MASTER

The effect of feedback on the similarity of biosignals on social connectedness and empathy

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The effect of feedback on the similarity of biosignals on social connectedness and empathy

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Abstract

Nowadays, social technology allows people to connect with one another, even when being physically apart. However, given the scarcity of social cues in online communication, which are especially relevant for conveying emotional meaning, it can be questioned how well people can socially connect online and empathize with one another. This is something to be concerned about, as empathy is essential to human communication and social connection is critical to our health and mental well-being. One way to address this issue is by reintroducing new social cues into online environments. Promising as new social cues are biosignals, - such as heart rate, respiration, and skin conduction -, as they tell us something about someone's emotional state.

Besides, they also possess intrinsic social characteristics; people's biosignals might show a similar pattern due to a shared experience or a social interaction. In this study, we investigated the effect of similar biosignals on empathy and social connectedness.

In a sample of 98 participants, we compared feelings of empathy and social connectedness with other participants with either similar or non-similar biosignals, i.e., the heart rate pattern of another participant is – or is not – similar to the heart rate pattern given to the participant. Results demonstrate that feedback about similar biosignals increases feelings of empathy and social connectedness compared to feedback about non-similar biosignals. Additionally, we found that the relationship between similar biosignals and feelings of closeness is stronger for participants who have higher trait empathy. This study suggests that similar biosignals might be applied in remote communication to increase feelings of empathy and social connectedness.

Keywords: biosignals, empathy, social connectedness, similarity, psychophysiological synchronization

Content

1. Introduction

The rapid growth of the internet created a world in which there are many ways to communicate with one another. Despite this, communication via the internet is often experienced as shallow and impersonal (Moody, 2001). This is because technology-mediated communication provides fewer nonverbal cues (e.g., facial expressions, body posture) compared to face-to-face communication (Baym, 2015). The scarcity of social cues online can lead to less emotional understanding (Baym, 2015), and that in turn to decreased feelings of empathy and connectedness. This is worrying as empathy is a fundamental social process necessary for understanding, cooperating, and caring (Decety & Ickes, 2009) and our need for social connection is as fundamental as our need for food and water (Lieberman, 2013). This need is even so profound that a lack of social connection can lead to decreased physical and mental health (Cacioppo & Patrick, 2008; Cohen, 2004; Lynch, 1978).

However, due to fast technological developments new opportunities arise in establishing more emotionally connecting communication via the internet (Feijt et al., 2018). Nowadays, with the development of wearable biosensing devices of increasing quality and affordability, we have the possibility to measure our physiological activity in an unobtrusive way, which gives us access to signals such as heart rate and skin conductance. These physiological signals, normally invisible to other people, provide information about someone's emotional state (Cacioppo et al., 2007). Sharing these biosignals could therefore potentially enrich online communication by serving as a new expressive social cue in online communication (Liu et al., 2017b). Being able to perceive such private information from someone else may enhance our inferences and may increase our feelings of empathy because of a better understanding of someone's emotional state (Liu et al., 2017a; Liu et al., 2017b). On the other hand, sharing such private information can also be experienced as uncomfortable and people might be concerned about the revealingness of biosignal information (Feijt et al., 2020; Liu et al., 2019b). Thus, there is still a lot unknown about how we process biosignals and how sharing biosignals influences social interaction.

One phenomenon that is particularly interesting is Psychophysiological Synchronization (PS), which occurs when people's physiological signals synchronize, meaning that their physiological signals follow the same pattern. PS has been studied in relation to empathy, and findings generally suggest that feelings of empathy are linked to higher levels of PS (Palumbo et al., 2017). PS can also occur because of sharing a similar experience (Palumbo et al., 2017).

When two people's physiological signals follow a similar pattern, because of an empathic conversation or a shared experience, receiving feedback about this could reinforce the idea that they had a similar experience. In turn, then, believing that you have had a similar experience can increase social connectedness, i.e., the feeling of belonging and relatedness (Van Bel et al., 2009b). As social connectedness is essential for our well-being (Baumeister & Leary, 1995), and more and more interactions will take place via a digital medium, new digital communication forms should be designed that promote social connectedness, for instance through showing synchronization in biosignals.

Investigating how people interpret feedback about similar biosignals might help in developing new technologies which could support feelings of empathy and connectedness. Studies showed that providing feedback about someone else's biosignals can enhance empathy (Liu et al., 2019b; Winters et al., 2021) and social connectedness (Buschek et al., 2018; Janssen et al., 2010). However, there is little investigation on how feedback about intrinsic social qualities of biosignals, such as PS, influence this process. For example, if physiology would synchronize when having an empathic conversation via a video call, how would receiving feedback about similar physiological signals change the situation? Would people, despite the physical distance, feel closer to one another? Having similar physiological responses could also happen when interaction partners are remote but are sharing a similar experience, for example when watching the same movie. How would providing feedback about similar or non-similar physiological responses affect the process of empathy and social connectedness?

In order to employ similarity of biosignals to support interpersonal communication, we need to understand how people interpret them, what the underlying mechanisms are, and most importantly how they ought to be deployed to facilitate the processes of empathy and social connectedness. Therefore, the focus of the current study is to investigate the effect of similar and non-similar biosignals on empathy and social connectedness.

1.1 Prior research on biosignal sharing

Prior research on biosignal sharing has been focused on how it affects social interaction (see Feijt et al., 2021 for a review). It must be noted that it is a fairly new research area and that the quantity of existing research is relatively limited, and a big part of it was conducted as a part of a design process. These studies reported the benefits of sharing biosignals, as well as discomfort with sharing signals and mixed interpretation of biosignals (Feijt et al., 2021). The majority of research focuses on how biofeedback can enhance the interpersonal relationship between interlocutors. Despite the diverse measures that were applied, the overall finding based on the review paper by Feijt et al. (2021) was that biosignal sharing - in the right circumstances - has the potential to increase feelings of connectedness, empathy, intimacy, affective interdependence, and sharing of an experience. Heart rate sharing, for example, has been found to evoke feelings of intimacy, because of its strong relationship with someone's emotional state (Janssen et al., 2010).

People can experience the intimacy of sharing biosignals as a benefit, but on the other hand, they can also experience sharing this intimate information as uncomfortable. Several studies found that participants did not feel at ease or preferred not to share biosignals because of the deeply personal nature of this information (Liu et al., 2017a; Slovak et al., 2012). The explanation Slovak et al. (2012) gave for users feeling uncomfortable or not willing to share their heart rate was that sharing undermines *impression management*. This concept refers to the phenomenon that in some situations people prefer to keep up a certain impression. For example, a presenter would like to give the impression that he or she is feeling relaxed. When sharing biosignals, the biosignals could reveal that the presenter is actually quite nervous. In this case, sharing biosignals undermines impression management. Furthermore, sharing such intimate information might raise concerns with respect to privacy (Liu et al., 2019b). Another issue that arises with biosignal sharing is with regard to how to interpret its meaning. In multiple studies, participants interpreted biosignals as emotional information (Merrill & Chesire, 2016; Slovak et al., 2012). However, the interpretation of the signal is perceived as difficult because the signals are ambiguous. One reason for this is that there is no one-to-one relationship between physiological signals and emotions (Fairclough, 2009). For example, a biosignal such as skin conductance does not distinguish between positive and negative valence (Cacioppo et al., 2007). In a study by Curran et al. (2019), participants had indeed difficulties with interpreting skin conductance, because they could not read from the skin conductance levels if someone was either excited or nervous. In addition, participants are not familiar with this kind of data, which might make it even harder to interpret (Curran et al., 2019). The unfamiliarity and ambiguity of biosignals make participants question the added value of sharing biosignals in communication (Hassib et al., 2016; Liu et al., 2017a; Liu et al., 2019a; Merrill & Cheshire, 2016).

In short, research in biosignal sharing has demonstrated some potential benefits, as it can socially connect interactional parties. But it has also pointed to various complexities as people might feel discomfort when sharing such intimate and private information and people might experience difficulties in giving meaning to biosignals.

1.2 Expressive biosignals and empathy

As previously described, sharing physiological signals gives us the opportunity to share and receive insightful information about emotions that could not be shared before, which might enhance the process of empathy.

The concept of empathy has been debated over many years and there is no consensus about its definition (Elliott et al., 2018; Plank et al., 1996). Due to its complex and multidimensional nature, various theories and underlying constructs have been developed and are described in literature and research (Elliott et al., 2018). Nonetheless, and irrespective of the different terminologies used, it is generally accepted that empathy consists of three core components: cognitive empathy, emotional convergence, and empathic responding (Janssen, 2012). Cognitive empathy is the ability to reason about and infer what another person is feeling (Janssen, 2012). A concept strongly related to cognitive empathy is empathic accuracy, which can be described as the accuracy of inferring other people's thoughts and feelings (Janssen, 2012; Curran et al., 2019). Emotional convergence, also defined as the affective component of empathy, can be described as the ability to experience someone else's emotions (Janssen, 2012). Empathic responding, also referred to in literature as the behavioral component of empathy, is the response of a person to another person's distress (Janssen, 2012).

Barrett-Lennard (1981) has conceptualized empathy in a different way, focusing on empathy as a process. His model, the Empathy Cycle, distinguishes three phases of an empathic interaction: a person empathizing (1), this person expressing their empathy towards another person (2) and a person receiving this empathy (3) (Barrett-Lennard, 1981). The experience of the person being empathized with is defined in literature as received or perceived empathy (Barrett-Lennard, 1981; Plank et al., 1996), and the process of empathizing with another person is defined as empathic understanding. It is a process happening inside the empathizing person, whereby the empathizing person resonates with the other person in such a way that the experiences of the other person become vivid to the empathizing person (Barrett-Lennard, 1981). This can happen without the empathized person's knowledge or even without his or her presence. Empathic understanding can occur when hearing sorrowful news on the news or while reading engaging literature.

Prior literature suggests that sharing biosignals affects the process of empathy. Recent work indeed shows that people infer and become more aware of someone else's emotional state when receiving feedback about someone's heart rate or skin conductance (Hassib et al., 2017; Howell et al., 2016; Liu et al., 2017b; Liu et al., 2019a). In a study by Liu et al (2019b), the authors explored the influence of biosignal information on emotional perspective-taking. Emotional perspective-taking (i.e., a component of cognitive empathy) is the inference of another person's emotional state. Liu, et al. (2019b) found that heart rate information presented as a graph alongside a story of a stigmatized group member led to higher emotional perspective-taking in at least some situations. This supports the idea that people use biosignal information to infer someone's emotional state in a given context.

Winters et al. (2021) studied the effect of hearing someone's heartbeat on shifts in emotional perspective (i.e., a component of cognitive empathy) and feelings of emotional convergence (i.e., affective empathy). Change in emotional perspective was measured by the change in the selection of emotions by the participants in the facial recognition task when provided with the sound of someone's heartbeat compared to visual-only (facial stimuli) conditions. Emotional convergence was measured by answering the question "How well did you feel what they were feeling?" (Winters et al., 2021). Their results demonstrated that hearing someone's heartbeat changed emotional perspective and increased emotional convergence when assessing someone's affective state during a facial recognition task. They suggest that auditory heartbeats can be applied in social interactive systems to create more empathic technologies (Winters, 2021).

Curran et al. (2019) explored biosensory data and its relation to empathy by letting participants watch a Virtual Reality (VR) narrative from a target person's field of view. This information was presented in three conditions, a baseline video, the video with narrative text, or the video with a graph of Electrodermal Activity (EDA) of the target. Empathic accuracy was measured as the extent to which the participant's rating of the target's emotion matched with the target's rating of their own emotion. State empathy was measured by having participants answer two questions about how well they could imagine being in the viewer's situation. Surprisingly, they found that compared to the baseline, providing information about the target's EDA decreased empathic accuracy and did not influence state empathy. One of the multiple interpretations Curran et al. (2019) gave for the result is that participants are unfamiliar with this type of information since they do not encounter EDA information in daily life. Interestingly, the interviews held after the experiment provided the insight that EDA as a cue made participants aware that the feelings of the target are different than their own. Despite that empathic accuracy decreased with the presence of biosignal information, the reminder that someone has different feelings might already be very valuable on its own (Curran et al., 2019).

Taken together, literature has investigated the relationship between biosignals and various constructs of empathy, finding mixed results, but the relationship between biosignals and empathic understanding, i.e. the first phase of the Empathy Cycle, has rarely been investigated. Therefore, in this research, we have chosen to focus on empathic understanding, which covers both aspects of cognitive and affective empathy, and focuses on the process of how the empathizing person builds empathy for the person that he or she empathizes with. Empathic understanding is relevant for online communication as it improves the understanding and feeling of the emotions of the other person, which is often missing in online communication (Baym, 2015; Moody, 2001). Understanding the relationship between biosignals and empathic understanding is a necessary step to be able to successfully use biosignal sharing for supporting technology-mediated communication.

