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Pain perception and physiological responses are modulated by active support from a romantic partner

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Abstract

As social animals, humans are strongly affected by social bonds and interpersonal interactions. Proximity and social support from significant others may buffer the negative outcomes of a painful experience. Several studies have investigated the role of romantic partners' support in pain modulation, mostly focusing on tactile support and showing its effectiveness in reducing pain perception. Nevertheless, no study so far has investigated the role of supportive speaking on pain modulation, nor has compared the effects of a tactile and vocal support within the same couples. The present study directly compared for the first time the efficacy of mere presence (*Passive Support*) and different forms of active (*Touch, Voice, Touch + Voice*) support from a romantic partner during a painful experience in a naturalistic setting. We assessed pain modulation in 37 romantic couples via both subjective (self-reported ratings) and physiological (skin conductance) measurements. We found that all three types of active support were equally more effective than passive support in reducing the painful experience at both subjective and physiological levels; interestingly, our results suggest that supportive speaking can reduce pain perception with respect to passive support to a similar extent as tactile support does. Overall, this study highlights the relevance of an active support in reducing pain perception, with active types of support being more effective than passive support, regardless of its specific modality.

KEYWORDS

autonomic response, electrodermal activity, pain modulation, romantic partner support, skin conductance responses, tactile support, vocal support

1 | INTRODUCTION

Humans are naturally driven by a phylogenetically rooted motivation to belong and to be socially connected to others (Baumeister & Leary, 1995; Bowlby, 1969), to the extent that their individual well-being is crucially affected by others (Gil et al., 1987; Holt-Lunstad et al., 2010). Brown et al. (2003) have shown that the mere presence of a supportive individual attenuates pain perception: it raises pain tolerance and decreases its perceived intensity, even without explicit verbal or physical support. Furthermore, social modulation of experimental pain has been proven to be boosted by emotional intimacy (Coan et al., 2006; Floyd et al., 2018). Several studies have shown that the support provided by a romantic partner is more effective compared with the one provided by a friend or a stranger (Coan et al., 2006; Floyd et al., 2018; Goldstein et al., 2017; Reddan et al., 2020) and that the mere activation of a partner's representation (e.g., looking at their pictures) is sufficient to alleviate the individual sufferance resulting from a painful experience (Eisenberger et al., 2011; Master et al., 2009; Younger et al., 2010). It has been argued that, when facing threatening situations, romantic partners may function as safety signals helping the individuals to better cope with adversities, by providing them with feelings of security and protection (Eisenberger et al., 2011). However, it is still debated whether safety signal represents a reliable construct in experimental psychology (Laing & Harrison, 2021) and whether significant others do really function as safety signals (Morato et al., 2021). When specifically dealing with pain modulation, it has also been proposed that safety signaling provided by attachment figures might reduce perceived painfulness by affecting either interoceptive or contextual salience associated with an upcoming noxious stimulus (Krahé et al., 2013). In the last few decades, a variety of studies have examined how tactile support from a romantic partner (e.g., supportive handholding) reduces the perception of physical pain when induced in a laboratory setting (Che et al., 2021; Coan et al., 2006; Floyd et al., 2018; Goldstein et al., 2017; Goldstein et al., 2018; Kreuder et al., 2019; López-Solà et al., 2019; Reddan et al., 2020; von Mohr et al., 2018). It has been shown that receiving a supportive touch by a romantic partner decreases arousal levels by reducing the activity of brain areas involved in alarm processing (Coan et al., 2006; Triscoli et al., 2017), promotes recovery following a stressful event (Roberts et al., 2015), diminishes pain perception, and prompts physiological coupling between partners (Chatel-Goldman et al., 2014).

However, a small portion of studies has investigated the effects of a vocal support in reducing a painful experience. It has been shown that a gentle and supportive speaking can reduce anxiety levels and individual distress (Seltzer et al., 2010, 2012). Nonetheless, such effects were only investigated in relation to mother-daughter dyads and stressful situations, without involving romantic couples or painful experiences. Thus, little is still known about the beneficial effects of a romantic partner speaking to someone in pain, and no studies have compared the effects of a tactile and vocal support within the same couples during a real-life interaction.

Finally, although it is well known that the experience of physical pain is associated with autonomic responses such as skin conductance responses (SCRs; Gründahl et al. 2022; Leknes et al., 2008), only a small portion of studies have investigated the physiological correlates of social support from a romantic partner within the pain domain (Che et al., 2021; Goldstein et al., 2017). Specifically, only one study has reported a decrease in SCR following tactile support during a painful procedure (Reddan et al., 2020). However, research in this domain is limited and totally absent for vocal support (either alone or combined with tactile support), and further studies are needed to better understand how the partner's support can directly affect autonomic responses.

In the present study, we compared different kinds of partner's support on pain perception. We induced regulated experimental pain on young females and compared the effects of passive and active support from their romantic partners at the subjective and physiological levels (i.e., subjective ratings and SCRs). To promote a naturalistic interaction and enhance the effects of a partner's support, we designed and implemented a live ecological paradigm. First, we investigated the differences between passive (mere presence) and active support on pain perception. We hypothesized to find a stronger pain reduction during an active support promoted by the partner compared with a passive support. Second, we compared the efficacy of different kinds of active support within the same couple. Because we were interested in exploring whether a specific type of support modality could be more effective than others in alleviating individual distress, we compared the effects of supportive touch and supportive speaking at the subjective and physiological levels. We hypothesized that not only tactile but also vocal support would contribute to reduce the perception of experimentally induced painful stimuli. Third, we investigated whether the conjunction of tactile and vocal support would strongly reduce pain perception in our participants compared with when they received solely supportive touch or supportive speaking from their partners. We hypothesized a synergetic effect where the combined effect of the two support modalities would exceed the sum of the parts. Thus, we expected to find both at the subjective and physiological level that subjects would benefit more from partners' support when receiving tactile and vocal support simultaneously compared with solely touch or speech. Additionally, because previous studies have highlighted the contribution of emotional intimacy in pain reduction (Coan et al., 2006; Floyd et al., 2018), we wanted to investigate whether and to which extent the quality of the relationship might have affected the perception of being supported, and the subjective and physiological responses to a painful stimulus. Specifically, we expected to find a positive correlation between the relationship quality and the perception of being supported, and negative correlations between the relationship quality and the subjective and physiological correlates of pain perception.

