Computers in Human Behavior 122 (2021) 106781

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: http://www.elsevier.com/locate/comphumbeh

Full length article

Exposure to social suffering in virtual reality boosts compassion and facial synchrony

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ARTICLE INFO

Keywords:
Social VR
Social presence
Synchrony
Empathy
Compassion
360 video

ABSTRACT

Virtual reality (VR) has recently been popularized as the "ultimate empathy machine," and yet the science behind the effects of VR on empathy is scarce. In this media-comparison study, we assessed the impact of VR upon physiological and subjective indicators of empathy. Furthermore, we investigated the role of social presence, i.e. the experience of being there with real others, in modulating the empathic responses. We filmed a 360° 3D video of a person disclosing a painful autobiographical story from her past. This empathy-eliciting video was presented either in a VR head-mounted display or on a computer screen. Centrally, autonomic and facial responses were recorded both from the target in the video and from participants who viewed the video. We found that the VR condition enhanced viewers' empathic care and facial synchrony with the target. Viewers in the VR condition also reported higher levels of social presence, which mediated the effects of VR on empathic care as well as on facial synchrony. The current study highlights the potential of VR to elicit social connectedness and a caring motivation to help. Our findings imply that VR has a unique potential to motivate empathy in situations where face-to-face encounters are not possible.

1. Introduction

Empathy is one of the distinctive virtues allowing people to feel the pain of others and driving them to act in others' interests (Batson, 2010; Shamay-Tsoory, 2011). It is suggested to be an innate biological mechanism necessary for group survival and the flourishing of its members (de Waal, 2008; Decety et al., 2012). Despite its evident biological roots, empathy is a fragile flower, shaped by multiple contextual factors (Weisz & Zaki, 2018). Hence, finding avenues to promote empathy towards strangers in need can have a significant impact on society. There is a recent wave of interest in virtual reality (VR) as a potential medium to enhance empathy, presumably allowing viewers to experience, connect and understand the pain of others in a more profound way. Accordingly, VR has even been publicly claimed to be the "ultimate empathy machine" (Milk, 2015); nevertheless, the scientific questions beyond these popular claims are still widely open: what do we mean by empathy, does VR indeed offer means to facilitate empathy, and if so, what are the underlying mechanisms?

While the research focusing on the impact of VR on empathy is steadily growing (e.g. Schutte & Stilinović, 2017; Wijma et al., 2018), it's results are mixed. Furthermore, many past VR studies suffer from methodological drawbacks, such as a lack of control condition and over-reliance on self-reports, which are prone to multiple biases. Accordingly, whether and how VR affects empathy towards unknown strangers is unclear.

The current study attempts to address this important issue while focusing on a widely accessible VR methodology, that is, a photorealistic 360° 3D video presented to viewers in a VR headset. We compare the effects of an empathy eliciting 360° 3D video experienced in VR with the effects of the same content presented as a two-dimensional video on a desktop computer. We assess the impact of VR on the two main components of empathy: the emotional response of empathic distress and the motivational component of concern for the welfare of the suffering target (Batson et al., 1987; Weisz & Zaki, 2018). Centrally, we also study the effect of VR on physiological and affective synchrony with a target - a profound measure of empathy and social connection (Golland et al.,

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https://doi.org/10.1016/j.chb.2021.106781
Received 5 May 2020; Received in revised form 10 January 2021; Accepted 14 March 2021
Available online 12 April 2021

2015, 2019; Levenson & Ruef, 1992; Soto & Levenson, 2009). Finally, we examine a potential mechanism for empathy facilitation in VR, a sense of "social presence", i.e. an enhanced experience of being there with real others (Biocca et al., 2003; Oh et al., 2018).

1.1. Empathy and its subcomponents

Empathy is a multifaceted phenomenon, comprising of many interrelated processes. Early psychological models, as well as more recent neuroscientific findings, suggest that facing the suffering of others may elicit two different emotional responses, that is, empathic distress and empathic care or concern (Batson et al., 1988; Eisenberg et al., 1988; Shamay-Tsoory & Lamm, 2018; Singer & Klimecki, 2014).

Empathic distress, also termed affective empathy, is the negative affect arising in response to others' suffering. It is the "feeling with" component of empathy, allowing observers to experience the negative feeling of the empathy target. Accordingly, empathic distress is believed to be grounded in a vicarious sharing of others' emotions and sensations and to serve as a visceral bridge into others' emotional states (Singer & Lamm, 2009; Zaki & Ochsner, 2012). In line with this perspective, exposure to others' suffering elicits activations of the brains' emotional and somatic circuits, including the limbic structures as well as somatosensory and insular cortexes (Ashar et al., 2017; Nummenmaa et al., 2014; Raz et al., 2014). This neural activity is believed to be the "hallmark" of affective empathy, supporting the first-person "embodied simulation" of others' pain and distress (Shamay-Tsoory & Lamm, 2018).

Above and beyond such automatic emotional resonance, the pain of others can also evoke warm feelings of care and concern. Empathic care, also termed compassion, is the concern for others' well-fare, characterized by tender, caring feelings and a sense of connection with others. It is driven by an other-focused motivation to alleviate others' suffering and distress (Ashar et al., 2016; Batson et al., 1981; Eisenberg et al., 1989). Further, it is based on a distinctive neural system, mainly comprising the brain's dopaminergic reward circuit, associated with intrinsic motivation and close connections (Ashar et al., 2017; Singer & Klimecki, 2014).

Notably, while empathic care and empathic distress are functionally different and rely on different neural substrates, both were shown to predict pro-social behavior (Ashar et al., 2016). Furthermore, these two aspects of empathy are affected by multiple contextual factors, such as the intensity of targets' pain, affiliative feelings, and in-group out-group relationships (Cikara et al., 2011; Weisz & Zaki, 2018). Despite their profoundly different functional nature, these two empathic responses have been rarely differentiated in the VR-focused empathy research.