1.3 Expressive biosignals, social connectedness and I-sharing

As described in the beginning of the introduction, the digital world we live in has changed the way we interact. While digital communication increases our feeling of belonging by providing more opportunities for social interaction, at the same time it also decreases this feeling because of reduced quality of interaction. Since belonging is essential for human well-being (Baumeister & Leary, 1995), it is important to design communication systems that foster the feelings of belonging. Digital communication systems should afford “a short-term experience of belonging and relatedness” (Van Bel et al., 2009a, p.1), a concept which is referred to as social connectedness (Van Bel et al., 2009a). Van Bel et al. (2009a) conceptualized social connectedness by establishing its underlying dimensions, in order to develop a measure that can assess social outcomes of communication systems. A relevant dimension of this conceptualization is Sense of sharing and involvement, which consists of the following four sub-dimensions: Feelings of closeness, Knowing each others’ experiences, Shared understandings and Social awareness (Van Bel et al., 2009a; Van Bel et al., 2009b). Feelings of closeness refers to the connection someone feels towards another person. Knowing each others’ experiences is knowing what the other person thinks/feels in a situation. Shared understandings covers the feeling of sharing experiences/commonalities with another person. Social awareness basically covers how salient the relationship is in someone’s life.
As briefly mentioned before, prior research demonstrates that sharing biosignals can affect closeness with one another: different applications for sharing heart rate have been developed, such as rings, mobile chat applications, or smartwatches, and studies suggest they could increase feelings of connectedness between remote family and friends (Hassib et al., 2017; Liu et al., 2019a; Werner et al., 2008). Janssen et al. (2010) showed that hearing the heartbeat of a stranger increases their feelings of closeness with this person. Participants reported higher feelings of intimacy when hearing the heartbeat of an unknown person compared to silence. The reported feelings of intimacy when hearing a heartbeat were similar to those at a small interpersonal distance or during mutual gaze, which are known as highly intimate nonverbal cues. As biosignals can be seen as intimate and personal information, sharing this can create a closer connection, since sharing intimate information increases feelings of closeness.
Another way biosignal sharing can improve social connectedness is by giving people the feeling that they have shared the same subjective experience. The belief that one has the same experience as someone else in response to a stimulus is a concept called “*I-sharing*” (Pinel et al., 2006). A

study by Van Bel et al. (2009b) demonstrated that in a computer-mediated interaction with a stranger I-sharing enhances three out of four dimensions of social connectedness, namely: Feelings of closeness, Knowing each others' experiences, and Shared understandings. To our knowledge, it is not yet known if receiving feedback about similar physiological responses promotes I-sharing, and thereby if it increases these three dimensions of social connectedness. In the current work, we seek to investigate if providing feedback about similar physiological responses increases these three dimensions of social connectedness.

1.4 Psychophysiological Synchronization (PS)

Biosignals have also been found to possess intrinsic social qualities (Feijt et al., 2021). For instance, studies show that when people feel empathy towards each other their physiological signals can synchronize (Palumbo et al., 2017). The synchronization of physiological signals is called Psychophysiological Synchronization (PS). Palumbo et al. (2017) define PS as "any interdependent or associated activity identified in the physiological processes of two or more individuals" (p. 100). The alignment of physiological activation between two people can happen because of interpersonal relationships or because of matched physiological responses to another variable. Most studies about PS focus on interpersonal relationships, but PS can also happen in the absence of direct interaction (Palumbo et al., 2017).

Within interpersonal relationships, PS has been mostly studied during emotion-laden interactions, such as therapeutic sessions between therapists and patients (DiMascio et al., 1957; Marci et al., 2007) and conflict conversations between marital couples (Levenson & Gottman, 1983). Marci et al. (2007) found that higher PS between patient and client leads to higher reports of perceived empathy by the client. Research from more than half a century ago shows that when there are feelings of antagony between patient and client their heart rate showed opposite patterns, i.e. negative PS (DiMascio et al., 1957). In contrast, Levenson & Gottman (1983) found that couples developed positive PS during negative interactions, for example when discussing a marital problem.

PS can also originate from two people experiencing the same in response to a given stimulus since physiology reflects the experience (Palumbo, 2017). This could for example happen when two people watch the same film, even if they are in a different place. PS in this case shows how similar their responses to the film were (Palumbo et al, 2017). A study by Golland et al. (2015) investigated if people's physiology can synchronize while watching emotional movies without direct face-to-face interaction. They found that being 'merely' copresent was enough to establish synchronization of physiological signals between participants and that and that the level of synchronization was associated with the convergence of their emotional responses.

Recent work began to explore how providing feedback about PS influences the level of synchronization and feelings of empathy (Feijt et al., 2020; Salminen et al., 2019; Wikström et al., 2017). Wikström and colleagues (2017) designed a game in which the participants were shown a visualization of their physiological signals and were challenged to synchronize their psychophysiological states. This study suggests that intentionally synchronizing physiological signals can improve emotional understanding of one another. A study by Salminen et al. (2019) developed a VR meditation exercise including visualized biofeedback of respiration and EEG activation to promote empathy and physiological synchronization between users. Their results demonstrate that biofeedback, compared to no feedback, enhances empathy in a VR meditation exercise. Additionally, they found that participants reported more empathy when there was a stronger EEG frontal asymmetry synchronization between interactional partners (Salminen et al., 2019). A study by Feijt et al. (2020) also explored the effect of feedback about PS. In contrast to the other studies about PS feedback, this study was a controlled lab experiment, which focused on the effect of low vs high synchronization (simulated) feedback on perceived empathy and social connectedness. In this study, the participants met a confederate shortly, watched the same movie in separate rooms while receiving (fake) real-time feedback through colored borders about their level of synchronization of skin conductance. The results showed that the high synchronization group had increased feelings of empathy and connectedness with the other participant compared to the low synchronization group (Feijt et al., 2020).

To summarize, PS can originate because of multiple reasons which can either be due to interpersonal relationships or because of a matched response on another variable (Palumbo et al., 2017). Recent work shows that sharing biofeedback seems to be a promising way to elicit PS and enhance feelings of empathy (Salminen et al., 2019; Wikström et al., 2017) and that providing feedback about high compared to low synchronization increases feelings of empathy and connectedness (Feijt et al., 2020). As research about providing feedback about PS and its relation to empathy and social connectedness is still in its infancy, it is relevant to investigate the robustness of this relationship, e.g. whether it applies in a wider range of settings.

1.5 Applying biosignal sharing through HR

Now that we have elaborated on the potential benefits of biosignal sharing, it is good to consider what would be practical implementations in real-life applications. Looking at the various kinds of biosignals that can be shared, heart rate seems particularly promising to support empathy and connectedness. Measuring heart rate is already quite common in daily life. For example, wearables such as Fitbit (Fitbit, 2021) allow users to track their heart rate continuously. Some applications, such as Cardiogram (Cardiogram, 2020), even allow sharing this data with a doctor or family. Heart rate is thus an easily measurable and accessible physiological signal. Besides, due to the prevalence of these wearables, most people are already more familiar with this type of physiological signal and how to interpret it compared to other types of signals. Therefore, people might more easily grasp the understanding of a heart rate signal compared to other biosignals.

In Western culture, people relate the heart to love and emotion (Slovak et al., 2012). The emotional aspects of the heart are naturally integrated in our common language. Think about expressions such as “having a broken heart” or “a big-hearted person”. Further, the emotional interpretation of the heart is also visible in how the heart is symbolically embedded in our culture as an expression of love. Literature indeed demonstrates that people tend to interpret a heart rate signal as emotional information (Slovak et al., 2012). Presenting people with bogus heart rate feedback can even change their interpretation of the situation (Parkinson, 1985; Valins, 1966). For example, participants judged themselves as being more aroused when receiving higher false heart rate feedback indicating arousal (Valins, 1966).

Because of the strong relationship heart rate has to emotions both physiologically and culturally, heart rate sharing might be perceived as intimate. Indeed, previous studies have demonstrated that heart rate sharing increases intimacy and feelings of connectedness (Howell et al., 2019; Janssen et al. 2010; Slovak et al., 2012; Werner et al., 2008). Slovak et al. (2012) suggests that heart rate sharing is emotionally connecting because people see heart rate as part of the other, and therefore receiving heart rate feedback creates the feeling that someone is physically closer.

1.6 The present research

Thus far we have seen that sharing biosignals seems to be a promising tool to increase feelings of empathy and social connectedness and that people’s physiological signals can synchronize, meaning that their signals follow a similar pattern. However, it has rarely been investigated if feedback about the similarity of biosignals affects feelings of empathy and social connectedness. Therefore, the current research is driven by the main research question: “What is the effect of feedback on the similarity of biosignals on social connectedness and empathy?” Since we have seen that heart rate is a particularly promising biosignal because of its practical benefits and its strong connection to emotions both physiologically and culturally, we will approach the research question by using the heart rate signal as a biosignal.

This research is inspired by the study by Feijt et al. (2020) for several reasons. First of all, in the study of Feijt and colleagues (2020) participants received feedback in real-time. However, if sharing biosignals will be used in remote communication, users might receive this asynchronously, meaning that there is a time delay between messages. So far, to our knowledge, no study has investigated whether receiving similar biofeedback in an asynchronous manner will have the same effect on empathy and social connectedness. Investigating asynchronous biofeedback will contribute towards how biosignal sharing can be used in digital communication. Furthermore, in the study by Feijt et al. (2020), the participant met the other participant. To test the robustness of the effect of synchronized biosignals, it would be interesting to investigate if participants will still feel empathy and social connectedness, based on biosignal information only, towards someone they have not met. Lastly, in the study by Feijt et al. (2020), the participants received correlational feedback about their synchronization levels, whilst biosignal feedback is often represented in graphs (Liu et al., 2019b). Therefore in this study, psychophysiological synchronization is conceptualized as the similarity of heart rate patterns, and feedback on this similarity is presented by means of a graph.

We are particularly interested to find out if providing feedback about another person's heart rate response similar to their own (similar heart rate feedback) elicits more feelings of empathy and social connectedness compared to another person's heart rate response non-similar to their own (non-similar heart rate feedback).

Feijt et al. (2020) demonstrated that providing feedback about high synchronization in comparison to low synchronization leads to higher levels of empathy. Therefore, we expect that "similar heart rate feedback" (that is: feedback that shows similar HR patterns) will lead to higher levels of empathy compared to "non-similar heart rate feedback" (depicting non-similar HR patterns).

H1: Similar heart rate feedback leads to a higher level of empathy compared to non-similar heart rate feedback

Prior research shows that sharing biosignals increases feelings of connectedness. Feijt et al. (2020) demonstrated that receiving feedback about high PS compared to low PS increases social connectedness. As described in the paragraph about Psychophysiological Synchronization, people's physiology can also synchronize in the absence of interaction, reflecting a similar emotional experience. For example, when two remote friends watch the same movie they could show a similar physiological response. Providing feedback about this could strengthen their belief that they were having the same experience. Thus, receiving similar heart rate feedback on the same stimulus as another person might strengthen the idea that one had a similar experience, meaning that the participant I-shares with the other person. As described before, I-sharing increases three dimensions of social connectedness (Van Bel et al., 2009b). Combining these findings, we expect that similar heart rate feedback compared to non-similar heart rate feedback will lead to higher levels of social connectedness.

H2: Similar heart rate feedback leads to a higher level of social connectedness compared to non-similar heart rate feedback.

2. Method

2.1 Design

The study used a within-subject experiment with two experimental conditions, whereby participants watched a short movie and received heart rate feedback about themselves and other participants on this movie. The study was online and consisted of two sessions. The experimental conditions were "similar" (i.e., the feedback depicted a heart rate pattern of another participant that was similar to the heart rate pattern of the participant) and "non-similar" (i.e., the feedback depicted a heart rate pattern of another participant that was non-similar to the heart rate pattern of the participant). For each condition, the dependent variables were empathy and social connectedness.

2.2 Participants and data collection

The sample consisted of 98 participants who were randomly recruited through the J.F. Schouten participant database of Eindhoven University of Technology. The participants included 54 women, 42 men, 1 non-binary and 1 person preferring not to indicate gender, with an age ranging from 18-74 years (M=25.2, SD=10.2). The sample was reasonably diverse in educational background; they had obtained either a high school degree (38.8%), MBO (2.1%), HBO (6.1%), Bachelor's (31.6%) or Masters (21.4%) degree. Furthermore, more than half of the participants (52.0%) indicated to be not at all or just slightly familiar with measuring heart rate signals. About one third of the participants (29.6%) indicated to be moderately familiar and about one fifth of the participants (18.4%) indicated to be very or extremely familiar with measuring heart rate signals. There were 48 participants who had the similar condition first and 50 participants who had the non-similar condition first. A considerate number of participants, namely 34 participants, had either suspicions about the real aim of the study, or about that the heart rate feedback was fake, or both.