2 | METHOD

2.1 | Participants

In this study, we recruited 37 romantic couples ($N = 37$). With our sample size, we had 99% of statistical power to detect differences among the supportive conditions (computed with G*Power; Faul et al., 2007) based on a similar study that reported greater support of handholding compared with gentle touch (comparing different supportive conditions) with an effect size of Cohen's $d = .85$ in a t-test planned comparison (Reddan et al., 2020). All couples were in a stable relationship (≥6 months) and reported elevated levels of relationship quality (mean = 103.264 ± 1.466 SE), according to the Italian version of the Dyadic Adjustment Scale (DAS; Spanier, 1976). Within our sample, 35 couples were opposite-gender couples and 2 were same-gender couples (lesbian couples). Participants had no history of psychiatric, neurological, or other relevant medical conditions. Female participants were pre-assigned to the role of "Experimental Subject" receiving painful stimulations, whereas males were pre-assigned to the role of "Partner." In the case of same-gender couples, the role of "Experimental Subject" was assigned randomly. All participants gave written informed consent to participate to the study approved by the Local Bioethical Committee of the University of Turin.

2.2 | Experimental setting and design

We included four experimental support conditions: (1) *Touch Condition*: the Partner was instructed to support the Experimental Subject by touching her left hand or arm; (2) *Voice Condition*: the Partner was instructed to gently speak to the Experimental Subject; (3) *Touch + Voice Condition*: the Partner was instructed to concurrently touch and speak to the Experimental Subject; (4) *Passive Support Condition*: the Partner was instructed to not say or do anything, besides looking at the Experimental Subject (Figure 1a). To promote an ecological live setting, the Partner was given complete freedom regarding the way of touching (i.e., squeezing the lover's hand, caressing her, etc.) or concerning the choice of supportive words. In the voice condition(s), some general supportive expressions (i.e., "don't worry," "you are doing great," "we are almost done") were displayed on the monitor in front of the Partner. However, those were just meant as hints and the Partner was explicitly encouraged to use his own expressions, unless struggling. The only explicit instruction for the Partner was to actively support the Experimental Subject.

Before the beginning of the session, the Experimental Subject underwent an electric stimulation calibration (see below for details). During the session, the two participants sat in front of their own monitor, as shown in Figure 1b. The Partner was given instructions about the type of support to provide on the monitor in front of him/her. The Experimental Subject was instructed to stare at a fixation cross displayed on the monitor screen in front of her, without moving or talking. At the beginning of each trial, the Partner was given instructions about the kind of support to provide in that trial. We provided the Experimental Subject and the Partner with different instructions for the whole trial.

2.2.1 | Experimental subject

At the beginning of each trial, we presented a fixation cross to the Experimental Subject that lasted for 12 s. After 7 s from the beginning of the trial, she received a painful stimulation that lasted 4 s on her right ankle. Then she was presented with a Visual Analogue Scale (VAS) ranging from 0 (no pain at all) to 100 (unbearable pain) (Figure 1c). The Experimental Subject was instructed to explore the screen freely, and then to fix her gaze on the spot of the line that corresponded to her perceived pain intensity. A Tobii© X2-30 Eye Tracker Compact Edition (Tobii©) was used to record the Experimental Subject's responses during the VAS. VAS ratings were used as behavioral self-report measures of pain perception. At the end of the four blocks, the Experimental Subject was invited to fill in the Perceived Supportiveness Form (*Questionnaire* section for details).

2.2.2 | Partner

At the beginning of each trial the Partner's monitor displayed the instruction about the type of support to use in that trial (e.g., "Support your partner by touch"; from 0 to 5 s); then, his/her support started and lasted 6 s (from 5 to 11 s). A countdown displayed on the monitor helped the Partner to keep count of the timing. At the end of the support an inter-trial interval (ITI) fixation cross was presented for 2 s (from 11 to 13 s); after the ITI, the instructions for the next trial were displayed on the monitor (e.g., "Get ready to support your partner by voice!") (Figure 1c).

The whole experiment consisted of four blocks, each of them involving 20 trials. Participants were exposed to each experimental condition five times per block (i.e., a total of