1.2. The effects of VR on empathic care and empathic distress

A series of recent media-comparison studies have directly examined whether 360° VR outperforms other, more traditional modes of presentation, such as 2D video, in eliciting empathic distress, and care towards strangers. The results of these studies are far from being conclusive. For example, Bang and Yildirim (2018) did not find any differences in reported empathy when participants watched a short 360° documentary about a prison inmate in solitary either in a VR condition or on a computer screen. On the other hand, another study reported enhanced empathic care towards refugees, following a virtual tour in the refugee camp via VR 360° video as compared to a 2D video (Schutte & Stilinović, 2017). An additional study, using a New York Times 360° video, "the Displaced ", examined the effects of three different media: VR 360° video, computer screen 360° video, and text upon empathy towards children who lost their homes in wars (Sundar et al., 2017). The results showed that both VR and 2D 360° videos elicited higher empathic care and willingness to share the story (as a marker of pro-social behavior) as compared with text. However, there were no significant differences between the VR and the 2D video on the above measures. Another recent media comparison study has investigated the effects of perspective-taking on empathy to a homeless person (Herrera et al., 2018). This study compared VR-based perspective-taking with more traditional and less immersive techniques, such as guided imagery, 2D computer video, and textual facts. Taken together, the results of this research have suggested that while all perspective-taking approaches were more efficient as compared to textual facts, VR-based perspective-taking. wasn't beneficial over the video based perspective taking.

To summarize, the results from a series of studies that directly compared content delivery in VR to a standard desktop presentation do not provide a clear picture as to the enhancing effects of VR upon empathy. While some studies suggest beneficial effects of VR as compared with 2D video, others fail to find these effects. Accordingly, a further investigation, employing more refined and objective measures of empathy-related behaviors, is required.

1.3. The effects of VR on social presence

Since its early days, VR has been conceptualized as a social medium in which individuals could communicate, interact, and co-exist (Biocca & Levy, 2013). One of the benefits of VR is believed to be the level of social presence it affords in comparison to other forms of technology-mediated communication (Oh et al., 2018). Social presence or co-presence refers to the subjective experience of "being there with another" (Biocca et al., 2003). In mediated communication, social presence has been associated with a variety of positive consequences, such as persuasion, attraction, trust, and enjoyment (Fogg & Tseng, 1999; Hassanein & Head, 2007; Lee et al., 2006). Social research has demonstrated that the experience of social presence instills profound effects on human responses (Gallotti & Frith, 2013). Thus, physical or implied presence of others has been shown to increase the intensity of emotional experiences and expressions (Bruder et al., 2012; Hess et al., 1995; Shteynberg et al., 2014). The experienced degree of social presence amplified neural empathy for pain (Akitsuki & Decety, 2009) and synchrony with a target's feelings (Golland et al., 2017).

While a large body of work has investigated the factors affecting social presence in VR environments (Oh et al., 2018), less focus has been given to its interpersonal outcomes. Indirect evidence suggests that virtual characters exhibiting features that enhance social presence, imposed more significant social effects on observers, including persuasion (Bailenson et al., 2005); increased neural empathy (Kampe et al., 2001; Schilbach et al., 2006, 2010, 2012); and helping behavior (Slater et al., 2013; Steed et al., 2018). Crucially, a recent study has demonstrated that the degree of social presence in empathy eliciting VR environment was positively correlated with a feeling of connection and empathy towards a victim (Herrera et al., 2018).

Building upon this evidence, in the current study, we aimed to examine whether the hypothesized effects of VR upon empathic responses emerge due to an enhanced experience of co-presence with a victim in a shared social space.

1.4. Physiological synchrony with others as a hallmark of social experience

A tremendous recent progress in the neural substrates of sociality has allowed to introduce physiological markers into the research of empathic interactions. One of the most recurring physiological markers linked with different aspects of social connection and empathy is physiological synchrony between people (Butler, 2015; Goldstein et al., 2017; Golland et al., 2015; Levenson & Ruef, 1992; Palumbo et al., 2017). Research has demonstrated that social contexts, in which feelings are shared between people, are characterized by neural, autonomic and facial markers of synchrony (Feldman, 2012; Goldstein et al., 2017, 2018; Golland et al., 2015, 2019; Kinreich et al., 2017; Levenson & Ruef, 1992; Soto & Levenson, 2009). For instance, dyads of strangers who exhibited higher synchrony in their autonomic responses, such as heart rates, while co-viewing a video, also reported more similar emotional states following the viewing (Golland et al., 2015, 2019). A similar pattern was found in a series of studies in which autonomic synchrony was assessed between observers of pre-recorded video excerpts and targets appearing in those videos. Specifically, higher autonomic synchrony with the video targets was linked with higher empathic accuracy on behalf of the observers, i.e., the observers' ability to correctly identify the targets' emotional states (Levenson & Ruef, 1992; Soto & Levenson, 2009). Recently, such social synchrony has been demonstrated for facial behavior as well. It is well known that people mimic others' facial expressions and that such mimicry promotes understanding of others' feelings and emotional contagion (Hess & Fischer, 2014; Prochazkova & Kret, 2017). A recent study has extended the mimicry findings into the domain of temporal synchrony, showing that co-present individuals tend to become synchronized in their facial dynamics, and such facial synchrony is linked with emotional similarity (Golland et al., 2019). Taken together, a large body of research suggests that autonomic and facial synchrony are associated with empathy and emotional similarity.

Above and beyond emotional similarity, synchrony between people is also indicative of affiliative social context, trust, and closeness (Bourgeois & Hess, 2008; Golland et al., 2019; Kinreich et al., 2017; Prochazkova et al., 2018; Weyers et al., 2009). For instance, neural synchrony during communication was higher in couples than in strangers (Kinreich et al., 2017). One of the most robust markers of affiliation is the return of a smile or smiling synchrony (Fischer & Hess, 2017; Wróbel & Imbir, 2019). For example, synchrony in facial activity underlying smiling behavior was highly predictive of strangers' affiliative feelings towards each other (Golland et al., 2019). To summarize, previous research has suggested that in social contexts, people become synchronized with each other in their emotion response systems. While synchrony in autonomic signals has been mainly linked with emotional similarity and empathic accuracy, synchrony in facial activity, linked with smiling, is a marker of affiliative social bonds.