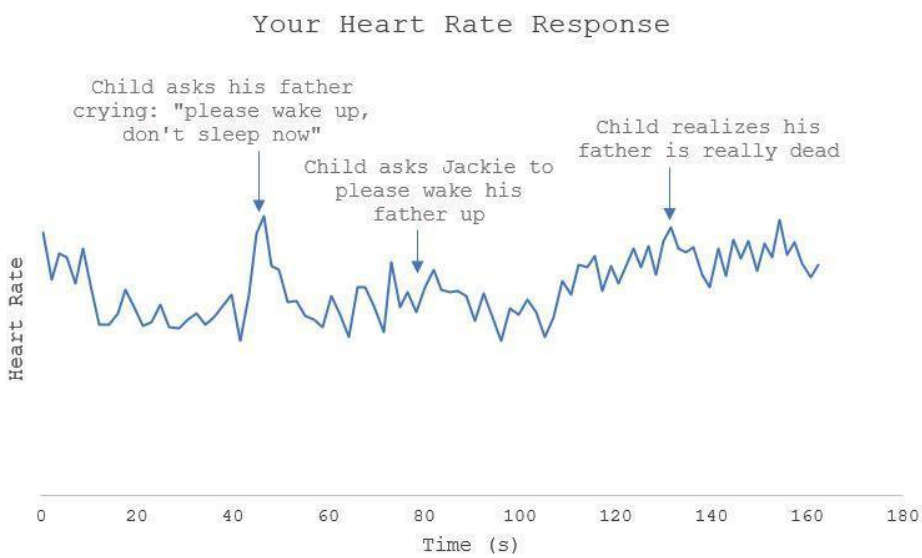
The required sample size for this study was 97 participants. This was calculated with G*Power 3.1.9.7. First, the effect size was estimated based on the results of the study by Feijt et al. (2020), with the following formula: Cohen's D = M_{diff}/ (SD1 + SD2/2). However, this resulted in a large effect size of d = 1.1, and performing the power analysis with this effect size resulted in a very small sample size. Nevertheless, although some of the measures are the same, the Feijt et al. study (2020) applied a different research design with real-time data which might yield a different (stronger) effect. Therefore, we decided to look at the smallest effect size that would be of interest.

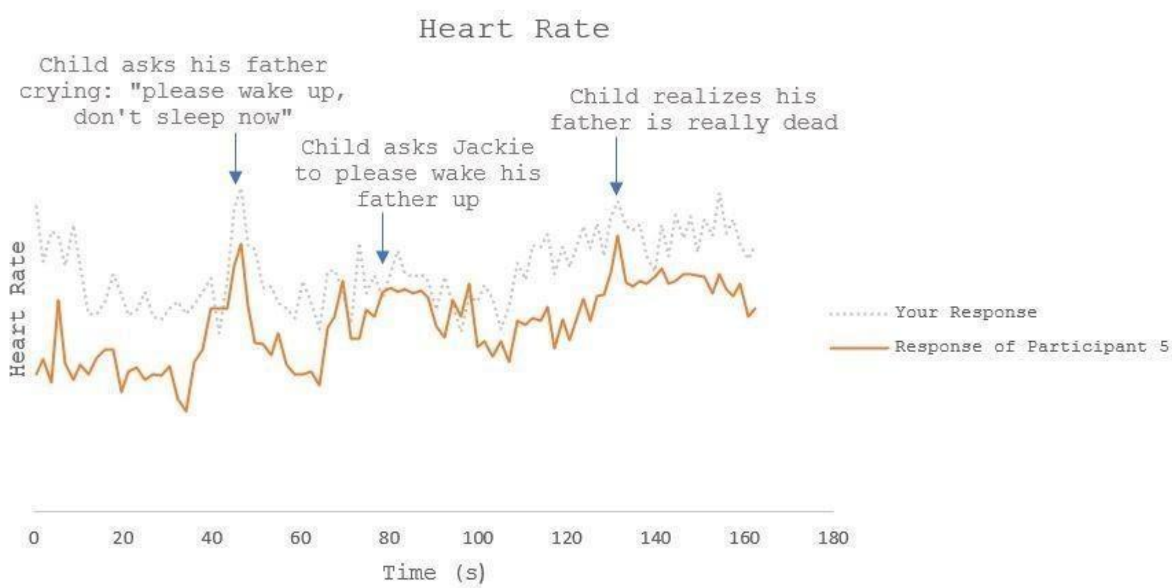
This would be a medium effect size (d = 0.30). This simulation resulted in a required sample size of 97 participants.

2.3 Methodological choices

2.3.1 Simulated Visual Heart Rate feedback

It was chosen to represent the heart rate signals in a graph because they are typically presented that way, i.e. consumer applications, such as Fitbit (Fitbit, 2021), that track biosignals commonly use graphs to visualize data. Besides, in a study by Liu et al. (2017b), in which they explored the impression of different visualizations of biosignals, they found that participants thought that graphs are a familiar, straightforward and trustworthy way to represent biosignals. The heart rate responses presented as their own and that of the other participants were not measured but simulated by the researcher. To create a credible heart rate response, the heart rate of the researcher was measured during the preparation of the experiment using a TMSi-Mobi (TMSi, n.d.) device while she watched "The Champ". This graph was provided to participants as being their own response, which is labeled in the graphs in both conditions as "Your Response". Then, the feedback in the similar condition was created by modifying this graph. The non-similar response was created in such a way that the response peaked and dropped at different moments than "Your Response" and in this way created a different overall pattern than "Your Response". Three points on the graphs were labeled indicating an emotional moment from the video, such as "Child realizes his father is really dead". Figure 1 shows the heart rate responses. The generation of these HR response stimuli was optimized in a pilot study (see appendix A for a description of the pilot).


Your Heart Rate Response
Child asks his father crying: "please wake up, don't sleep now"
Child asks Jackie to please wake his father up
Child realizes his father is really dead
Heart Rate
0
20
40
60
80
100
120
140
160
180
Time (s)


Heart Rate
Child asks his father crying: "please wake up, don't sleep now"
Child asks Jackie to please wake his father up
Child realizes his father is really dead
Heart Rate
Your Response
Response of Participant 5
0
20
40
60
80
100
120
140
160
180
Time (s)

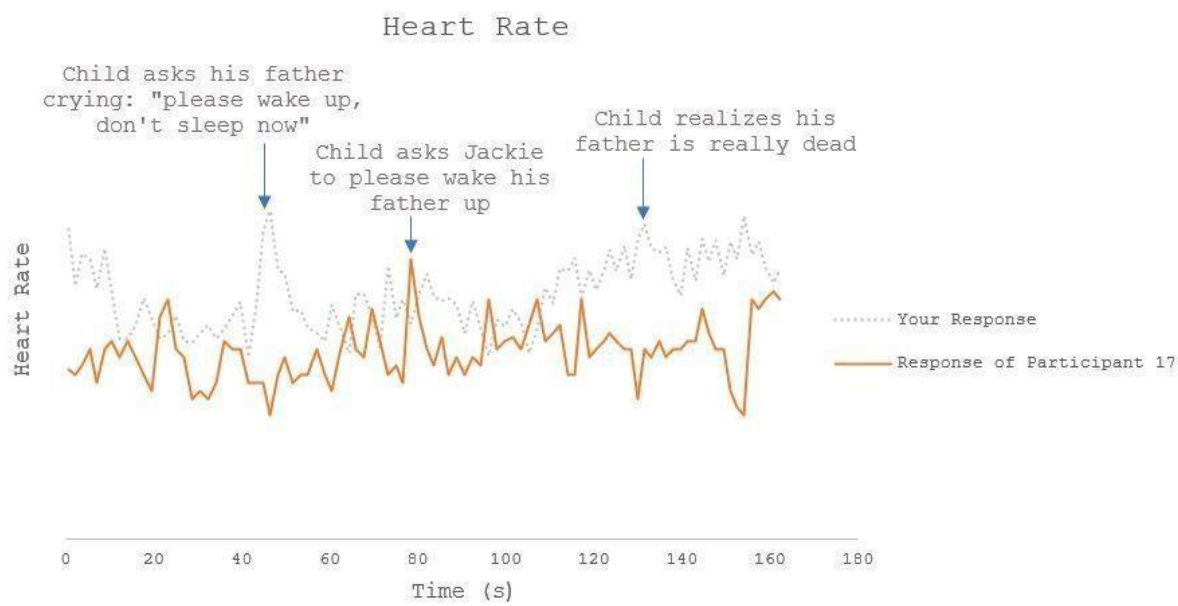


Figure 1

The heart rate responses of their own response (upper graph), the similar condition (the middle graph) and the non-similar condition (the lower graph).

2.3.2 Cover story

A cover story was created to make sure the participants would not find out the real aim of the study and they would believe that the heart rate feedback presented their own and other participants' signals. The participants were told that it was still unknown how good people are in estimating others' emotions based on biosignals and that therefore the aim of the study was to investigate how people interpret physiological responses of other persons to an emotional video clip. To support the cover story, we included the SAM and a few open questions about feelings.
To create the false belief that the heart rate of the participants was measured the participants were asked to record their face while watching the video. They were told that the researcher would analyze the video recording with FaceReader software, which is based on subtle color changes in the face, using remote photoplethysmography (RPPG) techniques to derive HR (see Appendix B for the participant instructions).

2.3.3 Emotional Video

For this study, a highly emotional video was chosen, since highly emotional videos usually elicit more psychophysiological activation compared to neutral videos (Fernandez et al., 2012).
Furthermore, emotionally arousing films, such as tragedies, increase the sense of belonging (Dunbar et al., 2016), and might therefore create a stronger effect of social connectedness.

A scene from the film: "The Champ", where the child cries over the death of his father, was chosen because it has been found to elicit high levels of sadness (Gross & Levenson, 1995). A review by Kreibig (2010) showed that the heart rate response of sadness is variable, as several studies reported that films inducing sadness increased HR (Kunzmann & Grühn, 2005; Luminet et al., 2004), whilst other studies reported that it decreased HR (Britton et al., 2006; Eisenberg et al., 1988). Due to this variable relationship between HR and sadness, we think participants will accept HR increases as well as HR decreases as potential responses to this film clip, without implying that someone was more or less sad at that moment.

2.4 Materials

A functioning laptop, webcam, and internet connection were required to participate in this study. The online survey platform LimeSurvey was used to conduct the questionnaires. The collected data was stored in an encrypted Research Drive to ensure safe storage.

2.5 Measures

2.5.1 Self-Assessment Manikin

The Self-Assessment Manikin (SAM; Bradley & Lang, 1994) is a non-verbal pictorial that measures emotional response (see Appendix C). In this experiment, SAM was not only used to measure the emotion of the participants themselves, but also for having participants estimate the emotions of presumed other participants. The original version assesses three dimensions of emotions: pleasure, arousal, and dominance. In this study, dominance is left out, since it did not fit the context. The pleasure dimension had figures ranging from an unhappy figure to a happy figure, with a corresponding scale ranging from 1 (*very unhappy*) to 9 (*very happy*). The arousal dimension had figures ranging from a sleepy figure to an active figure, with a corresponding scale ranging from 1 (*very calm*) to 9 (*very excited*).

2.5.2 Interpersonal Reactivity index

The Interpersonal Reactivity (IRI) index is a 28-item scale that measures trait empathy (Davis, 1980) (see Appendix D). An example of one of the items is: "After seeing a play or movie, I have felt as though I were one of the characters". All items were rated on a 5-point Likert scale ranging from 1 (*does not describe me well*) to 5 (*describes me very well*). The IRI was included to explore if being more empathic influences feelings of empathy and social connectedness towards someone based on a similar/non-similar heart rate signal.

2.5.3 Perceived Revealingness

For their own and the other person's heart rate responses, the participants had to rate the revealingness of the signal, on a scale ranging from 1*(not at all revealing)* to 7 *(very revealing)*. This is a question from a study about revealingness of own versus other responses by Pronin et al. (2001). As perceived revealingness was measured for another study and falls beyond the scope of this research it will not be discussed any further.

2.5.4 Perceived Valence

For their own and the other heart rate responses the participants had to rate the perceived valence of the signal by responding to the items: "I perceive my heart rate feedback as…" and "I perceive the heart rate feedback of participant 5/17 as…", with the answer options ranging from 1 *(completely negative)* to 5 *(completely positive)*. As perceived valence was measured for another study and falls beyond the scope of this research it will not be discussed any further.

2.5.5 Perceived Similarity

To measure if the manipulation of the independent variable was successful the participants had to rate the similarity between their own response and that of the other participants on a scale from 1 *(very different)* to 5 *(very similar)*.

2.5.6 Empathy

Empathy was assessed with four statements, measuring empathic understanding (See Appendix E). These questions were answered on a scale ranging from 1 *(strongly disagree)* to 5 *(strongly agree)*. The items were based on a perceived empathy scale originally created by Plank et al. (1996) and adapted to context by Feijt et al. (2020). Since, in the current study, the participants did not meet each other, only three items from their questionnaire fitted the context of the current experiment. As we intended to measure empathic understanding, two questions which were third-person perspective were altered to first-person perspective (See Appendix A for a description of the pilot in which the questions were altered). An example of an altered item is: "I really understand the feelings of participant 5". One extra item was added to also include a question about emotional empathy. This concerned the item: "I can feel with participant 17 in this situation". Although this item is not from a previously used and validated questionnaire, it aims to measure if someone's feeling with the other person's emotional experience, which is closely related to the definition of affective empathy.