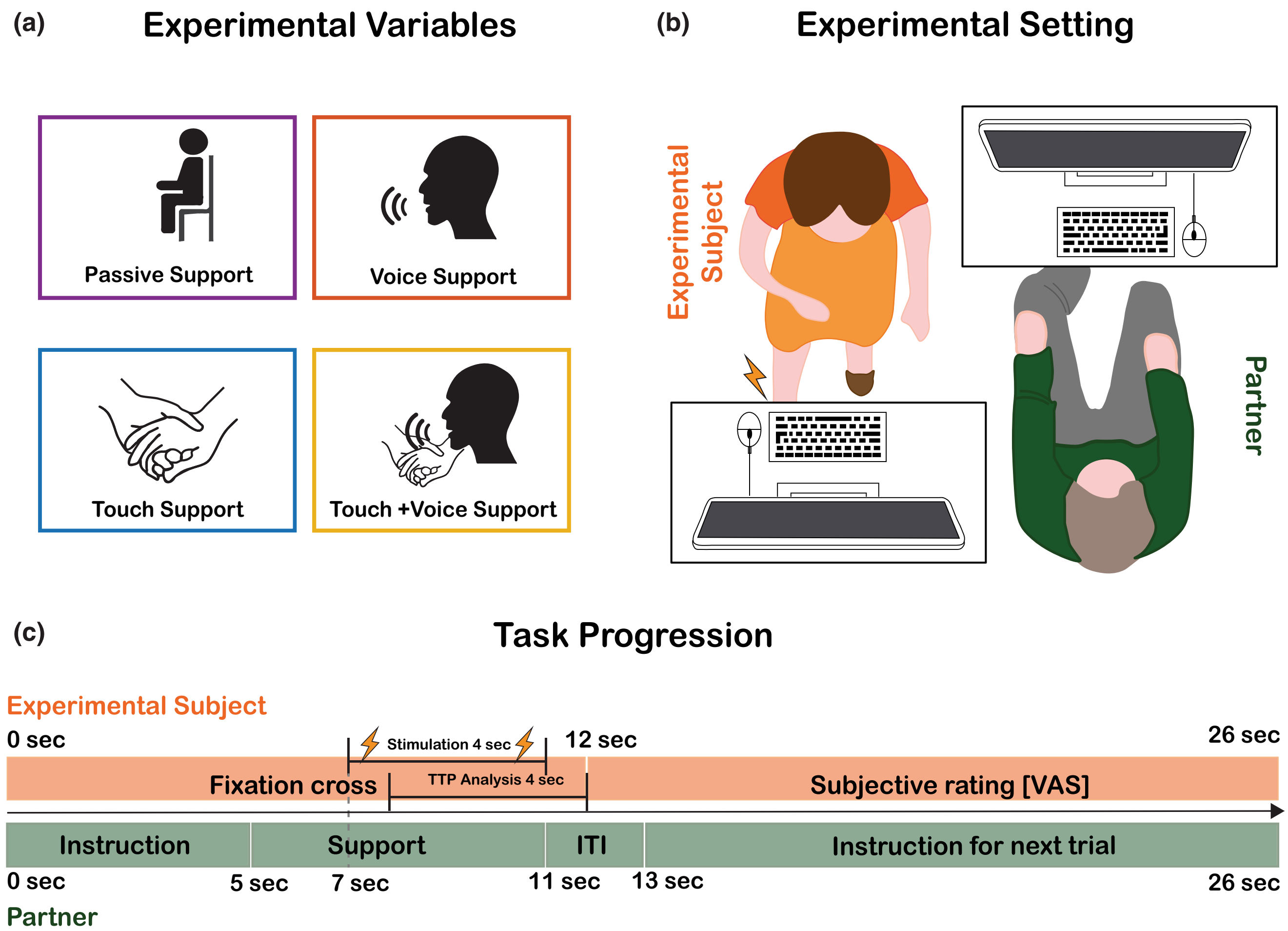

FIGURE 1 **(a)** *Experimental variables*. In each trial, the participant acting the supporter role (the Partner) was randomly instructed to support the Experimental Subject via mere presence (*Passive Support Condition*), touch (*Touch Condition*), voice (*Voice Condition*), or both touch and voice (*Touch + Voice Condition*). **(b)** *Experimental setting*. Participants sat in front of their respective monitors in an allocentric shifted position. **(c)** *Task progression*. Each trial started with a fixation cross displayed on the Experimental Subject's monitor for a total of 12 s (from time 0 to time 12 s); concurrently, a 5 s instruction was displayed on the Partner's monitor illustrating the support condition for that trial (from time 0 to time 5 s); then, the Partner started supporting the Experimental Subject for a total of 6 s (from time 5 to time 11 s), whereas the painful stimulation started 2 s after the beginning of support (at time 7 s). Next, the Experimental Subject was asked to report the perceived pain on a VAS ranging from 0 (no pain at all) to 100 (unbearable pain) displayed on her screen for a total of 14 s (from time 12 to time 26 s), whereas, after a 2 s ITI, the Partner received the instructions for the support condition of the following trial (from time 13 to time 26 s).

20 trials per condition over the entire procedure). To prevent sequence and order effects, support conditions (Touch, Voice, Touch + Voice, Passive Support) were presented in a random order within each block. Additionally, within each block 70% of the stimuli corresponded to the target intensity found in the threshold procedure, 20% were weaker-intensity stimulations, and 10% were catch trials (i.e., trials without stimulation) meant to prevent expectation and habituation.

2.3 | Questionnaires

Before the experimental session, participants were asked to fill out the DAS, a 32-item questionnaire meant to survey the dyads' relationship quality. The DAS questionnaire involves four sub-scales, which refer to Dyadic Consensus (agreement on important topics), Dyadic Satisfaction (how much the partners feel satisfied with their relationship), Dyadic Cohesion (the number of pleasant activities the partners engage together), and Affectional Expression (satisfaction on their affective and sexual life). The questionnaires were completed by the two members of the couple separately before the beginning of the experiment.

