *Trial.zscore* on *Subject*, *Emotion* on *Subject*, and *Condition* on *Subject*.

We tested the interaction of the fixed effects of *Emotion* and *Condition* by comparing the main model to a reduced model that was identical in structure, but which included both fixed effects as individual main effects. Post-fixed effects as individual main effects. Post-hoc investigations were guided by plotting the data with the average value for each emotion within each condition alongside 95% confidence intervals. All our analyses were preregistered.

Results

Reported emotion strength. There was no statistically significant interaction between emotion type and condition (individual and dyad) ($\chi 2(df = 3) = 7.53$, $p = .06$) on participants ratings of how strongly they felt the emotion. Instead, and after fitting a separate model which included all fixed effects as main effects only, we found that participants' emotion ratings varied with the type of emotion participants were asked to recall ($\chi 2(df = 3) = 26.14$, $p < .001$). The positive emotions happiness ($M = 5.23$, $SD = 1.25$) and pride ($M = 5.03$, $SD = 1.22$) were experienced more strongly than the negative emotions sadness ($M = 4.94$, $SD = 1.42$) and especially shame ($M = 4.51$, $SD = 1.45$).

Upper-body chest height. We found that participants' chest height varied systematically with both the emotion they recalled and the condition in which they did so, $\chi 2(df = 3) = 12.41$, $p = .006$ (see Fig. 3). In the individual condition, both positive emotions, i.e., happiness ($M = 0.07$cm, $SE = 0.08$cm) and pride ($M = 0.15$cm, $SE = 0.07$cm), resulted in greater postural elevation, compared to negative emotions, i.e., sadness ($M = -0.02$cm, $SE = 0.08$cm) and shame ($M = 0.03$cm, $SE = 0.07$cm). This pattern was different for the dyadic condition where both social emotions, pride ($M = 0.09$cm, $SE = 0.09$cm) and shame ($M = 0.03$cm, $SE = 0.07$cm), resulted in higher levels of postural elevation compared to the two basic emotions, happiness ($M = -0.103$cm, $SE = 0.099$cm) and sadness ($M = -0.13$cm, $SE = 0.66$cm). We did not find effects of Trial ($\chi^2(df = 1) = 0.38$, $p = .53$) or Block ($\chi^2(df = 1) = 0.31$, $p = .58$) but we found effects for Distance ($\chi^2(df = 1) = 9.32$, $p = .002$) and Sex ($\chi^2(df = 1) = 7.25$, $p = .03$).

Upper-body chest angle expansion. We did not find evidence for chest expansion varying systematically with both the emotion they recalled and the condition in which they did so, $\chi 2(df = 3) = 6.67$, $p = .08$. Instead, and after fitting a separate model which included all fixed effects as main effects only, we found that participants' upper-body expansion angle varied with the type of emotion participants were asked to recall, $\chi 2(df = 3) = 13.25$, $p = .004$. Specifically, and across both condition, adults showed greater posture expansion for the positive emotions of happiness ($M = -0.34^{\circ}$, $SE = 0.25^{\circ}$) and pride ($M = -0.18^{\circ}$, $SE = 0.19^{\circ}$) compared to the negative emotions of sadness ($M = -0.8^{\circ}$, $SE = 0.25^{\circ}$) and shame ($M = -0.8^{\circ}$, $SE = 0.25^{\circ}$). There were no effects of Condition ($\chi^2(df = 1) = 2.13$, $p = .14$), Distance ($\chi^2(df = 1) = 1.36$, $p = .24$), Trial ($\chi^2(df = 1) = 0.02$, $p = .9$), Sex ($\chi^2(df = 2) = 0.14$, $p = .93$), or Block ($\chi^2(df = 1) = 1.19$, $p = .28$).

Movement calculated via angles. We found that participants' movement varied systematically with both the emotion they recalled and the condition in which they did so, $\chi 2(df = 3) = 7.82$, $p = .05$. In the individual condition, both positive emotions, i.e., happiness (M = 0.251, SE = 0.12) and pride (M = 0.145, SE = 0.13), resulted in greater postural elevation, compared to negative emotions, i.e., sadness (M = -0.708, SE = 0.12) and shame (M = -0.567, SE = 0.11). A similar pattern was observable for the dyadic condition in that happiness (M = 0.375, SE = 0.11) and pride (M = 0.430, SE = 0.11) led to more movement than sadness (M = -0.422, SE = 0.11) and shame (M = -0.585, SE = 0.12). Both positive emotions elicited more movement in the dyadic compared to the individual condition. We did not find effects of Trial ($\chi^2(df = 1) = 0.75$, $p = .39$), Block ($\chi^2(df = 1) = 0.32$, $p = .57$) or Distance ($\chi^2(df = 1) = 0.14$, $p = .70$) but we found an effect for Sex ($\chi^2(df = 2) = 6.71$, $p = .035$).