2.5.7 Social Connectedness

Two subscales of the Social Connectedness Questionnaire were used to measure Knowing each others' experiences and Shared understandings (Van Bel et al., 2009a). To measure participants' feelings of closeness the Inclusion of Other in Self Scale (IOS) was used. We included these three measures, because they have been found to be significantly increased in case of I-sharing (Van Bel et al., 2009b). Furthermore, the fourth sub-dimension of social connectedness (Van Bel et al., 2009a; Van Bel et al., 2009b); Social awareness was not measured in this experiment as it did not fit the context and it also did not increase I-sharing in the experiment by Van Bel et al., 2009b.

Inclusion of Other in Self Scale. In the study by Van Bel et al. (2009b), they used, aside from two items to measure feelings of closeness, the IOS to measure participants' feelings of closeness. However, only the IOS has been found to be significantly increased in case of I-sharing (Van Bel et al., 2009b). In the current study, to measure participants' feelings of closeness IOS was used (see Appendix F). In this single-item pictorial the relationship between the self and the other is depicted in overlapping circles, in which one circle says "self" and the other circle says "other". The images in this scale range from the two circles not overlapping to the two circles almost completely overlapping. The overlapping circles refer to the connection between the self and the other, in a way that the more the circles overlap the more connected the self feels towards the other (Aron et al., 1992).

Knowing each others' experiences. Knowing each others' experiences was measured with four items (See Appendix G). An example is; "I know what participant 17 feels in this situation." (Van Bel et al. 2009a). All items were rated on a 7-point Likert scale ranging from 1 *(completely disagree)* to 7 *(completely agree)*.

Shared Understandings. Shared understandings was measured with three items (See Appendix H). An example is; "I feel I have a lot in common with participant 5" (Van Bel et al., 2009a). Two items were rated on a 7-point Likert scale ranging from 1 *(completely disagree)* to 7 *(completely agree)*. However, as one of these items overlaps with one of the items of our empathy scale, namely, "I feel as if I am on the same wavelength as participant 17", this item was rated on a 5-point Likert scale ranging from 1*(strongly disagree)* to 5*(strongly agree)*. The participants answered this item only once, but it was used in the analysis for both scales.

2.5.8 Open questions

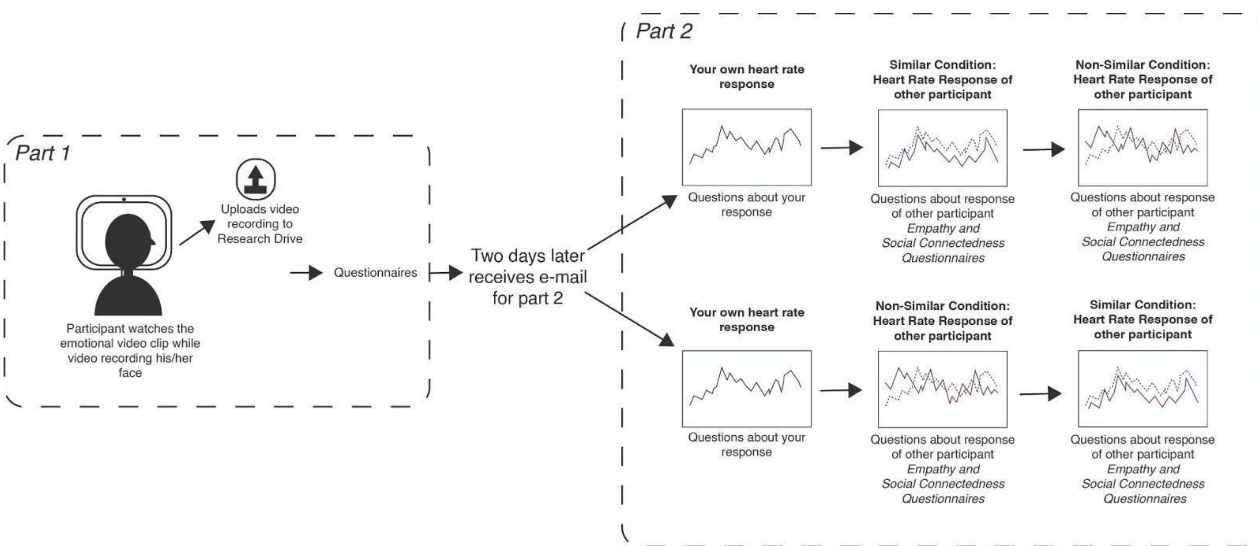
Additionally, there were several open questions in this experiment. The participants had to answer the following open questions about their feelings: "How would you describe your feelings about the video clip?" and "How do you think your heart rate feedback is related to your feelings during the video?". To investigate what people think their heart rate reveals about them they were asked to respond to the following question: "Please write down anything that comes to mind about what your heart rate reveals about you." To estimate the emotions of the presumed other participants the participant had to answer the following question: "How do you think participant 5/17 was feeling while watching the video based on his/her heart rate feedback?". To be able to investigate if people had any suspicion about the aim or the set-up of the study the following question was asked: "What do you believe is the objective of this research?".

2.6 Procedure

Figure 2 shows an overview of the procedure. The study consisted of two sessions; in the first part participants watched a video and in the second part they answered questions about the heart rate responses.

Figure 2

Overview procedure



2.6.1 Part 1

Participants were invited via an email including the link to the first part of the study through the J.F. Schouten participant database of the Eindhoven University of Technology. Participants were also recruited by the researcher via sharing the link on WhatsApp, personal emails, and Facebook. After signing the informed consent form (Appendix I), the participants were presented with an introduction to the task (Appendix B), in which the aim of the study according to the cover story was explained as well as the technique of deriving heart rate signal from a face recording. Subsequently, they were asked to record their face via their webcam while watching the emotional video "The Champ". After watching and uploading the video, the participants were asked to complete a questionnaire (i.e., the SAM, an open question on their experienced emotions, and the IRI). The last question of part one was if the participants would give consent to share their heart rate with other participants. This question was included to strengthen the belief that their heart rate was recorded. Finally, they were thanked for participating in the first part and informed that they would receive a link for the second part within a day or two.

2.6.1. Part 2

After approximately two days the participants received an email telling them that their data had been analyzed and that they could participate in the second part of the study by clicking on the link included in the email. In this part participants received multiple graphs with simulated heart rate patterns of themselves and other participants on the video. In the first graph their own (fake) heart rate signal was displayed followed by a questionnaire (i.e., the SAM, revealingness and valence of the signal and two open questions about the revealingness of the signal and how their heart rate is related to their feelings). After answering these questions they were either first exposed to the similar condition followed by the non-similar condition, or vice versa. Both the similar and the non-similar condition showed the (fake) heart rate of another participant. Their own heart rate feedback was still shown in both graphs vaguely in the background, as they were told that this could help them in interpreting the other participants' emotions. In reality, their own heart rate signal was shown as an indication of whether their heart rate was similar or non-similar to the heart rate signals of the other participants. In both conditions they had to complete the same questionnaire (i.e. the SAM, open question about feelings, revealingness and valence of the signal, empathic understanding, IOS, Knowing each others' experiences, and Shared understandings). The experiment ended with some questions on demographics, their thoughts on the objective of this research and their preferred reward for participation (i.e. monetary reward or course credit). Finally, they were thanked for their participation and a few days later they received a debriefing explaining the real purpose of the study and explaining that their heart rate was not extracted from their face recording, but instead simulated by the researcher.

2.7 Pre-processing, data analysis and statistical analysis

The data was analyzed using the statistical software package StataIC 16 (Statacorp, 2019). The datasets were exported from Limesurvey and they were merged into one dataset. The participants who only finished the first part of the study were removed from the dataset. Two new variables were created, one variable which indicated if the participant had a suspicion about the aim or set up of the experiment and one variable which indicated the order in which the participant had received the conditions. The variable suspicion was created by analyzing the answers to the question about the objective of this research.

In order to calculate the results for the dimension Shared understandings, these items needed to be standardized since one of the items was rated on a different scale than the others. After creating standardized values for each item of Shared understandings, the internal consistency of Shared Understandings (α=0.84) was checked. The internal consistency was also checked for Knowing each others' experiences (α= 0.93), empathy (α=0.85), and for the IRI (α=0.89). For each measure, the average of the items was taken and used for analysis.

Before doing the main analyses, it was checked for each dependent variable and for perceived similarity whether the difference between the two conditions followed a normal distribution and whether the difference between the two conditions included any outliers. The normality assumption of Perceived similarity and Knowing each others' experiences were not met, and therefore non-parametric Wilcoxon signed-rank tests were performed.

One outlier was detected in Knowing each others' experiences; the effect of similarity was very strong for this participant, meaning that this participant gave a very high score on Knowing each others' experience for the similar condition and a very low score on Knowing each others' experience for the non-similar condition. Two outliers were detected in empathy and one in Shared understandings; the outliers were inspected and based on their answers to the open questions and the other questions it did seem that they filled in the questionnaire seriously. To check whether the outliers would influence the results the tests were also performed without outliers; this led to somewhat bigger effect sizes, but did not change the outcomes. Therefore it was decided to keep the outliers in the data set.

To check whether the manipulation of similarity of the heart rate signals was successful, a non-parametric Wilcoxon signed-rank test was performed on the Perceived similarity scores. In order to investigate the effect of similarity on empathy, IOS, Knowing each others' experiences and Shared understandings, three paired sample t-tests and a non-parametric Wilcoxon Signed Rank test were performed. These tests allowed us to determine whether there was a significant difference in means of the two conditions for each dependent variable and for perceived similarity. To correct for performing multiple tests Bonferroni corrections were applied, which did not change the outcome of any of the tests.

Linear mixed models (LMM) were performed for each dependent variable to investigate the role of the following covariates: age, gender, trait empathy, familiarity, suspicion, and task order.

Before running the LMMs, the assumptions for doing these analyses were checked. Only the plot of the LMM with the dependent variable empathy suggests heterogeneity. However, it was still decided to run this model as LMMs are proved to be quite robust to violations of residual variances (Schielzeth et al., 2020). For the dependent variables with outliers, models were run with and without outliers, which did not result in different outcomes for empathy and Knowing each others' experiences. Therefore, it was decided to perform these models including the outliers. In the model of Shared understandings, only age was not significant anymore without the outlier. However, as this participant filled in the questionnaires seriously, it was decided to perform the model including the outlier.

Although the normality assumption of Knowing each others' experiences was not met, it was decided to run the model without doing any transformation, as the extent of the violation seemed small and violations of normality often have little impact on LMMs (Schielzeth et al., 2020).

The open questions about the feelings of the similar and non-similar participants were analyzed by counting which answers were frequently provided (Appendix J).

3. Results

3.1 Manipulation Check

The non-parametric Wilcoxon signed-rank test was performed to test if the similarity manipulations were successful. The effect was significant ($z=8.61$, $p<0.001$): participants gave a higher score on perceived similarity of heart rate feedback for the similar condition ($M=4.35$) compared to the non-similar condition ($M=1.80$), indicating that the similarity manipulation was indeed successful.

3.2 Main Questions

Figure 3 depicts the means and confidence intervals of both conditions. Table 1 shows the descriptive statistics of the scores on the measures for both conditions.