At the end of the experimental procedure, the Experimental Subjects were asked to fill out a "Perceived Supportiveness Form," a brief Likert scale questionnaire specifically developed by the experimenters for this study. Through a six-item questionnaire, the

Experimental Subjects were asked to subjectively rate the degree of supportiveness of their partners, on a scale ranging from 0 (not supportive at all) to 7 (extremely supportive). The first 4 items of the questionnaire were meant to assess how much the Experimental Subjects felt supported by their Partners during the four different support conditions: *Touch*, *Voice*, *Touch + Voice*, and *Passive Support* conditions with the goal to observe whether they had detected any difference among the efficacy of the different types of support ("How supportive did you find your partner while he was supporting you through touch/voice/touch and voice/sitting next to you?"). The last two items, instead, surveyed the extent of perceived romantic support during the entire procedure (item 5: General Perceived Support: "Overall, how supportive did you find your partner to be during the whole procedure?") and generally in everyday life (item 6: Daily life Support "How supportive do you find your partner to be in everyday life?").

2.4 | Electric stimulation: Apparatus calibration

The painful stimuli consisted of mild electrical stimuli (train of constant square-wave pulses lasting 200 ms, with a single pulse duration of 500 μs) generated with a direct current stimulator (DS7A Constant Current Stimulator, Digitimer). Impulses were delivered through classical disposable surface electrodes (5-mm diameter bipolar Ag/AgCl) located on the Experimental Subject's right ankle. Two different stimulation sites were fixed a priori for every subject (the internal and external part of the subject's ankle, that is, above the medial malleoli and above the lateral malleoli). During the experimental procedure, the stimulation site was shifted at the end of each block, alternately, to prevent habituation. Prior to the experimental session, the electrical stimulation intensity was individually calibrated through a staircase procedure (Cornsweet, 1962), to determine the intensity of the painful stimuli. A series of 4-s electrical stimuli of increasing intensity were delivered to the Experimental Subjects, starting with the near the perceptible tactile threshold (~0.05 mA). After each stimulus, participants were asked to verbally rate their pain on a scale from "0" (not painful at all) to "10" (unbearable pain). They were solicited to focus selectively on the painful stimulations, avoiding rating the merely tactile sensations. The intensity was increased in steps of 0.5 and 0.3 mA until subjects rated the electric stimulus with "8." At the end of the procedure, the amplitude of the target intensity (the painful stimulus) was set at the current level (mA) corresponding to the mean rating of "7." As pain sensitivity might differ according to the stimulation site, we ran two different calibration procedures for the two sites (medial and lateral malleoli): this allowed us to identify a target stimulation intensity for each site, whereby each target intensity (in mA) corresponded to a subjective pain rating of "7," despite they could differ in terms of current levels (mA). The stimulation site and the corresponding target intensities were shifted at the end of each block and remained stable for the whole duration of the subsequent block (among all four conditions).

2.5 | Physiological measures

Electrodermal activity (EDA) was recorded from the Experimental Subjects throughout the whole experiment (2 hours ca.). EDA was recorded using a BIOPAC MP160 biosignal amplifier working with a specific acquisition module for EDA100-C (Biopac Systems, Inc.). EDA was measured as skin conductance using a direct current, constant voltage methodology (Exosomatic Measurement with Direct Current). Two Reusable Wired EDA Transducer (BIOPAC TSD203, 6 mm diameter contact area) filled with GEL101 isotonic gel (0.05 molar NaCl) were attached to the proximal phalanges of subjects' right index and middle fingers by Velcro straps, approximately 10 minutes before starting recording. The gain parameter was set at 10 μSiemens (μS)/Volt and the signal sampled at 500 Hz with a 0.05 Hz high pass filter, to only record phasic SCRs. SCRs were assessed by computing the trough-to-peak (TTP) amplitudes within the 4-s window, starting 1 s after the painful stimulus onset and ending 1 s after the end of electrical stimulation. This peak detection method was implemented via Ledalab (an open-source tool for MATLAB©, The Mathworks Inc.; Benedek & Kaernbach, 2010) and indicates SCR amplitudes as the difference between the value at its peak and the preceding trough (Horvers et al., 2021).

To control for interindividual variability, TTP values were normalized: within each subject and each block, we extracted the maximum and minimum TTP amplitudes across trials and recomputed each value x according to Equation (1):

$$x_t = \frac{(x - \min)}{(\max - \min)} \tag{1}$$

then, the normalized value x_t was log-transformed (Curran-Everett, 2018) according to Equation (2). All following statistical analyses refer to the transformed TTP value x_{t_log}.

$$x_{t\_log} = \log_{10} x_t. \tag{2}$$

2.6 | Statistical analyses

Statistical analyses were run on questionnaires, subjective ratings (VAS) and physiological measures (skin conductance). One subject was excluded from the analyses due to technical failure in painful stimulation delivery, as suggested by an average VAS rating lower than 45. For both subjective ratings (VAS) and TTP, we ran two separate one-way repeated measures ANOVAs with Support Condition (*Touch, Voice, Touch + Voice*, and *Passive Support*) as within subject factor. In case of violation of sphericity assumption, we applied Greenhouse–Geisser correction as provided by the software IBM SPSS Statistics. Significant effects were followed up by Bonferroni-corrected pairwise t tests and values of $p < .05$ were considered significant.

To test whether *Passive Support* was sufficient to reduce pain perception, we ran a one-tail, one-sample, t-test contrasting VAS scorings in the *Passive Support* condition against 70 (the pain threshold value "7" set during calibration linearly transformed by multiplying it by a factor 10 to match the VAS scales). A value significantly lower than 70 would indicate a reduction in pain perception during the experimental task. In addition, we used item 4 (*Passive Support*) of the Perceived Supportiveness Form and ran a one-tail, one-sample, t test against zero. Values significantly larger than zero would indicate that Experimental Subjects perceived even the mere presence of their Partners as supportive.