1.5. Current study

Aiming to extend previous research, in the current work we conducted a well-controlled media comparison study of the effects of VR upon empathy-related subjective and physiological markers. Employing a well-validated empathy-eliciting experimental setup (Soto & Levenson, 2009; Zaki et al., 2009), we recorded a female target who disclosed a painful autobiographic story from her past, using a 360° 3D camera rig.

This video was later presented to participants either as an immersive 360° 3D video in a head-mounted display (VR condition) or as a two-dimensional video on a desktop PC (2D condition). The 360° 3D video format provides some of the essential characteristics of VR, such as sensorimotor contingencies (Sanchez-Vives & Slater, 2005) between head movement and visual field, as well as audio-visual isolation from the external world. Most often, as well as in our case, 360° 3D video is not interactive. The participant's actions are limited to rotating their head, and their point of view is determined by the position of the camera (i.e., they see the video from the location of the camera when it has been filmed). However, the advantage of 360° 3D video over computer-generated forms of VR is that it presents human interaction partners in a photorealistic way as opposed to representing them by synthetic characters (i.e., avatars). Finally, this approach allows for a high degree of experimental control, as it allows to create a 2D video version of the stimulus which is highly compatible with the VR condition in terms of audio-visual stream of information. Accordingly, here we compared the effect of the VR and the 2D conditions on the different components of empathy, including negative distress linked with affective empathy and empathic care linked with compassion. We also assessed affiliative feelings towards the video target, linked with social bonding and compassion (Gilbert, 2017).

Centrally, we extended measures of social bonding and empathy to include physiological markers of synchrony. During the pre-recording of the video, facial and autonomic responses of the target were collected. Similar facial and autonomic measures were recorded from participants during the viewing session, which allowed us to quantify autonomic and facial synchrony between participants and the video target. Autonomic measures collected in this study included heart rate and electrodermal activity, which are tightly linked with emotional experiences (Golland et al., 2014; Kreibig et al., 2007; Levenson, 2014). Autonomic synchrony served as an index of emotional similarity or affective empathy (Golland et al., 2015; Levenson & Ruef, 1992). Facial activity was collected via facial electromyography (EMG) responses, measured over *zygomatic* and *corrugator* sites. EMG activity at the *corrugator* muscles is indicative of frowning and was consistently linked with negative emotional experience (Golland et al., 2018; Lang et al., 1993; Larsen et al., 2003). Similarly to autonomic synchrony, corrugator synchrony was taken as an index of emotional similarity and affective empathy. In contrast, *zygomatic* activation, mapped to the cheek muscles, is associated with smiling (Lang et al., 1993) and returning a smile (Heerey & Crossley, 2013; Hess & Bourgeois, 2010). Zygomatic synchrony, in particular, has been indicative of affiliative social bonds (Bourgeois & Hess, 2008; Golland et al., 2019). We examined the effects of the viewing condition (VR vs. 2D) upon indexes of autonomic and facial synchrony with the video target.

Finally, we also assessed the degree of social presence, which is the subjective experience of being present with a "real" person (Biocca et al., 2003; Oh et al., 2018), elicited in the VR and the 2D conditions. Aiming to understand the underlying mechanism of VR-induced empathy, we investigated whether this distinctive feature of social VR mediates the effects upon subjective empathy and physiological synchrony with the social target appearing in the video.

The experimental and analytical details are specified in the material and methods section, the results section presents the results of the analyses which are discussed in details in the discussion section.

2. Material and methods

2.1. Participants

Seventy female students participated in the study (age: $M = 23.6$, $SD = 1.7$). Participants were all females to avoid between-gender effects when watching a female protagonist. A power analysis (G*Power 3.1, Faul, Erdfelder, Buchner, & Lang, 2009) indicated that a sample size of 70 participants was sufficient to achieve 80% power for a directional comparison analysis with a medium effect size. Participants received four course-credits or were paid 80 NIS (approx. 25$) for taking part in the experiment. The experimental procedures were approved by the Ethics Committee for Behavioral Studies at the Interdisciplinary Center Herzliya. Before the initiation of the experiment, and after the procedures have been fully explained to them, participants signed a written informed consent.

2.2. Social distress video (SDV)

A female protagonist participated in the recording stage in exchange for monetary compensation, after signing an informed consent. She was connected to physiological sensors (see below) and was then seated in front of a 360° 3D stereoscopic camera rig (ZCam E1, with iZugar 220° lenses) facing the camera directly (Fig. 1A). To enhance a social story sharing environment, one of the authors (D.L.) sat behind the camera lenses and asked questions when needed. After an initial introduction phase, the protagonist (hereafter, target) told a painful autobiographical story from her past. The video (hereafter, a social distress video, 'SDV') was later edited to include an opening (2-min introduction) and an emotional (6- minutes) part. The two-dimensional format (2D) was created by cropping the center frame of a panoramic version of the 360° 3D video. Critically, this procedure provided us with the SDV video in