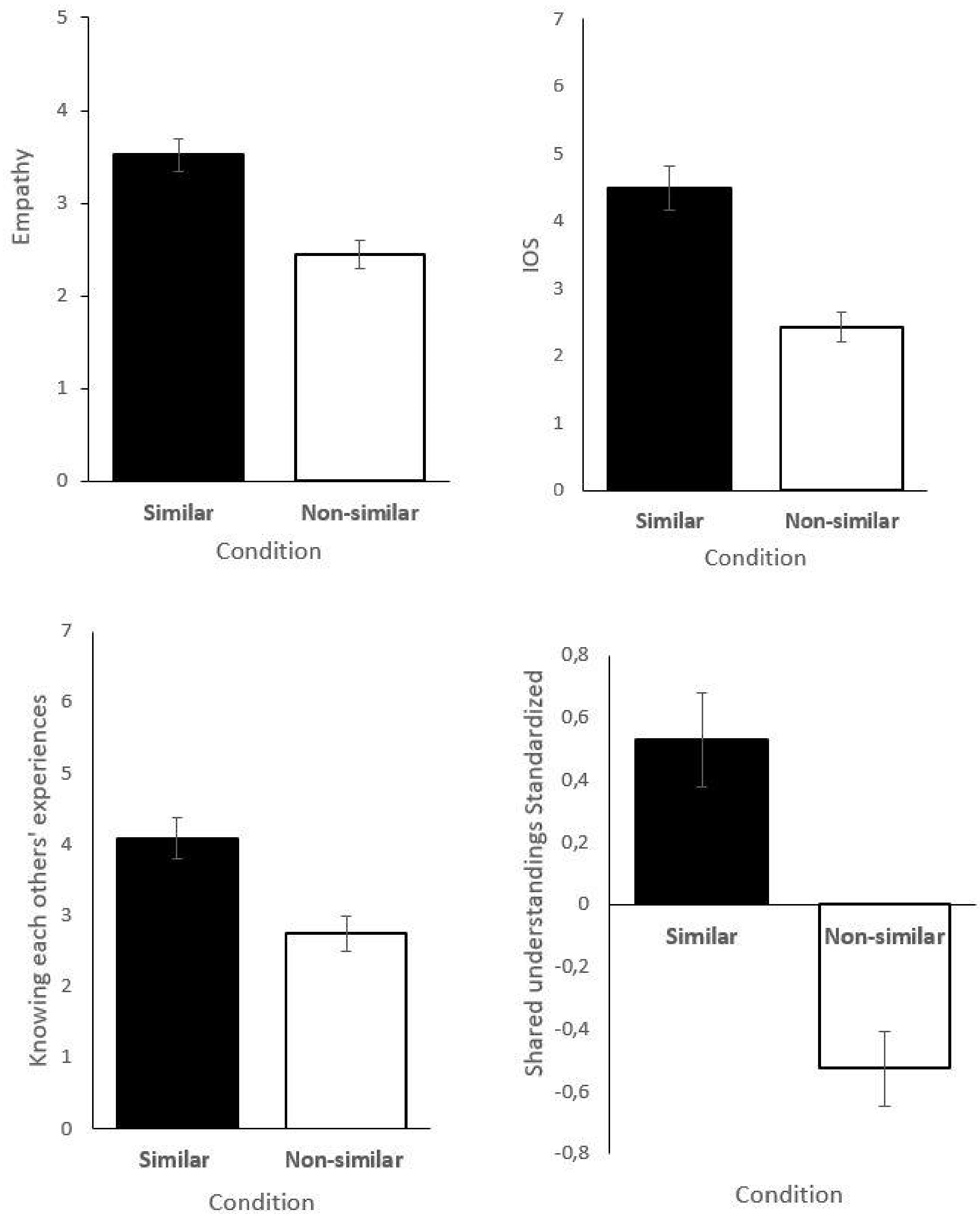


Figure 3

Means and confidence intervals on the dependent variables for both conditions. For all variables the difference between both conditions was significant.

Condition	IOS		Empathy		Knowing each others' experiences		Shared understandings standardized scores	
	M(SD)	95%CI	M(SD)	95%CI	M(SD)	95%CI	M(SD)	95%CI
Similar	4.49 (1.6)	4.17-4.81	3.52 (0.84)	3.35-3.69	4.08 (1.44)	3.79-4.36	0.53 (0.76)	0.37-0.68
Non-similar	2.43 (1.16)	2.20-2.66	2.44 (0.72)	2.30-2.59	2.74 (1.24)	2.49-2.99	-0.53 (0.62)	-0.65 - -0.40

Table 1

Descriptive statistics of the scores on the measures for both conditions. For all variables the difference between both conditions was significant.

3.2.1 Empathy

We hypothesized that similar heart rate feedback leads to a higher level of empathy compared to non-similar heart rate feedback (H1). A paired sample t-test was performed to test the effect of similar heart rate feedback vs non-similar heart rate feedback on empathy. The effect was statistically significant: participants gave a higher score on empathy for the similar condition ($M = 3.52$, $SD = 0.84$) compared to the non-similar condition ($M = 2.44$, $SD = 0.72$; $t(97) = 12.29$, $p<0.001$, $d = 1.24$). These results support H1.

3.2.2 Social Connectedness

We hypothesized that similar heart rate feedback leads to a higher level of social connectedness compared to non-similar heart rate feedback (H2), and this was tested on three of the subscales of social connectedness:

Inclusion of Other in Self Scale. The effect of the paired sample t-test was statistically significant: participants gave a higher score on the IOS for the similar condition ($M = 4.49$, $SD = 1.60$) compared to the non-similar condition ($M = 2.43$, $SD = 1.16$; $t(97) = 15.25$, $p<0.001$, $d = 1.54$). These results support H2.

Knowing each others' experiences. The non-parametric Wilcoxon signed-rank test was performed to test the effect of similarity on Knowing each others' experiences. The test revealed that there was a statistical difference between the means of the similar ($M = 4.08$, $SD = 1.44$) and non-similar groups ($M = 2.74$, $SD = 1.24$; $z = 7.65$, $p<0.001$, $r = 0.77$). Participants gave a higher score on Knowing each others' experiences for the similar condition compared to the non-similar condition. These results support H2.

Shared understandings. A paired sample t-test was performed to test the effect of similar heart rate feedback vs non-similar feedback on Shared understandings. The effect was statistically significant: the participants gave a higher score on Shared understandings for the similar condition ($M = 0.53$, $SD = 0.76$) compared to the non-similar condition ($M = -0.53$, $SD = 0.62$; $t(97) = 13.57$, $p<0.001$, $d = 1.37$). These results support H2.

3.3 Covariates

To investigate the effect of the following covariates: gender, age, trait empathy, suspicion, task order, and familiarity, linear mixed models were performed for each dependent variable. The main effects of the covariates, condition (similar and non-similar) and the effects of interaction between each covariates and condition were included. The main effect of condition remained significant for each dependent variable (empathy ($p<0.001$, $\beta=0.54$), IOS ($p<0.001$, $\beta=1.01$), Knowing each others' experiences ($p<0.001$, $\beta=0.66$), Shared understandings ($p<0.001$, $\beta=0.52$)).

The LMM analysis of IOS showed a significant main effect of task order ($p<0.001$, $\beta=-.40$) and a significant interaction effect between trait empathy and condition ($p=0.02$, $\beta=0.38$). The other effects were not significant. Post-hoc tests of the main effect of task order demonstrate that participants who had the non-similar condition first gave a higher score on IOS in both conditions. The investigation of the scatter plots of the interaction showed that participants who scored higher on trait empathy gave higher scores on the IOS for the similar condition, but lower scores on the IOS for the non-similar condition, meaning that the effect of similarity on IOS is stronger for participants who scored higher on trait empathy. The interaction effect is visualized in Figure 4.

Both the LMM analyses of empathy and Knowing each others' experiences as dependent variables did not show any significant main or interaction effect.

The LMM analysis with Shared understandings as dependent variable showed significant main effects of suspicion ($p=0.03$, $\beta=-0.27$), task order ($p=0.03$, $\beta=-0.12$), and age ($p=0.048$, $\beta=0.01$). Post-hoc tests showed that participants with suspicion about the aim or set-up of the experiment gave lower scores on Shared understandings compared to people without suspicion. Participants with the non-similar condition first gave higher scores on Shared understandings compared to participants with the similar condition first. Age was found to have a positive effect on Shared understandings.

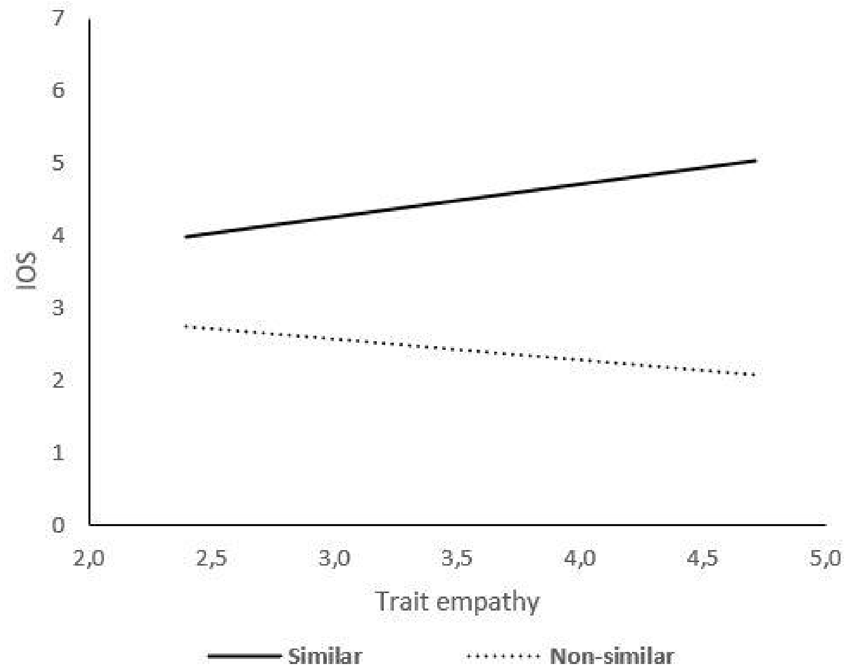


Figure 4

Interaction effect between IOS and Trait empathy. The effect was significant.

3.4 Open Questions

When analyzing the responses to the question "how do you think participant X was feeling?" it seems that in the similar condition people felt like the presumed other participant had a similar experience as them, as 58 (59.2%) of the participants responded that they thought the participant felt the same or had the same experience as they did. For example, one participant responded: "As such, I might presume them to have had a similar emotional experience as I did." The other participants mostly described the feelings of the other participant or said that the heart rate looked similar to their own. The emotions described for the similar participant were mostly that he/she felt sad or felt empathy for the child.

The responses to the question about the feelings of the non-similar participant were more mixed. As 31 (31.6%) participants described his/her feelings as neutral or calm, 18 (18.4%) described his/her feelings as less sad/ less affected by the video and 12 (12.2%) participants did not know how to describe or interpret it. However, there were also two participants who described the non-similar participant as even sadder. The other participants gave various descriptions which did not fit the previously mentioned categories. Some of these were quite detailed descriptions, often linking the peaks and valleys to certain emotions. The emotions they described were mostly different kinds of negative emotions. For example, one participant said: “The response seems not so similar to mine, but they are clearly still affected by for example the second peak. I'm guessing they probably felt sad as well but just about different things”. An example of how mixed the responses are is that one person said: “this participant’s heart rate seems to vary a lot”, whilst another person says “does not vary as much”.

4. Discussion

The aim of the current study is to investigate the effect of biosignal similarity on empathy and social connectedness. As more interactions take place online, we need new ways to emotionally connect with one another. Biosignals are new expressive cues that could be employed to foster feelings of empathy and social connectedness in technology-mediated communication. In order to analyze how biosignals should be deployed in communication to foster social connection it is important to explore how feedback about biosignals affects social interaction. The results indicate that feedback depicting similar heart rate patterns leads to higher levels of empathy and social connectedness compared to feedback depicting non-similar heart rate patterns.

4.1 Effects of Similarity of Biosignals on Empathy

In line with our expectations, we found that similar heart rate feedback leads to higher levels of empathy compared to non-similar heart rate feedback. This supports prior work which demonstrates that sharing biosignals enhances feelings of empathy (Liu et al., 2019b; Winters et al., 2021). The results are also in line with the study by Feijt et al. (2020) which showed that participants receiving high synchronization feedback with another person had increased feelings of perceived empathy compared to receiving low synchronization feedback. Our results extend previous works as it is the first study to demonstrate the effects of similar biosignals on empathic understanding, showing that receiving feedback about similar biosignals compared to non-similar biosignals leads to increased feelings of empathy towards the other person.

However, the possibility should be considered that any kind of perceived similarity could lead to increased feelings of empathy towards someone and that this similarity does not necessarily has to be similar biosignals. A popular theory amongst psychologists is that perceived similarity between strangers leads to empathy: we feel more empathy towards people that we think have similar personal characteristics as us (Batson et al., 2005; Davis, 1994). However, evidence for the link between empathy and perceived similarity is mixed and limited (Batson et al., 2005). Within studies supporting this theory (Krebs, 1975; Stotland, 1969), it remains unclear if the effect was caused by similarity, or by some concomitant of similarity, such as liking (Batson et al., 2005). For the present study, it is thus unclear via which mechanisms similarity of biosignals lead to empathy; is this direct or via perceived similarity, i.e. meaning that receiving feedback about similar heart rate signals leads to the belief that one shares personal characteristics with this other person. Or does any type of similarity lead to increased empathy?

To find out if any type of similarity, biosignal or other, leads to increased feelings of empathy, a follow-up study should be performed, also containing a similar and non-similar condition on a more random shared aspect (e.g. sharing a birthday or favorite color) to determine whether it leads to the same results. In addition, it would also be interesting to compare the effect of biosignal similarity with other types of relevant similarities, such as personality characteristics, behaviors, economic status, and attitudes. Future studies could also investigate if feedback about similar biosignals creates the idea that someone has similar attributes.