Finally, because we were interested in studying how the relationship quality affects the perceived support and the experience of pain, we ran different bivariate correlations between the DAS questionnaire and the Perceived Supportiveness Form (Spearman' correlations), the subjective ratings (VAS; Pearson's correlations), and physiological measures (TTP; Pearson's correlations). Significant effects were followed up by Bonferroni corrections.

3 | RESULTS

3.1 | Subjective ratings

The one-way repeated measure ANOVA on subjective ratings (VAS scores) showed a significant main effect of Support Condition [$F_{(3, 105)} = 19.187$, $p < .001$, $\eta^2 = 0.354$], indicating that the subjective perception of pain actually varied according to the kind of support provided. Specifically, post-hoc multiple comparisons revealed that the *Passive Support* condition showed larger values than all the others (active support conditions; all $ps < .001$), indicating that active support led to lower pain ratings than passive support. On the contrary, no differences were found comparing the three active support conditions with one another (all $ps > .05$; *Voice vs. Touch*, $p = .605$; *Voice vs. Touch + Voice*, $p = 1$; *Touch vs. Touch + Voice*, $p = .422$; Figure 2a). These results suggest that active support promotes a stronger pain modulation with respect to passive support independently of the type of active support.

3.2 | Physiological measures

The one-way repeated measure ANOVA on TTP amplitudes showed a significant main effect of Support Condition [$F_{(3, 105)} = 5.897$, $p = .002$, $\eta^2 = 0.144$], indicating that the

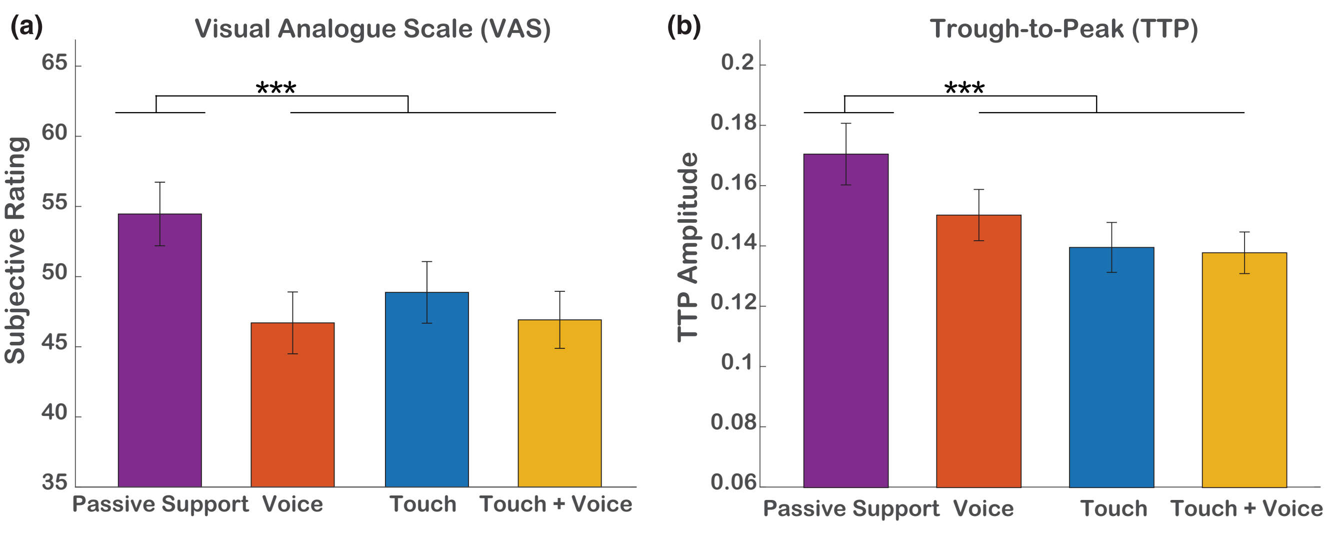

FIGURE 2 **(a)** *Subjective ratings*. Subjective ratings of pain perception in the four conditions as reported in the Visual Analog Scale. **(b)** *Skin conductance*. Log-normalized trough-to-peak skin conductance values in the four conditions. Bar plots display mean ± 1 SEM. ***$p < .001$.

support provided by the partner during a painful stimulation has an effect also on autonomic responses. Post-hoc *t-tests* revealed significant differences between the *Passive Support* condition [0.170 ± 0.010 (mean ± SEM)] and the three active support conditions (all $ps < .05$; *Passive Support vs. Voice*, $p = .044$; *Passive Support vs. Touch*, $p = .024$; *Passive Support vs. Touch + Voice*, $p = .023$), whereas no differences emerged from multiple comparisons between the active support conditions (all ps > 0.05; *Voice vs. Touch*, $p = 1$; *Voice vs. Touch + Voice*, $p = .722$; *Touch vs. Touch + Voice*, $p = 1$) (Figure 2b). These findings reflect, at a physiological level, the subjective ratings, with active support reducing the autonomic responses to painful stimulations with respect to passive support, regardless of the specific modality.

3.3 | Perceived supportiveness

The one-tail, one-sample, *t* test on *Passive Support* condition on VAS ratings showed that reported pain scores during passive support were significantly lower than 70 [54.462 ± 2.268 (mean ± SEM); $t_{(35)} = 6.851$; $p < .001$], indicating that the mere partner's presence can reduce pain perception.

The one-tail, one-sample, *t* tests contrasting the perceived partner supportiveness scores during the *Passive Support* condition against zero showed that subjects felt significantly supported even in the absence of an active support [3.19 ± 0.218 (mean ± SEM); $t_{(35)} = 14.683$; $p < .001$]. These results suggest that also a passive support can reduce pain perception.