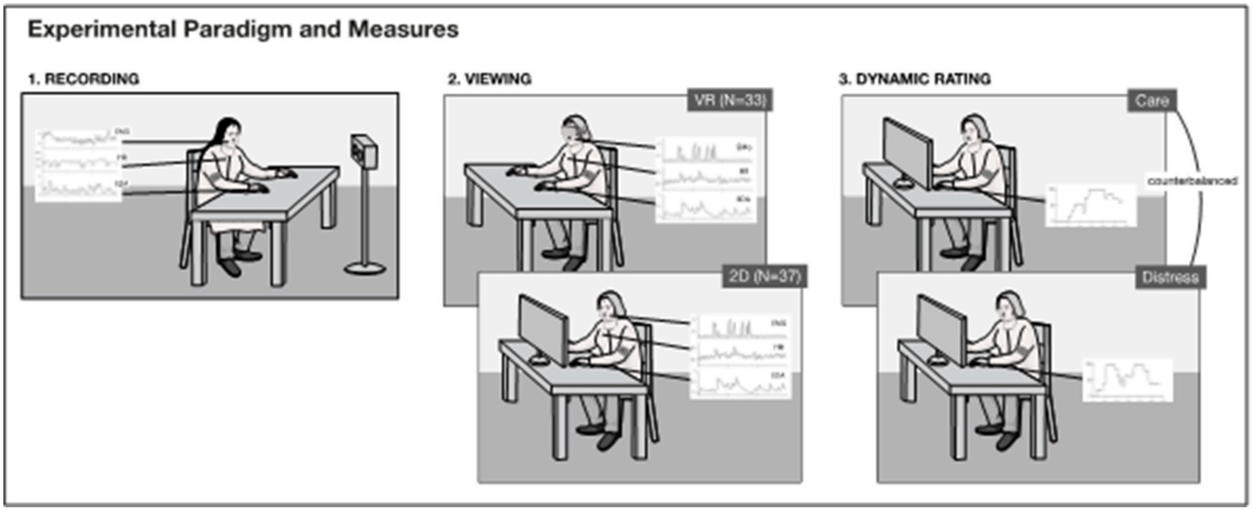

Fig. 1. 1. Recording: Initial stage during which a 360° 3D video recording of a female target, combined with time-locked physiological responses, was made. **2. Viewing**: Participants' autonomic and facial responses were recorded, while they viewed the video either in a VR or in a 2D condition. **3. Rating:** Participants from both groups re-watched the video in 2D, while rating moment-by-moment changes in their feelings of care and distress.

two presentation formats (VR, 2D), accompanied by the target's autonomic, facial, and subjective responses, time-locked to the SDV timeline.

2.3. Procedure

Before arriving at the lab, participants completed a trait empathy questionnaire at home, employing an online platform. Upon arrival, participants were randomly assigned to the 2D (N = 37) or VR (N = 33) conditions. Participants were connected to physiological sensors (see below) and were asked to refrain from talking and making gross movements throughout the experiment. Baseline measures were then recoded for 10 min while participants sat silently and kept their eyes open. They then viewed the SDV video in one of the two different conditions. In the 2D condition participants viewed the SDV on a computer screen (54 cm wide X 32 cm height), positioned ~85 cm from the participant, and the light in the room was dimmed. In the VR condition participants viewed the SDV by wearing an Oculus Rift HMD. Self-report questionnaires were collected before and after watching the SDV. Participants then re-watched the emotional part of the video (~5 min) again, while continuously rating their naturally arising feelings of care and their feelings of distress in order counterbalanced across participants. Prior to the rating session, participants received a detailed explanation on the feelings they were to track. The instructions stressed that they should monitor changes in their spontaneously - arising feelings while viewing the movie. They then practiced using the rating device by moving a computer mouse along a visual scale at the bottom of the screen from low (left) to high intensity (right). Finally, they viewed the video while continuously rating their feelings of care in one viewing and their feelings of distress in another viewing session.

2.4. Self-report measures

Trait empathy questionnaire: Interpersonal Reactivity Index (IRI) questionnaire, a well-established 28-item measure of trait empathy, answered on a 5-point Likert scale ranging from "does not describe me well" to "describe me well" (Davis, 1983).

Prior and following the first SDV viewing participants rated the degree of their current positive and negative feelings and arousal. Immediately following the SDV viewing participants filled a series of self-report measures, including: *emotional intensity* ("I felt emotionally involved", "the story elicited a strong emotional experience"; α Cronbach = 0.7); *affiliative feelings* ("I like Galia", "I would like to know Galia better", "I would like to meet Galia; α Cronbach = 0.8); *social presence* items (adapted from (Biocca et al., 2003) "I felt me and Galia are at the same room"; "I felt Galia is looking directly at me", "I felt me and Galia are present in the same place, "I felt Galia is talking directly to me", α Cronbach = 0.8). Finally, we collected measures of empathy (Batson et al., 1987; Herrera et al., 2018). *Empathic Care* items included: "warm feelings", "care", "sympathy", "wanting to help", "wanting to comfort", α Cronbach = 0.8; *Empathic Distress* items included: "discomfort", "uncomfortableness", "stress", "lack of silence" (α Cronbach = 0.7). All self-report items were rated on a 7-point Likert scale ranging from "not at all" to "to a strong degree".

2.5. Physiological data collection and preprocessing

Continuous physiological measures were recorded with a Bionomadix (BIOPAC Systems Inc., Santa Barbara, CA) MP150 data acquisition system and Biopac® Acknowledge 4.4 software at 1000 Hz sampling rate.

The cardiovascular activity was recorded using a modified lead II configuration. The heart period series (inter-beat interval; IBI) was assessed using the Mindware HRV 2.16 biosignal processing module (Mindware, Ohio). This procedure included: (a) identifying the R–R intervals; and (b) detecting physiologically improbable R–R intervals based on the overall R–R distribution using a validated algorithm (Berntson et al., 1990). Afterward, data were also inspected manually to ensure that R-waves were correctly identified. Data that included more than 10% undefinable Rs was excluded from the analysis. Lastly, IBI series were transformed to continuous 1 Hz heart rate time-series (HR) using custom software.

Electrodermal activity (EDA) was recorded using pre-gelled, disposable foam Ag/AgCl electrodes, placed on the middle phalanges of the left index and ring fingers of the non-dominant hand. Participants failing to show more than ten >0.03 μV responses were marked unresponsive and excluded from the analysis. Continuous 1 Hz time-series of phasic electrodermal activity were extracted from raw EDA responses, using continuous decomposition analysis instantiated through the Ledalab software (Benedek & Kaernbach, 2010a, 2010b).