4.2 Effects of Similarity of Biosignals on Social Connectedness

We demonstrate that similar biosignals increase social connectedness compared to non-similar biosignals. The results are in line with prior work which demonstrates that sharing biosignals can enhance feelings of social connectedness (Buschek et al., 2018; Hassib et al., 2016). Moreover, our results extend past work by showing the effects of similar biosignals compared to non-similar biosignals: we demonstrate that feedback about similar biosignals increases social connectedness, especially in remote communication. As posed in the introduction, this might be promoted by I-sharing, as I-sharing also increases these three dimensions of social connectedness. The answers to the open questions seem to support the idea that participants had the belief that they were sharing a similar experience with the similar participant and not with the non-similar participant, and thus were I-sharing with the similar participant. The role I-sharing plays can be interpreted as a mediator, meaning that receiving feedback about similar physiological responses with someone to a certain stimulus creates the belief that one has shared an experience with someone else, thus causing I-sharing, which is known to increase social connectedness (Van Bel et al., 2009b). However, further research is needed to establish the role I-sharing plays within biosignal sharing.

The questions posed in the previous paragraph about if any kind of similarity could lead to increased empathy could also be posed for social connectedness, as a known theory in sociology is homophily, which involves that similarity breeds connection (McPherson, 2001).

Our experiment demonstrates that receiving similar biofeedback compared to non-similar biofeedback increases feelings of social connectedness towards a stranger. It could be expected that these effects are even bigger when someone does know the other person, but research is needed to establish this. Overall, our results are promising and indicate that similarity of biosignals could be used to design communication systems that enhance social connectedness. However, genuine physiological signals might not show such a similar pattern as our simulated feedback did. As such the effects of real feedback and real physiological data need to be investigated to determine if the effect persists.

4.3 Effects of trait empathy, task order and suspicion

The results indicated that trait empathy influenced the effect of similarity on feelings of closeness. For empathy and the other aspects of social connectedness, we did not find such an interaction. The interaction effect showed that the effect biosignal similarity has on feelings of closeness is stronger for participants who score higher on trait empathy. This is in line with earlier findings, which demonstrated that the relationship between interpersonal attraction and attitudinal similarity was much stronger for people with a high empathic tendency compared to people with a low empathic tendency (Grover & Brockner, 1989). One of the main reasons they give for this effect is that people with high empathic tendency are more sensitive to others' viewpoints compared to people with low empathic tendency (Grover & Brockner, 1989). Grover and Brockner (1989) also suggest that empathy does not necessarily involve liking just anyone, but that empathy enables people to connect with others when there is a reason to connect, such as seeing that someone is similar to oneself. It could be that, in the current study, participants who are more empathic were more affected by the similarity of biosignals because they are better at adapting to others' perspectives and affective experiences. However, we should be careful with drawing any conclusions, as we did not find such an effect for empathy and the other aspects of social connectedness. These mixed results make it difficult to interpret what the underlying reasons are. Future research should be done to understand its underlying mechanisms. Additionally, as we found this effect on feelings of closeness, instead of interpersonal attraction it might be interesting for future research to investigate the influence of trait empathy on the relationship between similarity of biosignals and interpersonal attraction.

The effect of task order found on both feelings of closeness and shared understandings could be due to the fact that when seeing the dissimilar condition first, the participants did not have a comparison yet and thus they did not know that there was also a possibility of having more similar signals with someone, so they still felt a bit connected. Conversely, participants with the similar condition first, saw how dissimilar the other signal was and therefore gave lower scores compared to the participants with the non-similar condition first.

Suspicion about the aim or set-up of the experiment only influenced shared understandings; participants with suspicion gave lower scores to both conditions. It could be that when participants suspect that the heart rate data is not their own they feel less connection, as they then know the connection with a presumed other participant is not based on their own data. However, as we did not find this for the other dependent variables it is difficult to draw a conclusion. It is interesting to note that despite the fact that people with suspicion gave lower scores on shared understandings, the effect of similarity was still present. Apparently, having suspicion about the aim or set up of the experiment did not influence the effect similarity has on empathy and social connectedness.

4.4 Generalizability to other biosignals and representation of the signal

Our results show that receiving feedback about similar heart rate signals has a positive effect on empathy and social connectedness. However, the research question posed in this experiment was about biosignals in general. Looking at the advantages of heart rate signals, described in the introduction, it could be questioned if the effect of similarity is generalizable to other biosignals. As described in the introduction, Curran et al. (2019) did not find an effect of biosignals on state empathy, possibly because participants were unfamiliar with skin conductance data and they found the data hard to interpret. On the other hand, in our experiment, the responses to the open questions suggest that participants had more difficulties with the emotional interpretation of the heart rate signal of the non-similar participant, although not necessarily with that of the similar participant. This suggests that people also have difficulties with interpreting heart rate data when it is not similar to their own. Thus, it seems that participants could interpret the similar signals, because of their similarity, not because it was a heart rate signal. This would imply that the similarity of the signal, instead of the type of biosignal, led to a better emotional understanding of the other person. In line with this reasoning, it could also be that Curran et al. (2019) did not find an effect of biosignals on state empathy because the skin conductance response of the other person did not correspond to what the participants would expect based on their own emotional interpretation of the content, and thus the participants had difficulties with interpreting what the other person was feeling. As described before, Feijt et al. (2020) found that participants receiving feedback indicating high synchronization of skin conductance reported increased feelings of empathy and social connectedness compared to feedback indicating low synchronization. Their results are in line with our results, but they employed another type of biosignal. Taken together, it is likely that our results are generalizable to other types of biosignals, but more research is needed to establish this. It could be that the effect is stronger or less strong depending on the type of biosignal. Future studies should investigate if the effect of similarity on empathy and social connectedness differs in strength for different types of biosignals.

Additionally, future work should also investigate different ways of representing similar signals and their effect on social connectedness and empathy. A study by Liu et al. (2017b) showed that the way biosignals are visualized can affect feelings of closeness with one another. They explored the influence of different brain visualizations on impression formation and they found that visualization of light resulted in higher feelings of connection compared to other representations.

Another study (Liu et al., 2019b) demonstrated that presenting heart rate in a graph as opposed to through a text describing heart rate leads to higher levels of interpersonal closeness with a stigmatized other. They conclude that providing heart rate information increases awareness about someone's state and visualizing the changes in heart rate can improve the relationship with this person. So, sharing biosignals can improve closeness because it discloses intimate information about someone. However, it is important to be critical on how to convey biosignal information, since the intimacy is affected by how biosignals are presented.

4.5 Implications for Technology

Our results support and extend prior work by demonstrating that feedback about similar patterns of biosignals increase feelings of empathy and social connectedness compared to feedback about dissimilar patterns. This provides insight in how receiving feedback about similar biosignals can create a stronger connection between distant others, but also in how receiving feedback about non-similar biosignals can decrease feelings of empathy and connectedness. Receiving feedback about how a distant other reacts differently than oneself could create even more distance and people might feel even less connected compared to when they would not receive feedback. Thus, when implementing feedback about similarity of physiological patterns in online communication, it should be taken into account that dissimilar signals could drift people apart. Future research should compare the effect of feedback about (dis)similar signals to receiving no biosignal feedback on empathy and social connectedness, to establish possible negative effects of sharing (dis)similar signals. Furthermore, it could be that synchronization of physiological signals does not happen that often during online communication. Future studies should investigate the occurrence of synchronization in online communication and how feedback about this affects connectedness in different types of technology-mediated communication. To conclude, feedback about similar signals is promising in increasing connectedness, but the implementation of feedback about similarity of biosignals should be dealt with carefully as dissimilar signals might decrease connectedness and the occurrence of synchronization might not happen that often online.

We suggest that feedback about similar biosignals, when implemented correctly, can add value to interpersonal communication, by increasing emotional understanding between remote others. Our results are for instance relevant for online psychological treatment, as these sessions become more common, but practitioners are worried about online therapy being less empathic and socially connecting due to the absence of non-verbal cues (Stoll et al., 2020). Feedback about similar biosignals, serving as new expressive social cues, could be used to create more empathic interactions during online therapy sessions. Furthermore, our results encourage exploring the use of feedback about similar biosignals in other social settings, such as interactive games or remote collaborations. As the biosignal feedback used in our experiment was asynchronous, the results are also promising for communication forms having time delay between messages.

There are some important ethical and design considerations that need to be taken into account when working with such sensitive data, as biodata is. First, users' privacy should be prioritized, which entails that they should be able to give consent and be aware of with whom they share their biodata. As found in previous studies, users might be concerned about the intimacy and revealingness of this data; thus the user needs to have control of what they share and with whom they share their data (Feijt et al., 2021). In this study, for example, despite the data being fake, we explicitly asked the participant for consent to share their heart rate data with other participants. Furthermore, it is important to consider that users' beliefs about what biosignals reveal could be wrong. Merrill et al. (2019) investigated what people think biosensors can reveal about thoughts and feelings, finding that beliefs about biosensing technologies are shaped by what we believe our bodies can reveal. This results in a mismatch between what people believe a sensor can reveal and what it actually reveals, meaning that some devices seem more revealing than they are and others seem less revealing than they actually are (Merrill et al., 2019). For example, people believed that electroencephalography (EEG), or brain waves, was one of the most revealing biosignals, whilst in reality, EEG data is difficult to interpret. Conversely, a device such as GPS was believed to be less revealing (Merrill et al., 2019), whilst a study found a significant correlation between smartphone location traces and depressive moods (Canzian & Musolesi, 2015). Thus, designers of biosignal sharing systems should be cautious that their devices might come across as creepy and users should be aware that seemingly innocent devices might reveal more about their mental health and emotions than they would expect (Merrill et al., 2019). In addition, designers should inform the user well about what it means to share specific data and what it could potentially mean in the future. Next to this, because of the inherent ambiguity of biosignals users should be well informed about how to read and interpret biosignals.

4.6 Limitations

One limitation in the study is that the non-similar heart rate graph had only one peak labeled with an emotional moment of the video, whilst the similar heart rate graph had two peaks labeled with emotional moments of the video (see figure 1). This might have strengthened the effect, as the similar participant might have come across as more emotionally involved compared to the non-similar participant. As empathy is a process of understanding and responding to another person's emotions (Janssen et al., 2012), participants might have responded with more empathy towards the participant who seemed to have a more emotional reaction towards the video. Some responses indeed show that people thought the non-similar person was more stable and less affected by the video. However, other responses indicate that participants thought this person just had different feelings than they had. To avoid this confound, future studies should try to create graphs that despite being different have as much variation and have the same number of peaks labeled.

Another limitation is that some participants did not believe the simulated heart rate was theirs. A possible reason for this is that the fake HR presented to them as their own did not match with their emotional response. Another reason for participants not believing the fake heart rate was theirs is that people found it hard to believe that the heart rate data presented was measured via their webcam. In future studies, the credibility of the measurements could be improved by using more common technologies measuring heart rate, such as a wearable or another physical device. As mentioned before, another drawback of the heart rate data presented being fake is that the heart rate patterns might not have been a realistic representation of real PS.

Additionally, a number of participants figured out it was about whether they felt more connected with a person with a similar or non-similar heart rate. This could be due to the classical psychological experimental set-up of the study clearly including two conditions. Being exposed to both conditions makes it more likely for participants to notice what the real aim of the study is. Future studies could prevent this by using a between-subject design or by having multiple conditions with graphs varying in the degree of similarity.

However, having suspicions about the set-up or aim of the study did not seem to affect the outcomes. Despite that participants with suspicion gave lower scores on shared understandings the effect of similarity was still present.

The study was a controlled online experiment with a population mostly consisting of young college students. Controlling the experiment allowed us to manipulate the independent variables but created a setting that is unrealistic to encounter in real life. Future studies should consider using genuine feedback, field studies, and a more representative population.

Lastly, we chose to have the presumed other participants to be unknown to the participants, but often in online interactions people do know the other person, or at least see, know or hear more of them than only a heart rate signal. In reality, mediated communication involves a higher level of interaction. It is likely that this will lead to more feelings of empathy and connectedness, but further research should explore how the level of interaction and the relationship between people influences this effect.

5. Conclusion

To the best of our knowledge, the current study is the first study to demonstrate that receiving feedback depicting similar heart rate patterns compared to feedback depicting non-similar heart rate patterns increases empathy and social connectedness. As communication via the internet is often experienced as less emotionally connecting and impersonal (Baym, 2015; Moody, 2001), our results are particularly promising to facilitate closer connections via technology-mediated communication. However, in reality, people's physiological signals might not show such similar patterns as in our study and synchronization of signals during online interaction might not happen that often. Thus, future research should investigate the effect of feedback depicting (dis)similar biosignals on empathy and social connectedness with actual physiological data and in a natural setting. Finally, we hope that our results will contribute to the development of new online communication forms which connect people at a deeper physiological level and that this will ultimately lead to a more connected society.

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Appendices

Appendix A. Pilots

Before the start of the study, we ran two pilots. One shorter pilot, in which the aim was to find out if the manipulation of the similarity of the heart rate graphs was successful. The other pilot was a test run of the actual study, in which the aim was to find out if the study was comprehensible, if the cover story was believable, and if the participants would believe the heart rate graphs were their own.