3.4 | Correlations

Because we were interested in studying how the quality of the relationship between romantic couples might affect pain perception in our female participants, we then investigated this issue in more detail. First, we found a significant positive correlation between the DAS Total Score and the General Perceived Support score ($r = .351$, $r^2 = .123$, $p = .036$), indicating that subjects that were more satisfied with their relationship also perceived their partner as more supportive during the experimental procedure—regardless of the support perceived during the experiment. We also found a significant positive correlation between the DAS Total Score and the Daily Perceived Support score ($r = .611$, $r^2 = .373$, $p < .001$) confirming that subjects involved in higher quality relationship also perceived their partners as more supportive during everyday life. However, contrary to our expectations, the quality of relationship (DAS) did not correlate with subjective ratings (VAS) [*Passive Support* ($r = -.039$, $r^2 = .001$, $p = 1$); *Voice* ($r = -.017$, $r^2 = .001$, $p = 1$); *Touch* ($r = -.190$, $r^2 = .036$, $p = 1$); and *Touch + Voice* ($r = -.209$, $r^2 = .044$, $p = .884$)]. Additionally, the quality of relationship (DAS) did not correlate with any of the physiological (TTP) measures [*Passive Support* ($r = .122$, $r^2 = .015$, $p = 1$); *Voice* ($r = .257$, $r^2 = .066$, $p = .52$); *Touch* ($r = .096$, $r^2 = .009$, $p = 1$); and *Touch + Voice* ($r = .306$, $r^2 = .094$, $p = .28$)].

4 | DISCUSSION

The goal of the present study was to investigate the effects of romantic support on pain perception both at the subjective and physiological levels. As it is well known that the mere presence of a romantic partner reduces the perception of physical pain (Duschek et al., 2020; Edwards et al., 2017), we investigated whether active (i.e., supportive touch, supportive speaking, the conjunction of both) versus passive (i.e., mere presence) support as well as different types of active support provided by a romantic partner, differentially modulated pain perception in young females. Overall, we found that in young females active support reduced pain perception both at subjective (perceived pain) and physiological (skin conductance) levels, and that different types of active support do not quantitatively differ in modulating pain perception and autonomic responses. In addition, we found that the quality of the relationship between two romantic partners played a key role in determining the efficacy of social support during painful experiences.

In agreement with our hypothesis, we found that an active support from the partner decreased pain perception with respect to passive support. It has been shown that a supportive presence alleviates pain perception (Brown et al., 2003; Vlaeyen et al., 2009) and affects the associated physiological activity, decreasing skin conductance and heart rate responses during thermal pain experiences (Sambo et al., 2010). Nevertheless, other studies have found no difference between the mere presence of another person during painful situations and a condition where the participant was alone (Modić Stanke & Ivanec, 2010; Roberts et al., 2015). However, because the latter studies mainly involved the only presence of an unfamiliar observer during painful procedures, it is plausible that the unfamiliarity of the supporter attenuated the perceived supportiveness of such presence. In this respect, a study by Edwards et al. (2017) found a difference in pain reduction when comparing the effects of unfamiliar and familiar observers during painful situations, suggesting that the degree of emotional closeness with the observer may play a role in the perception of support and the alleviation of physical pain. Moreover, several studies showed how emotional intimacy can boost the effects of social support on pain perception (Coan et al., 2006; Floyd et al., 2018; Goldstein et al., 2017; Reddan et al., 2020), and just a picture of a romantic partner can be sufficient to alleviate individual distress (Eisenberger et al., 2011; Master et al., 2009; Younger et al., 2010).

A possible mechanism explaining our results, however, might be the analgesic effect played by distraction due to the Partner's touch or voice. It has been demonstrated that the elaboration of noxious stimuli is prevented or inhibited when attentional resources are oriented toward a distracting stimulus that differs from the pain source (Birnie et al., 2017; Peters, 2015; Rischer et al., 2020). Nonetheless, previous studies have shown that the beneficial effect of romantic support on pain perception differ from the analgesic effects of distraction (Master et al., 2009; Younger et al., 2010). Indeed, only support from a romantic partner, and not distraction, is associated with activations of brain regions strongly implicated in pain analgesia, such as the reward and limbic systems (Thompson & Neugebauer, 2019; Younger et al., 2010).

Consistently with previous studies, we found that tactile support from a romantic partner significantly reduced pain perception both at the subjective (Coan et al., 2006; Floyd et al., 2018; Goldstein et al., 2018; Kreuder et al., 2019; von Mohr et al., 2018) and physiological level (Che et al., 2021; Goldstein et al., 2017; Reddan et al., 2020), thus confirming previous observations reporting the efficacy of this type of support in alleviating sufferance during painful experiences. Manifestations of affection (i.e., social touch, warm caresses, handholding, hugs) represent a fundamental aspect of intimate interpersonal interactions, and several studies have investigated their direct and indirect association with oxytocin release (Grewen et al., 2005; Holt-Lunstad et al., 2008; Kreuder et al., 2019). Specifically, social touch has been proven to elicit oxytocin release in rodents (Tang et al., 2020; Yu et al., 2022) and non-human primates (Gothard & Fuglevand, 2022), and to increase endogenous levels of oxytocin in humans (Handlin et al., 2022). Oxytocin plays a key role in driving socially relevant behaviors (Dal Monte et al., 2014; Evans et al., 2014). Specifically, it has been found to promote interpersonal affiliation, nursing, pair bonding (Marlin & Froemke, 2017; Olff et al., 2013; Ross & Young, 2009), and intimate manifestations of affection. Interestingly, oxytocin has been reported as a valid mediator of stress-buffering effects (McInnis et al., 2017; McQuaid et al., 2016), specifically when associated with physical affiliative contact (Uvnäs-Moberg et al., 2015). Given the cardinal role of oxytocin in human romantic bonding (Ditzen et al., 2009; Scheele et al., 2012, 2013) and the contextual valence of social touch (Sailer & Leknes, 2022), it is plausible that the effects of haptic forms of support provided by a romantic partner (i.e., touch support and the conjunction of touch and voice in the present paradigm) may be reinforced by the combined release of oxytocin. Specifically, a gentle and supportive touch from a romantic partner may promote an endogenous boost of oxytocin levels, with stress-buffering effects on the outcomes of negative situations (i.e., experimental administration of painful stimuli). Importantly, there is a strong regulatory relationship between oxytocin and other neuromodulators such as the serotonergic and opioid systems (Dal Monte et al., 2017; Fan et al., 2020). Thus, further studies are needed to investigate the role of oxytocin and other neuromodulators about the beneficial effects over pain perception of active support provided by a romantic partner and to enlarge the body of knowledge about their neural correlates.