Facial EMG was collected over the zygomaticus major and corrugator supercilia sites, placed at the left side of the face (Fridlund & Cacioppo, 1986). EMG signals were pre-processed in accordance with previously published routines (Golland et al., 2018, 2019). Specifically, EMG signals were filtered with a 50 Hz notch filter. Manual inspection for artifacts was made using custom software (Beniczky et al., 2013). A Fast Fourier Transform was performed on all artifact-free data to derive estimates of spectral power density (μV)in the 45–200-Hz frequency band in 1 s windows. Finally, these values were log-transformed to normalize the data (Heller et al., 2014; Lapate et al., 2014; Van Reekum et al., 2011). The above procedures yielded continuous 1HZ EMG_{ZYG}, EMG_{CORR}, EDA, and HR time-series. All time series were smoothed with a 30 s moving window filter, linear trends were removed and the first 30 s and the last 5 s of the time-series were cropped to remove non-specific accommodation effects and preprocessing artifacts.

2.6. Missing data

Three participants did not complete the trait empathy questionnaire. Post viewing self-reports data for one participant were missing. The following number of data points were excluded from the physiological data set due to the presence of artifacts, corrupted recordings, or irresponsive electrodermal signals: EDA - fifteen; HR – two; EMG_{ZYG} – thirteen; EMG_{CORR} – fourteen participants. Due to the multivariate nature of the study, missing data in one of the measures didn't lead to an exclusion of the participant from the dataset.

2.7. Synchrony with the target's responses

One of the central measures in the current work is the observer-target synchrony, which is a temporal similarity between the viewers' response time-courses and the target's response time-course. To assess such temporal correspondence, we applied a cross-correlation analysis, which provides a measure of similarity between two series as a function of temporal displacement of one relative to the other (Golland et al., 2017, 2019; Stephens et al., 2010). This approach has allowed us to examine temporal alignment with the target, allowing for possible temporal shifts in such an alignment. For each participant j, we computed the cross-correlation between x_j, the response time-course of participant j, and y, the response time-course of the SDV target. Individual correlation indexes were then computed by extracting the maximal absolute value of correlation in the temporal window of ±5 s. Synchrony indexes were computed for the two autonomic measures, producing syncEDA, and syncHR indexes, and for the two facial measures, producing $syncEMG_{ZYG}$, $syncEMG_{CORR}$ indexes.

3. Results

3.1. Preliminary analysis of between-groups differences

There were no significant differences in the initial degree of positive feelings ($t(68) = -0.813$, $p = 0.42$), negative feelings ($t(68) = 1.62$, $p = 0.11$) and arousal ($t(68) = 0.2$, $p = 0.83$) between the VR and the 2D groups. Similarly, we did not find significant group differences in the IRI questionnaire ($t(65) = 1.4$, $p = 0.18$).

3.2. Effects of VR on social presence, affiliative feelings, and emotional intensity

There were no group differences in the reported emotional intensity of the SDV between conditions ($t(67) = -1.46$, $p = 0.15$). In contrast, participants reported an enhanced experience of social presence ($t(67) = -3.29$, $p = 0.002$) and higher affiliative feelings towards the video target ($t(67) = -2.3$, $p = 0.024$) in the VR as compared with the 2D condition.

3.3. Effects of VR on empathic distress and empathic care

We next examined whether the video presentation medium (i.e., VR or 2D) affected the different components of empathy, i.e., empathic distress and empathic care. Descriptive statistics are presented in Table 1. A multivariate analysis of variance (MANOVA) was conducted with condition (VR, 2D) as the between-subjects factor and distress and care as dependent variables. A Kolmogorov-Smirnov test indicated that care and distress variables followed a normal distribution both in the 2D and VR condition ($D(37) = 0.09$, $p = 0.2$; $D(37) = 1.3$, $p = 0.09$; $D(32) = 0.11$, $p = 0.2$; $D(32) = 0.13$, $p = 0.18$). We found a main effect of condition ($F(2,66) = 4.3$, $p = 0.017$, $\eta_p^2 = 0.117$). Univariate analysis further revealed that caring feelings were significantly higher in the VR as compared to the 2D condition ($F(1,67) = 5.3$, $p = 0.024$, $\eta_p^2 = 0.074$). In contrast, negative distress was lower in the VR as compared with the 2D condition, yet this difference was not statistically significant ($F(1,67) = 2.53$, $p = 0.116$). These results remained similar after controlling for participants' trait empathy (care: $F(1,63) = 5.3$, $p = 0.025$; distress: $F(1,63) = 3.2$, $p = 0.08$).

These results were further confirmed by the measures extracted from the rating sessions. Specifically, we examined the effect of viewing conditions on the average levels of care and distress, provided during the rating sessions (Fig. 2B). Average ratings of care were higher in the VR as compared to the 2D condition ($F(1,65) = 4.7$, $p = 0.03$, $\eta_p^2 = 0.07$). Average ratings of distress were not different between the conditions ($F(1,63) = 0.02$, $p = 0.8$).

Table 1
Descriptive statistics for the main study variables.

	VR	2D	p
Social presence	M = 4.9 ± 1.35	M = 3.7 ± 1.7	0.002
Emotional intensity	M = 5.54 ± 1.1	M = 5.1 ± 1.37	0.15
Affiliative Feelings	M = 4.9 ± 1.35	M = 4.1 ± 1.6	0.024
Empathic Care and Distress			
Care - self reports	M = 5.5 ± 1.1	M = 4.8 ± 1.34	0.024
Distress - self reports	M = 3.3 ± 1.2	M = 3.8 ± 1.5	0.12
Care - ratings	M = 65.7 ± 20.3	M = 53.5 ± 24.2	0.03
Distress - ratings	M = 51.2 ± 22.1	M = 50.4 ± 25.1	0.9
Synchrony with the target			
syncEDA	M = 0.06 ± 0.26	M = 0.12 ± 0.24	0.38
$syncEMG_{ZYG}$	M = 0.28 ± 0.38	M = 0.03 ± 0.31	0.004