Pilot 1: Similarity heart rate responses

In the first pilot, the heart rate responses were shown to five participants, after which short interviews were held to assess their evaluations. They were shown similar and non-similar conditions. Three participants were shown the similar heart rate response first and two were shown the non-similar heart rate responses first. They were first told that they should imagine that "Your Response" is their own heart rate response and that the other heart rate response is that of another participant. Then they were asked to speak about what comes to mind when seeing the heart rate responses. The pilot ended with asking the participants to rate the similarity.

Interestingly three participants responded to the similar condition that the other participant had kind of the same experience, but less intense, because their own response was higher. Only one participant understood that the other participant had probably a similar experience, but his/her resting heart rate was lower. All participants thought that the person with the non-similar response was less emotional. The results of this first pilot led to a few changes in the graphs. Since three participants thought that having a higher heart rate means having a more intense experience the researcher tried to reduce this effect by creating more overlap between the absolute values of the heart rate responses in the similar and non-similar condition. Another change made based on the reactions of participants was that a peak of the non- similar condition was also labelled with an emotional moment in the video. This is to show that the participant of the non-similar condition also shows reaction to emotional moments, but just to other emotional moments than the participant him/herself reacts to.

Pilot 2: Test run actual study

The second pilot was a test run of the actual study with additional interviews. The aim of this pilot was to optimize the final experiment, to check if there were any peculiarities within the study, to find out if the story and experiment were believable and the manipulations were successful. Ten people participated in the pilot and seven people were interviewed more elaborately afterwards. With the other three participants, there was text contact about their belief in the cover story. Six out of ten people believed the cover story and that their heart rate was theirs. Four participants had some doubts about the real aim of the study and if their heart rate was really theirs. Despite this moment of doubt they still assumed during the experiment it would be their heart rate feedback. These participants also suspected that the study was about the similarity of the signals. Therefore, we adapted the graphs to make them less obviously similar and non-similar. Furthermore, all participants thought the questions from the perspective of the other person were a bit odd and difficult to rate, as they did not even know if the other person knew of their existence. Therefore, it was decided that the questions which assumed the other participant would know at least something about the participant were altered into first-person questions. For example, "*Participant 5 really understood my feelings about this situation.",* became: *"I really understand the feelings of Participant 5 about this situation."*

Appendix B. Participant Instructions

Introduction to task part 1

From research, we know that our physiology is tightly linked to our mental states (Cacioppo, Tassinary, & Berntson, 2007). Think about blushing when you are embarrassed or your heart going faster when you are aroused. Thus, your physiology says something about the emotions you experience. By measuring and analyzing someone's physiological response, we can estimate that person's emotions. However, it is still unknown how good people are in estimating someone else's emotions based on biosignals. In this study we want to investigate how people interpret physiological responses of other persons to an emotional video clip. In order to do so, you will first watch the video clip yourself while video recording your face so we can derive your own heart rate response. Afterwards we will ask you some questions about your emotional experience and personal characteristics. To be able to derive your physiological responses while watching the video clip, we ask you to simultaneously record a video of your face using your webcam. The researcher will analyze the video using FaceReader software in order to extract your heart rate. Simply put, this analysis is based on subtle color changes in the face, using remote photoplethysmography (RPPG) techniques.

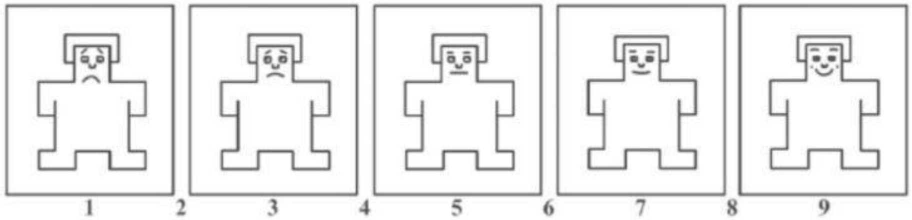
Introduction to task part 2

In the first part of the study, you watched a video clip and simultaneously recorded a video of your face. Afterwards, the researcher has analyzed this video using FaceReader software, which offers the opportunity to deduce the heart rate of a person based on color differences in the face. The heart rate signals of all other participants in this study were also extracted from their recordings in the exact same way.

Next, we will present to you the extracted heart rate signals. We would like to know how you estimate other participants' emotions based on their heart rate signals during the video clip. To give you an indication how a heart rate response can look like and how it is related to emotions, we will first show your own heart rate response. This can help by interpreting the other participants' emotions in the next part of the study, since you know how you felt while watching the video clip.

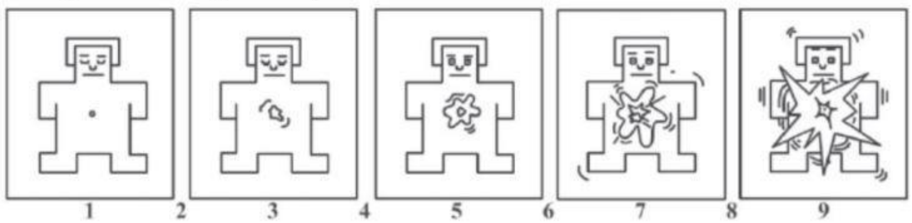
Appendix C. Self-Assessment Manikin

*Choose the picture that best depicts how (un)happy you felt while watching the video clip



	1 - Very unhappy	2	3	4	5	6	7	8	9 - Very happy

*Choose the picture that best depicts how active you felt while watching the video clip



	1 - Very calm	2	3	4	5	6	7	8	9 - Very excited

*The same measure was used to let the participant estimate the emotion of the other presumed participant with the accompanying sentence: "*Choose the picture that best depicts how (un)happy participant 5/17 felt while watching the film clip*"

Appendix D. Interpersonal Reactivity Index

1. I daydream and fantasize, with some regularity, about things that might happen to me. (FS)
2. I often have tender, concerned feelings for people less fortunate than me. (EC)
3. I sometimes find it difficult to see things from the "other guy's" point of view. (PT) (-)
4. Sometimes I don't feel very sorry for other people when they are having problems. (EC) (-)
5. I really get involved with the feelings of the characters in a novel. (FS)
6. In emergency situations, I feel apprehensive and ill-at-ease. (PD)
7. I am usually objective when I watch a movie or play, and I don't often get completely caught up in it. (FS) (-)
8. I try to look at everybody's side of a disagreement before I make a decision. (PT)
9. When I see someone being taken advantage of, I feel kind of protective towards them. (EC)
10. I sometimes feel helpless when I am in the middle of a very emotional situation. (PD)
11. I sometimes try to understand my friends better by imagining how things look from their perspective. (PT)

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12. Becoming extremely involved in a good book or movie is somewhat rare for me. (FS) (-)
13. When I see someone get hurt, I tend to remain calm. (PD) (-)
14. Other people's misfortunes do not usually disturb me a great deal. (EC) (-)
15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. (PT) (-)
16. After seeing a play or movie, I have felt as though I were one of the characters. (FS)
17. Being in a tense emotional situation scares me. (PD)
18. When I see someone being treated unfairly, I sometimes don't feel very much pity for them. (EC) (-)
19. I am usually pretty effective in dealing with emergencies. (PD) (-)
20. I am often quite touched by things that I see happen. (EC)
21. I believe that there are two sides to every question and try to look at them both. (PT)
22. I would describe myself as a pretty soft-hearted person. (EC)
23. When I watch a good movie, I can very easily put myself in the place of a leading character. (FS)
24. I tend to lose control during emergencies. (PD)

25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while. (PT)
26. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me. (FS)
27. When I see someone who badly needs help in an emergency, I go to pieces. (PD)
28. Before criticizing somebody, I try to imagine how I would feel if I were in their place. (PT)

Appendix E. Empathy Measure

I really understand the feelings of Participant 5 about this situation.

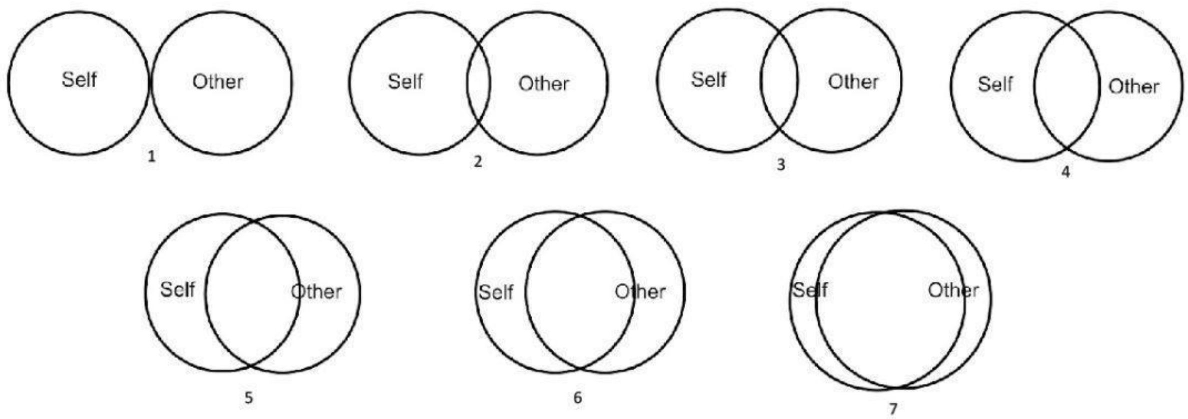
I feel as if I am on the same wavelength as participant 5.

I do not understand how Participant 5 thinks.

I can feel with Participant 5 in this situation.

Appendix F . Inclusion of Other in Self Scale

*Please choose the picture that best describes your relationship with participant 5



	1	2	3	4	5	6	7
	○	○	○	○	○	○	○

Appendix G. Knowing each others' experiences

I know what X feels in this situation.

I know what X thinks in this situation

I feel that X knows what I think in this situation

I sense that X knows what I feel in this situation

Appendix H. Shared Understandings

I feel that X and I share experiences.

I feel I have a lot in common with X

I feel on the same wavelength with X

Appendix I. Consent Form

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Information form for participants

This study is performed by Fenna Dam, a master student under the supervision of Milou Feijt, MSc, and Prof. Dr. Joyce Westerink of the Human-Technology Interaction group at Eindhoven University of Technology.

Before participating, you should understand the procedure followed in this study, and give your informed consent for voluntary participation. Please read this page carefully.

About this study

This study has the goal to measure how people estimate others' emotions based on heart rate feedback.

You will participate in this online experiment using your web browser. You must also have a webcam at your disposal. This study consists of two parts which are carried out with an intervening period of approximately two days. In the first part, you will be asked to watch a YouTube Video and simultaneously record a video of your face using the online recording tool: "Cam Recorder". This tool uses the built-in recording options in the browser, does not require any installation, and stores the recordings locally on your computer. This means that the recording will only be accessible to people with access to your computer. You can consult the terms and conditions using the following link: https://www.cam-recorder.com/contact. When the recording is finished, we will ask you to upload your face recording to a password-protected folder. Furthermore, some additional questions are asked in this first part of the study.

Afterwards, the researcher will analyze your physiological response using Face Reader software. Your heart rate while watching the YouTube video is derived from the recording of your face using Remote Photoplethysmography (RPPG) techniques.

In the second part of the study, your heart rate response and the heart rate response of other participants are presented to you. We will ask you to answer some questions about the heart rate responses.

This study will take 35 minutes to complete and does not involve any risks. The first part of the study takes about 20 minutes and the second part of the study takes about 15 minutes.

Voluntary Participation

Your participation is completely voluntary. You can stop participation at any time, but you will only receive your reward if you complete both questionnaires. You can also withdraw your permission to use your data up to 24 hours after completing this study. You will be paid €7,50 or you will receive 1 course credit (1 ects) if you complete this study.

Confidentiality and use, storage, and sharing of data

This study has been approved by the Ethical Review Board of Eindhoven University of Technology. In this study personal data (your age, gender, level of education, email address and participant database id) and experimental data (responses to questionnaires) will be stored. To protect your privacy, all data that can be used to personally identify you will be stored on an encrypted server of the Human Technology Interaction group for at least 10 years. The anonymized dataset that, to the best of our knowledge and ability will not contain information that can identify you, will also be stored on this server.

No information that can be used to personally identify you will be shared with others. The video recordings will not be distributed and will not be played back in the presence of people other than the researchers. The anonymized dataset will be used for scientific research and only be reported on a group level.

The data collected in this study might also be of relevance for future research projects within the Human Technology Interaction group. In any case, the video recordings will not be used for this purpose. This material will be deleted immediately after being analyzed.
The anonymized data set collected in this study and that will be released to the HTI data repository for future research will (to the best of our knowledge and ability) not contain information that can identify you. It will include all answers you provide during the study, including demographic variables (e.g., age and gender) if you choose to provide these during the study.