Additionally, we found that, similarly to tactile support, a vocal support in the form of gentle speaking can attenuate pain perception. In fact, although the beneficial effects of a tactile interaction during painful situations are well known, the role of gentle speaking in pain reduction has been poorly investigated so far. Humans continuously use vocalizations to communicate their emotions and physiological needs to other human beings (Cordaro et al., 2016; Cowen et al., 2019). Indeed, through voice humans as infants shape their first bonds with their significant ones (i.e., their caregivers), and during development, they continue to mutually share and receive information about each other's needs through language (Weitzman, 2013). In particular, through verbal communication humans provide and receive support to alleviate significant others' distress (Cohen, 2004). However, although the beneficial role of supportive speaking has been investigated in contexts of distress, this is the first study to show the efficacy of this communication channel in reducing pain perception as well as autonomic response in a naturalistic setting. To date, only a study by Sheykhasadi et al. (2019) has investigated the role of a romantic partner's voice in pain reduction. Despite coherent results (reduction in individual pain perception after being exposed to a loved one's voice), in their work vocal support was provided by means of recorded voice messages. For this reason, the authors themselves referred to the partner' voice as a means of distraction, rather than as an actual supportive tool. On the contrary, the present study was designed to capture and analyze the benefit of real voice in alleviating experimental pain as an efficacy mean of support. For this reason, we used a live ecological setting where the two participants were free to interact, with the only explicit instruction for the partner to be as much supportive as possible. In fact, on the one hand, social support was proven to be more effective when tailored on the recipient's personal needs (Cohen, 2004). On the other hand, other studies did not find free interaction as a valid modulator of painful experiences (e.g., Brown et al., 2003). However, this lack of pain modulation has been argued to be due to the possible presence of either ambiguous or negative transactions (e.g., negative gestures and pain-centered vocalizations) occurring between the social supporter and the person in pain (Brown et al., 2003; Krahé et al., 2013).

In our paradigm, we, therefore, asked romantic partners to be actively supportive and we left them free to express their vocal support as they thought it would have been more effective (without imposing specific or fixed phrase to use), by shaping their positive supportive intervention according to their lover's needs. Hence, both tactile and vocal support could have characterized the intimacy of a "shared reality" (Rossignac-Milon et al., 2021) of each single couple: this possibly allowed the Partner to trigger idiosyncratic attachment mechanisms in the Experimental Subject, independently of the communication channel adopted. Moreover, this could also explain why we observed lower levels of pain ratings and autonomic activations in active than in passive support conditions. The presence of a significant one in threatening situations activates attachment schemas (Bowlby, 1969) that are either fully or partially satisfied in the active and passive support conditions, respectively. This is in line with previous findings reporting absence of pain modulation when positive encounters with significant others occurred before, and not during, a painful experience (Borsook & MacDonald, 2010; Platow et al., 2007), thus highlighting the importance of the perceived possibility for action (Krahé et al., 2013).

The role of significant others as a pain-buffer has been sometimes attributed to their role as safety signals capable of preventing negative responses to threatening situations (Eisenberger et al., 2011). However, the construct of safety signal is still debated (Laing & Harrison, 2021) and whether the presence of significant others do rely on such a mechanism has not been always proven (Morato et al., 2021). A different view has proposed that significant others may function as "prepared safety stimuli," that is, signals that are typically associated with benefits for survival in an innate manner (Hornstein & Eisenberger, 2018). Such stimuli do not need exposure to Pavlovian conditioning for eliciting safety signaling functions (i.e., reducing fear acquisition and enhancing fear extinction), being ascribed to unconditioned inhibiting stimuli, instead (Laing & Harrison, 2021). Although such stimuli have been reported to be capable of inhibiting fear-conditioning (Hornstein et al., 2016) and reducing pain perception (Eisenberger et al., 2011), other studies did not find such inhibitory effects (Morato et al., 2021). Finally, Krahé et al. (2013) have reframed pain perception with a free-energy principle theoretical background (Friston, 2009) and suggested that others may function as a predictive signal of contextual safety (or threat, in case of a negative figure) capable of influencing the salience of an impending noxious stimulus and, therefore, reducing (or enhancing) perceived physical suffering.

In summary, these results pointed out that gentle speaking, as well as gentle touch from a romantic partner, is effective in promoting active support to young females in pain, and in reducing their individual sufferance. Such evidence clearly suggests that, in a free interaction context, voice itself can be considered a full-fledged valid form of support, with valid effects on pain modulation, comparable with the more traditionally studied form of support such as social touch.