3.4. Autonomic and facial synchrony with the SDV target

Finally, we examined whether the viewing conditions affected the degree of synchrony between the target's physiological responses while telling the SDV story and viewers' physiological responses while viewing the SDV video (Fig. 2A). Autonomic synchrony was computed between participants' and target's EDA and cardiovascular (heart rate, HR) responses. Facial synchrony was computed for the corrugator responses (EMG_{COR}), associated with negative emotions, and for the zygomatic responses (EMG_{ZYG}), associated with smiling behavior. Both zygomatic responses (0.14 ± 0.4, $t(1,56) = 2.6$, $p = 0.011$) and EDA responses (0.11 ± 0.27, $t(1,54) = 3.0$, $p = 0.003$) exhibited modest yet significant viewers-target synchrony. The corrugator synchrony ($M = 0.07 \pm 0.35$, $t(1,55) = 1.5$, $p = 0.13$) and the heart rate synchrony ($M = 0.01 \pm 0.39$, $t(1,67) = 0.242$, $p = 0.8$) were not significantly larger than zero.

Therefore, we examined the effect of viewing conditions on the zygomatic and electrodermal target-viewer synchrony, which showed significant synchrony indexes in the above analyses (Fig. 2B). We found that participants in the VR condition exhibited significantly higher zygomatic synchrony with the target ($F(1,56) = 9.04$, $p = 0.004$, $\eta_p^2 = 0.14$). No such effects were found for the electrodermal synchrony with the target ($F(1,53) = 0.769$, $p = 0.38$).

3.5. The enhanced experience of social presence in the VR condition mediated its effects on empathic care and zygomatic synchrony

Finally, we examined the association of the above observed effects of VR with the enhanced sense of social presence, reported in this condition. For that aim we first computed Pearson correlations for the degree of the reported social presence and the dependent variables that showed between conditions effects in the previous analysis. We found that social

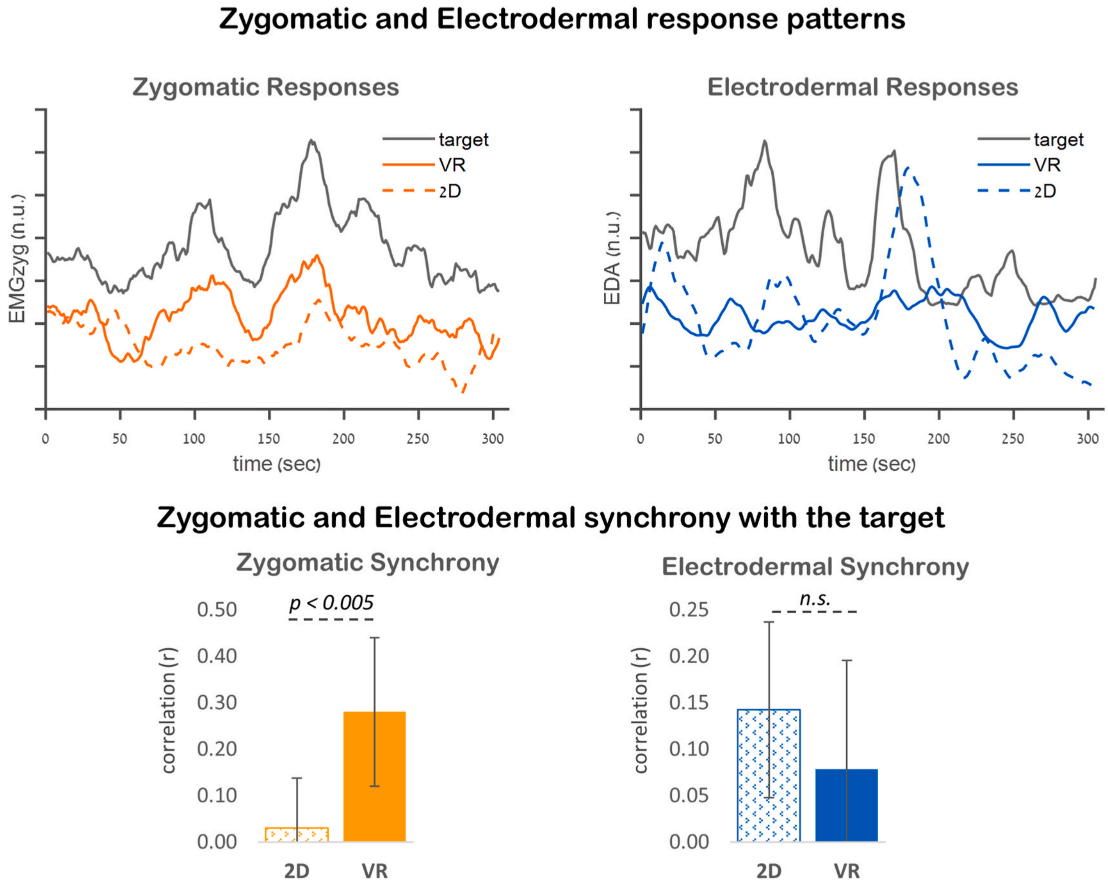

Fig. 2. Zygomatic and Electrodermal response patterns. The figure presents the average patterns of facial zygomatic responses (orange, left) and electrodermal responses (blue, right) while viewing the video in the VR (solid lines) and the 2D (dotted lines) conditions. The target's zygomatic (left panel) and electrodermal (right panel) responses during the SDV recording are shown in grey. Zygomatic and Electrodermal synchrony with the target. Figure presents group means of the participants-target synchrony for the zygomatic (orange, left panel) and electrodermal (blue, right panel) responses in the VR (solid) and 2D (dotted) conditions. Bars signify 2*SE.

presence was positively correlated with the degree of care (r = 0.429, p = 0.001) as well as with zygomatic synchrony (r = 0.468, p = 0.001).