Discussion

In the present study, we asked dyads of participants to recall emotional episodes together while we measured the dynamic unfolding of their emotional expressions via changes in their body posture using a LiDAR-sensor. Crucially, we included a comparison condition in which each participant recalled the emotion by themselves. This design allowed us to investigate whether basic and social emotions are differentially expressed when experienced by the individual alone, or together with another participant. Our main findings in relation to our hypotheses were as follows: Recalling positive emotions (happiness, pride) resulted in more upper-body chest elevation in the individual condition. In addition, we found more upper-body chest expansion in both conditions, and more overall movement in both conditions compared to recalling negative emotions (sadness, shame). In contrast, we found no strong evidence that recalling emotions together systematically changed how those emotions were non-verbally expressed.

More specifically, our results thus replicated previous findings that positive emotions resulted in greater postural elevation than negative emotions (see Suchodoletz & Hepach, 2021; Försterling et al., 2024). This lends support for *Hypothesis 1*. In contrast, we did not find support for *Hypothesis 2* or *Hypothesis 3*. Specifically, it was not the case that the expression of social emotions was more exaggerated than the expression of basic emotions, and experiencing emotions together did not result in more exaggerated expressions for the social emotions specifically. We did observe, however, that there was more movement in the dyadic compared to the individual condition, only for positively valenced emotions, but not for negative emotions.

In the present study, we introduced and demonstrated a novel method to combine recordings on a commercial iPad vis-a-vis the computer vision toolbox MediaPipe to extract 3D posture keypoints. This methodology has the significant advantage to previous studies which used posture tracking via computer vision for emotion detection in that it allows 3D pose tracking, not only 2D keypoint extraction (see e.g., Cao et al., 2019), and relies on one camera only, and does not require a set-up with multiple cameras. In addition, this method can utilize the cameras from commonly used smartphones, rather than relying on specialized hardware. This allows the system to be much more accessible while still providing a high degree of accuracy in tracking. Furthermore, by using MediaPipe as the tracking framework, our system should improve with time as more and more resources are put into developing the model for other applications.

In our study we not only included basic emotions, but also social emotions, which are relatively less frequently represented in the literature (e.g., Barrett et al., 2019). As outlined in the introduction, especially to investigate social emotions which are often experienced in the actual or imagined presence of other individuals, eliciting them together with another participant reflects the typical experience of these emotions more closely. In this study, we demonstrated that the combination of MediaPipe and Record 3D can be used with multiple participants simultaneously.

Limitations. The present study is the first to use a LiDAR-sensor to capture emotions via changes in body posture in adults. In comparison to previous work, the absolute effects in the present study were small and this may indicate that the experimental manipulations were not strong enough to engage participants sufficiently in recalling the respective emotional episodes. Nevertheless, it is noteworthy that the technology allowed us to capture relatively small overall effects and to estimate differences across conditions.

With respect to the dyadic condition, note that emotions were only recalled together with another person, but that person was not the actual social interaction partner with whom the emotion was originally elicited in the recalled situation. Specifically for the emotion shame, experiencing a shameful event in front of others may intensify the emotion, while relating a shame episode to someone who themselves shares a similar episode may reduce the individual experience of shame.

Conclusion

We pursued two aims with this study. First, to investigate how recalling emotions together affects the non-verbal expression of social (pride, shame) and basic (happy, sad) emotions. We did not find such systematic differences in the non-verbal expression of emotions. Instead, and in line with prior work, recalling positive emotions – whether by oneself or together with others – increases upper-body postural elevation and expansions and it increases overall movement in the expression of emotions. The second aim was to introduce a novel method which allows us to track 3D posture keypoints of two participants simultaneously. We found that posture indices reflected the emotional recall of participants, both when recalling the emotional episode by themselves or jointly with another person. Overall, the study demonstrates that tracking emotions via posture can also be used to gain insights into how emotions are experienced together with other individuals, which is especially relevant for the study of the category of social emotions.

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