Moreover, we found that tactile support in conjunction with vocal support was effective in reducing subjective and physiological measures of pain perception, equally to tactile support and vocal support alone. To our knowledge, no study so far has investigated the conjunct effect of tactile and vocal support on pain reduction. Human interactions are usually a combination of visual, auditory, and haptic stimuli. As a result, when support is to be provided, it usually involves both haptic and vocal forms of support (i.e., vocally comforting while caringly holding hands; Jones & Yarbrough, 1985). We had hypothesized a synergetic effect of the conjunction of tactile and vocal support on pain reduction, but our results confuted our hypothesis. We did not find any difference between the conditions of individual tactile support and individual vocal support compared with the combination of the two supportive modalities. Moreover, when we compared the effect of the distinct types of active support, we did not find any significant difference among the three conditions, suggesting that tactile support, vocal support, and the conjunction of both, are equally effective in alleviating individual pain. This is probably because people experience an attenuation of their individual distress when feeling to be actively supported, regardless of the type of support. This suggests that an active support from a romantic partner per se is sufficient to reduce pain perception in young females, regardless of both the specific modality and the variety and quantity of forms of support that are provided.

Finally, we found a positive correlation between the quality of the relationship and the individual perception of being supported during the whole experimental procedure. Such evidence suggests that the quality of the bonding between two romantic partners also plays a role in determining the efficacy of social support during painful experiences. This is in line with the view suggesting that support during painful events is more efficient when provided by people that are close to the recipient, as it can better match the recipient's needs and necessities (Cohen, 2004).

The scientific relevance of the present study lies on several grounds. First, the results confirm the beneficial role of romantic partners' presence in alleviating the experience of physical pain. Second, it proves active support to be more effective in reducing physical pain compared with passive support according to both subjective ratings and physiological responses. Crucially, such findings may be exploited to optimize therapeutical interventions in pain management within clinical populations and hospital contexts. Moreover, the identification of vocal support as a valid form of support, highly effective in reducing physical pain, represents a solid starting point for future implementations. The relevance of exploiting a non-contact supportive tool as vocal support becomes even more valuable if we consider those clinical situations where physical contact is discouraged (e.g., infectious diseases) or the current pandemic scenario, which imposes physical distancing and social isolation from people. Additionally, we brought a novel contribution to the physiological field, highlighting the role of romantic partners' support in affecting SCRs within the pain domain.

In our study, we decided to enroll only female subjects to maximize the benefits of social support and avoid stereotypical gender-role influences on pain reports (i.e., men tolerate pain longer and are more reluctant to publicly display their distress; Tracy, 2017). However, a comprehensive understanding of the effects of active and passive support from a romantic partner on men is still lacking. Future research should enlarge the present findings and investigate the effects of active and passive support on male subjects undergoing a similar procedure, to compare the results on a gender-differences basis. Furthermore, both the perception of social support and the experience of pain have been linked to age variation. Differences have been found regarding the type (explicit vs. implicit, emotional vs. instrumental) of social support that young and older adults seek and benefit from (Jiang et al., 2018). In addition, perceived social support from a romantic partner has been found to decline over age, for both women and men (Coventry et al., 2004). As in our study we obtained a sample composed of young couples only, it would be important for future research to survey and understand the benefit of social support from a romantic partner within the pain domain in elder subjects.

Finally, for the purposes of our study, we assessed the quality of the romantic relationship and the degree of supportiveness of the Partners, to analyze their influence on pain perception and support. Nonetheless, pain perception and the effects of social support may be affected by personality traits and individual tendencies such as empathic predispositions (Goldstein et al., 2017) or anxiety levels (Michaelides & Zis, 2019). Future research should extend such considerations and further investigate the influence of interindividual differences on pain perception and support sensibility. All these future approaches would contribute to enrich the knowledge about useful and effective types of support to reduce painful experiences.

5 | CONCLUSION

In the present study, we have shown that active support from a romantic partner reduces the perception of physical pain both at the subjective (self-reporting ratings) and physiological (skin conductance) level. We delivered painful stimuli to young females engaged in stable romantic relationships and found that active forms of support (i.e., supportive touch, supportive speaking, the conjunction of both) were more effective than passive support (i.e., mere presence) in attenuating pain perception. Furthermore, we found that different types of active support do not quantitatively differ in modulating pain perception and autonomic responses. Crucially, we proved that vocal support in the form of gentle speaking can reduce pain perception, with effects comparable with tactile forms of support. Additionally, we found that the quality of relationship between two romantic partners affects the efficacy of social support during painful experiences. We believe that the present study brings a novel contribution to the scientific and clinical field, demonstrating the key role of romantic partners' support in reducing pain perception, at the subjective and autonomic level.

AUTHOR CONTRIBUTIONS

Alessandro Mazza: Conceptualization; data curation; formal analysis; investigation; methodology; software; visualization; writing – original draft. **Tommaso Ciorli:** Conceptualization; data curation; formal analysis; investigation; methodology; software; visualization; writing – original draft. **Ilaria Mirlisenna:** Conceptualization; data curation; formal analysis; investigation; methodology; validation; visualization; writing – original draft. **Ilenia D'Onofrio:** Conceptualization; investigation; methodology. **Silvia Mantellino:** Conceptualization; investigation; methodology. **Martina Zaccaria:** Conceptualization; investigation; methodology. **Lorenzo Pia:** Conceptualization; methodology; project administration; resources; validation; writing – review and editing. **Olga Dal Monte:** Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; supervision; validation; visualization; writing – original draft; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data and code of the present study are available from the corresponding author upon request.

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