We next examined whether social presence mediated the enhanced feelings of care and the enhanced zygomatic synchrony in the VR condition (Fig. 3A and B). For that aim we conducted a mediation analysis using Hayes' (2013) PROCESS macro for SPSS (version 3.0, model 4; with 5000 bootstrap iterations and 95% bias-corrected confidence intervals). First, the model was specified with condition as the independent variable, social presence as the mediator variable, and empathetic care as the outcome variable (see Fig. 3, lower panel). As expected, the total effect ($\beta = 0.52$, CI = [0.10, 0.93], $t = 2.48$, $p = 0.02$) was reduced when the mediator variable was added ($\beta = 0.33$, CI = [-0.09, 0.74], $t = 1.57$, $p = 0.12$). The indirect effect did not include zero ($\beta = 0.21$, CI = [0.04, 0.43]), indicating a significant mediation of condition on empathetic care through social presence.

Second, a similar model was specified with condition as the independent variable, social presence as the mediator variable, and zygomatic synchrony as the outcome variable (see Fig. 3, lower panel). The total effect ($\beta = 0.67$, CI = [0.27, 1.08], $t = 3.29$, $p = 0.001$) was reduced when the mediator variable was added ($\beta = 0.48$, CI = [0.07, 0.89], $t = 2.34$, $p = 0.02$). The indirect effect did not include zero ($\beta = 0.19$, CI = [0.05, 0.37]), indicating a significant mediation of condition on zygomatic synchrony through social presence.

4. Discussion

In this work, we examined the effects of a 360° 3D video presented via the VR headset upon viewers' sense of social presence with the target, subjective indexes of empathy and physiological synchrony with the target. A series of findings indicated that facing others' distress in a VR environment boosts an affiliative caring experience, as indicated by higher subjective responses and enhanced physiological synchrony. Furthermore, the induced sense of social presence mediated the effects of viewing condition upon both the subjective and the physiological measures of empathy and social connection.

4.1. VR enhanced affiliative empathic care towards a target in distress

First, we found that participants in the VR condition exhibited higher empathic care towards the video target, as compared with participants who viewed the video on a 2D desktop display. The beneficial effect of VR upon care was found both in self-reports and in dynamic ratings of care, which took place at the post-viewing session.

Empathic care, comprising warm, tender feelings towards the sufferer and a desire to help, is a motivational pro-social response, linked with helping behavior and affiliative intents (Goetz et al., 2010; Weisz & Zaki, 2018). Our results showed that participants in the VR condition were not only more caring but also reported higher feelings of closeness with the video target. While we did not test for helping behavior in our study, self-reports of care were shown to predict donations in previous research (Ashar et al., 2016, 2017). Furthermore, a recent study has found that the main effect of VR in encounters with social suffering was evident in pro-social behavior towards a victim, such as higher rates of signing a petition to help homeless people (Herrera et al., 2018). Taken

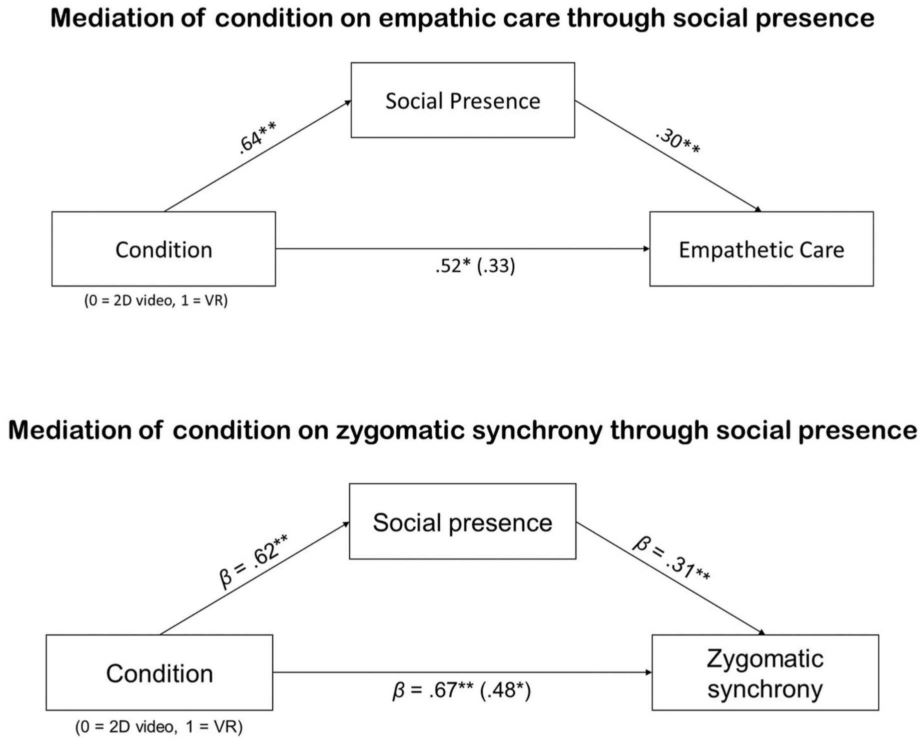

Fig. 3. Mediation of condition on empathic care (upper panel) and zygomatic synchrony (lower panel) through social presence. *$p < 0.05$, **$p < 0.01$ (the models show standardized beta coefficients).

together with our findings, we suggest that a VR-mediated social environment can uniquely target the human pro-social motivation system, eliciting care, social bonding, and, potentially, leading to higher rates of pro-social activism.

Interestingly, our results suggested that VR did not induce more robust emotional responses. Specifically, participants did not feel that the video was more emotionally intense in VR as compared to the 2D condition. Furthermore, empathetic distress – i.e., the emotional component of empathy, allowing individuals to feel what others are feeling – was not higher in the VR as compared with the 2D conditions. The lack of differential effect on empathetic distress is important. First, it shows that the main benefit of social interaction VR scenarios as compared with 2D videos is not its emotional impact, as indicated by a lack of difference in empathic distress, but its motivational impact, as indicated by higher care and wish to help the target. Second, it may be beneficial, as high levels of empathetic distress may lead to negative personal distress, empathic burn-out, and avoidance (Batson, 2010; Goetz et al., 2010; Singer & Klimecki, 2014).

Taken together, our findings suggest that the effect of VR upon empathic experiences is not a general effect of emotional arousal. Instead, VR seems to explicitly target the motivational component, underlying a compassionate stance towards suffering.

4.2. VR viewers showed enhanced synchrony with the target's facial dynamics

One of the aims of this research was to assess the effects of a VR-enhanced social environment upon objective markers of empathy, i.e., physiological synchrony with the empathy target. A preliminary test demonstrated that only zygomatic responses, marking smiling behavior (Lang et al., 1993), and electrodermal responses, signaling sympathetic arousal (Kreibig, 2010), showed significant synchrony with the target in our experiment. Among those two, zygomatic synchrony was significantly higher in the VR as compared with the 2D conditions. Centrally, following previous studies (Bourgeois & Hess, 2008; Golland et al., 2019), zygomatic synchrony in the current research has been measured as a marker of affiliative social bond with the video target.

Although the target was sharing a painful story, she frequently expressed smiles whose timing corresponded with the peaks of her zygomatic activity. Accordingly, the higher zygomatic synchrony in the VR condition stands for a continuous mimicry or return of smiles by participants who viewed the video in a VR headset. Returning a smile is a profound social behavior, which is modulated by a variety of social cues (Hess & Fischer, 2013; Wang & Hamilton, 2012), such as eye contact (de Klerk et al., 2018), attitudes (Seibt et al., 2015) and closeness (Fischer et al., 2012). Previous research of smiling synchrony and mimicry has similarly linked this phenomenon with social bonding, affiliative intents, and approach motivation (Golland et al., 2019; Heerey & Crossley, 2013; Hess & Bourgeois, 2010). Hence, we suggest that the enhanced zygomatic synchrony in the VR participants is indicative of closeness and approach motivation towards the human target. It thus complements the enhanced subjective experience of care and affiliative feelings.

4.3. A sense of social presence mediated the effects of VR upon empathic care and zygomatic synchrony

One of the central benefits of social VR is its power to induce an illusion of actually being with others (Biocca et al., 2003). This common assumption was fully supported by our study. Despite the substantial sensory similarity between the 360° 3D and the 2D videos, participants experienced the social target as being there, looking at them and talking to them to a higher degree in the VR condition. We suggest that the higher levels of social presence in the 360° 3D condition were facilitated by the subtle sensory-motor contingency cues, allowed for by the HMD presentation.

The sense of social presence may play a crucial role in empathy-eliciting VR environments. Indeed, social research has demonstrated that the experience of social presence instills profound effects on human responses (Gallotti & Frith, 2013). Thus, physical or implied presence of others has been shown to increase the intensity of emotional experiences and expressions (Bruder et al., 2012; Hess et al., 1995; Shteynberg et al., 2014). Furthermore, the degree of experienced social presence amplified neural empathy for pain (Akitsuki & Decety, 2009) and neural synchrony with a target's feelings (Golland et al., 2017).

Although a large body of work has investigated the contextual factors affecting social presence in VR environments, such as immersive qualities, contextual differences, and individual traits (Oh et al., 2018), less focus has been given to its direct interpersonal outcomes. Indirect evidence suggests that virtual characters exhibiting features that enhance social presence, such as eye contact, imposed greater social effects on observers, including persuasion (Bailenson et al., 2005), increased neural empathy (Kampe et al., 2001; Schilbach et al., 2006, 2010, 2012), and increased helping behavior (Slater et al., 2013). Finally, a previous study employing both VR and 2D perspective-taking approaches demonstrated that self-reports of social presence were correlated with feelings of empathic care (Herrera et al., 2018).

In the current study, we took a step forward and demonstrated that a sense of social presence mediated the beneficial effects of VR upon an enhanced feeling of care towards the target. We also demonstrate enhanced zygomatic synchrony with the target. In other words, participants cared about the target and returned her smiles because they had an illusory experience of being co-present with her in the same space. This result highlights the importance of systematic examination of factors enhancing social presence in VR. We would like to note that the enhancing effects of VR, observed in the current study, may potentially be modified by cultural aspects, as empathy related behaviors are culture sensitive (Cassels et al., 2010).

5. Conclusion

In the current study we demonstrate that a 360 video of a human painful story presented via a VR headset induces beneficial effects on viewers' empathy and social connection as compared with a rigorous control condition, i.e. identical audio-visual stream presented on a 2D display. Importantly, VR presentation exclusively boosted the pro-social motivational component of empathy, increasing viewers' tender feelings towards the suffering target and a desire to help and console. This pro-social effect of VR wasn't limited to subjective reports, but was evident also in the enhanced facial synchrony with the video target, indicative of affiliative social connection with the target. Centrally, both the subjective and the physiological effects of VR were mediated by the increased sense of being co-present with the target in the same environment, induced by the VR technologies. This study thus strengthens the potential of VR to provide a unique pro-social window into others' adversity when physical encounters are not possible. We believe that above and beyond empathy-specific contexts, understanding the nature, quality, and dynamics of virtual social encounters holds promise to facilitate the design of meaningful social experiences for a wide range of applications such as therapy, heritage, conflict resolution, art and education.

Credit author statement

Cohen, Daniela: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Project administration, Landau, Daniel H.: Conceptualization, Methodology, Writing – original draft, Friedman, Doron: Conceptualization, Writing – original draft, Hasler, Béatrice S.: Formal analysis, Writing – original draft, Levit-Binnun, Nava: Conceptualization, Writing – original draft, Golland, Yulia: Conceptualization, Methodology, Formal analysis, Writing – original draft.

Declaration of competing interest

None.

Acknowledgements

We thank Nurit Belou, Linda Joe Milham, Max Gering, Naama Kamari and Karen Shamir for a tremendous help with data collection and preprocessing. We thank Tali Aloni and Yair Dor-Ziderman for their help in Matlab scripts, we help Matan Sheskin for his help with a VR equipment. This work was supported by Israel Science Foundation (ISF) Grant 698/15 to YG and by the Joy ventures Grant program to NLB.

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