Further information
If you want more information about this study, the study design, or the results, you can contact Fenna Dam (contact email: f.s.dam@student.tue.nl). You can report irregularities related to scientific integrity to confidential advisors of the TU/e, whose contact information can be found on www.tue.nl.

Certificate of consent
By clicking on the I **do** button below I indicate that I have read and understood the study procedure, and I agree to voluntarily participate:

- ☐ I **do** provide consent to participate in this study
- ☐ I **do not** provide consent to participate in this study

By clicking on the I **do** button below I also give permission to make my anonymized data available to other researchers for future research projects within the Human-Technology Interaction Group:

- ☐ I **do** give permission to make my anonymized recorded data available for future research within the Human-Technology Interaction Group.
- ☐ I **do not** give permission to make my anonymized recorded data available for future research within the Human-Technology Interaction Group.

Appendix J. Answers to open questions

Answers to open questions about feelings of the presumed other participants

Answers Similar Condition

How do you think participant 5/17 was feeling while watching the video based on his/her heart rate feedback?

really calm, but reacts more heavily to the emotional parts

His heart rate seems to be generally increasing, with some noticeable peaks. This would mean that they felt increasingly more agitated/excited by the scene.

Less emotional than me generally, but more sensitive than me to the peaks that are appointed

A little less emotional it seems. The progression is pretty similar to mine except on a lower level

Participant 5 seems to have a lower normal heartrate, but shows the same peaks at the timestamps that have been highlighted by you guys. Since i did not really feel that sad i would say that participant 5 would have the same kind of response and not really feel that sad. If participant 5 actually were to be sad, i would have expected their heartrate to follow my own heartrate less and have more bursts at the given timestamps

probably quite similar. maybe a little less intense/touched

Sad for the boy

I think the participant was feeling rather sad.

Sad

A bit less active/sad.
Participant 5 was feeling relatively the same as me, experiencing emotion in an intense moment and then going back to the baseline. The trends in our heart rates follow the same pattern essentially.

their heart rates matches mine, but just a bit lower, so i think they were also feeling sad

less sad than I was, but he or she has more clear peaks

It is really similar to my heart rate, although is a bit lower, so it think respondent 5 was also inreasingly feeling sad

Less influenced by the movie

I think participant 5 is feeling waves of sadness, this started with the shock the participant got when the participant realised it was a scene in which someone close to the child died. after this the participant felt a wave of sadness to see the the child struggle with the idea that someone could wake his father. when the lady walked in the particpant felt normal, until the lady's ayes conveyed the message to the child in which the child realized the situation and the participant started feeling the sadness the child was experiencing.

Sad and tensed.

I think participant 5 had very similar feelings as I had. He felt sorry and had empathy for the child.

I believe participant 5 was feeling about the same way i was. A little sad but not too aroused

I see that this person also has a higher heart rate at the same times. at certain times this person also thought it was pathetic. But it's not that this person had high emotions all the time.

same as me

I think pretty much the same as me because the heart rate 'waves' look familiar. So I think participant 5 was sad about seeing the video but felt calm because we where standing stil.
I believe that there was a shock from the drastic start of the video at the beginning and then a feeling of sadness after realising what is the situation.

Similar to how I felt however a bit more at ease.

Pretty calm and normal

the participant's heart rate is very similar to mine, so they probably felt the same way. Which was a little sad but not that much affected by the video.

It seems that he was more relaxed then me, but still affected by the video

The overall pattern of our heart rates are quite similar. Peaks in approximately same place and near the end a gradually global increase. Assuming the person is not a psycopath, I think their emotions were similar to mine and they felt sadness.

It seems that the participant had the same reaction as mine, maybe a bit of sadness

I think the participant felt quite the same as I did since the response curves are very similar.

A bit the same as me, it grew more steady after looking at the video for a bit longer

I think he felt similar to me.

I think that the participant 5 also felt the same sad and grieving feelings that I felt, based on the similar peak trends during the key scenes in the movie clip.

almost the same as me. but more calm because his heart rate is lower than mine

Also touched by the boys' sadness.

around the same emotion intensity as me, but could be another emotion.

It seems that participant 5 experienced the video relatively in the same way i did.

It looks very similar to my own graph, so I'd guess they felt a similar sadness especially around the first peak.

Calm

Equal to me. I think this participant was sad for the child.

sad and emotional

sad

Participant 5 has very similar responses to mine. Overall it can be seen that participant 5 has a lower heart than me during almost the full duration of the clip. This may indicate that participant 5 was calmer than me and perhaps felt a little less emotional.

Is impacted in the same way, just has a slightly lower heart rate.

I think the same as I felt, the curves are rather similar. (I also have a hard time believing this person had completly different emotions about the clip than I, the clip was a pretty 'tranentrekker' - so I would find it weird he/she had way different feelings)

He was probably feeling a bit less intense the emotions.

Quite similar to me actually: uncomfortable, sad, aroused. What catches my attention is that on average, my heart beat has been higher all the time, but I have no explanation for that. The piques in the heart rate are comparable.

It overlaps mine in shape: having the first and biggest change in heart rate at the 'please wake up moment', heart rate gradually increasing as the video proceeds.
The response of P5 at the moment the child realizes his father is really dead is a bit more intense then mine, that maybe has to with that I already expected this moment in the video and it came more as a shock to P5.

I don't know, but I guess similar to me and participant 5

Probably pretty touched at certain scences, since there are more spikes, so sad, I assume

Sad

Was more relaxed at the beginning. Might have smiled too, just like me.

Was feeling and getting more and more emotional, there is a slight increase of overall heartrate from beginning to end.

They recognized the highlighted moments in a way that is similar to me. They probably felt sad and slightly emotional.

Maybe the same as me, a bit sad

Participant 17 has spikes for most of the emotional points in the video, which makes me believe that they were quite emotionally involved with the video and felt sad while watching.

The first and last peak of the participant really stand out from the other peaks, Therefore I think the participant was feeling emotional or actively involved with the clip which was shown. Or at least they felt an emotional shift.

the same as I but less intensive

Their heart rate feedback is much more similar to mine than that of participant 5, though overall their heartbeat tended to be lower (unless this was only moved down for visualization purposes). An overall lower heartbeat might not be a reflection of their emotional state, but rather just show that their baseline heartbeat tends to be lower. As such, I might presume them to have had a similar emotional experience as I did. They also had a peak when the child talked to his father, though the increase in heart rate was even greater than mine. This might suggest that they were not expecting themselves to get emotional.

He or she also felt sad at the same moments at me

I think participant 17 was going through the same feelings as I. Maybe a bit less compassionate. He was shocked at some times of the video clip and totally he was sad.

His/her emotional changes at 3 critical (saddest) point of the video so he/she may feel sad and moody while watching

Clearly shows spikes around the main events of the video (the ones mentioned with the arrows). So the participant must have felt sad as well during the video (especially during the spikes)

It is similar to my heartrate. Slightly sad

The participant might have felt sad at the heart rate peaks, maybe desperate too, because you don't want the father to be dead and the child to be sad. I think this participant was pretty excited (so not calm) because you see relatively high peaks.
Similar to me; emoted at important time stamps.

I think P17 was kind of similar to my own heart rate response. I feel like in the case of P17, they also felt strong emotions during the period where the strongest emotional parts apply (like the child realizing the father is no more).

Very similar, because this participant also responds with a higher heart rate at the same moments as me and
also shows an increased heart rate over time.

An emotional person when watching tearjerking movies, just like me...

The participant had similar reactions as me, feeling sorry for the boy in certain moments

very simular to how i was feeling, so sad.

Quite stable, with a few shocks

He/she was affected by the video

I seems that participant 17 was reacting to the emotional moments in the video.

With scene his/her heart rate was going higher. I think with a sad feeling he/she was taking deep breaths.

we share the exact same feeling and reaction throughout the video but he/she is calmer than i do and show less expression i guess.

The heart rate of participant 17 looks very similar to mine. I feel like this person felt very much for the child, explicitly on the specific moments.

Two clear peaks in the heart rate related to the highlighted fragments. This might indicate that the participant was touched by those fragments. Also, the heart beat increases during the video. This might indicate increase in emotions.

Feeling sadness and pain of child more

It seems he/she felt quite similar to me, also empathic towards the child in the video, although a bit less aroused

I think the participant was feeling sad also when she found out that the father was dead. As the lines are very similar I think the participant was experiencing similar emotions as I was experiencing.

I don't know, probably a bit sad or something

Slightly sad. Mostly neutral.

In this case the two heart rates are quite similar, almost identical. (S)he experienced negative emotions as I did, and we were mostly moved by the same things (this is what the similar peaks indicate). I can tell that this participant was emotionally connected in someway with the characters and felt the tragedy that they were experiencing.

More or less the same as me, I assume

Very similar; closer match than #5

17's heartrate was almost equal to mine, except a bit lower in value

Sad, but also calm.

sad, empathy

purely basing my answer on the exact same graphs I should say the same as I did

I think participant 17 was also very touched by the video, especially by the key moments in the video.

There are a lot of spikes in this heart rate feedback, which makes me think that participant 17 was very engaged in the video and feeling quite some emotions while watching

They had connected to the video clip just like i did

Somewhat the same as me, since we show similar spikes in heart rate

This is much more in line with my own experience of the video, than that with participan 5. Seeing this after the last participance I feel like my and participan 17 responded somewhat similar.

VERY similar to my heartrate, so probably felt the same emotions. A small spike in the main moments, but as I was not feeling very strong emotions, i feel this person did not either. Only big difference is my heart rate goes down in the first 30 seconds, and their's does not.

The graph looks a lot closer to mine than participant 5's graph. Since the highlighted moments caused the heartrate to go up, I think that the video affected the participant more than participant 5.

Answers non-similar condition

How do you think participant 5/17 was feeling while watching the video based on his/her heart rate feedback?

neutral and calm

This participant's heart rate seems to vary a lot, I'm actually not really sure how to interpret this. The first part did not surprise that person more than in general, while the middle part did and in the last their heart rate slowed down a lot. I think this person might've been bored at the end.

Their heart rate was lower, so probably more neutral. They got very different peaks from me, so they must be sensitive to different things.

It's weird how he doesn't respond to the start of the video. Maybe he didn't understand the situation and didn't feel sad because of it. Even less sentimental than me and participant 5

Man i'm really not sure. there a peak in their heartrate at a different timestamp than mine, but that really does not provide me with any more information to go off of. I'd say participant 17 was probably a bit bored or something as they do not have the peak at the first timestamp, which participant 5 and i both did have, but other than that i really cannot say anything sensible based on their heartrate.

i don't know

Bored

They were not very affected by the video, so i think they weer mostly feeling neutral.

Neutral

Not so sad about the video clip.

nonchalant. heart rate went down during a sad moment, but that could also mean that "their heart sunk" which I am not sure if it means a drop or rise in heart rate.’

i think they felt neutral

completely neutral

I think the participant was feeling things, however it is difficult to predict what exactly.

Even less influenced by the movie

i don't think the participant was feeling a lot while watching the video, perhaps he would have felt a bit of sadness when the child asked the others to wake him up. it even looks like that the did not faze the participant.

Stressed and agitated

I don't think the participant was really watching the video clip because his/her reaction don't align with the happening of the video.

more aroused than i was

This person has a higher heart rate at other times. I think this person got a lot of feeling at the beginning but it got less in the end.

does not feel connection with the characters

I really dont know, I think participant 17 had multiple feelings.

It looks as if this participant was not having too strong emotional response, maybe feeling neutral about the situation.

Less moved by the special moments.

Very neutral

It seems that participant 17 was not very much affected by the video. So their feelings were probably somewhat neutral.

Quite sad

There are some peaks, so I'm guessing emotions kicked in at these moments. Since it was a sad clip, I am assuming these emotions were sadness. There is also a clear momentarily decrease near the end, which I think is also a result of a strong emotion, which could still be sadness but I guess another type of sadness.

indiferrence compared to partecipant 5 and myself

I think this person had more neutral feelings towards the video as the curve is quite flat

Does not really feel the scene, but is very focussed on it.

I think he was feeling very neutral.

Looking at the overall hear rate feedback trendline, there is an upward going gradient, which might suggest feelings of anxiousness/worrisome. Furthermore, since the peak during the second scene is really pronounce ("Child asks Jackie to please wake his father up"), participant 17 really felt the situation as the child might be feeling, and then probably he understood gravity of the scene and therefore did not show more peak during further important scenes.

relatively the same over time. Probably not happy and calm

I think participant 17 was also touched by the emotions of the boy, though his hearth rate seems to decrease instead of increase.

sad – neutral

A bit more indifferent than me, except for the part where Jackie is asked to wake the childs father. The response seem less similar to mine, but they are clearly still affected by for example the second peak. I'm guessing they probably felt sad as well but just about different things.

Calm

I think the participant was less emotionally invested in the video, and I do not know how the participant felt. I assume sad.

less empathy

No idea

Participant 17 has very different heart rate responses compared to me, so I am not sure how he or she was feeling while watching this video. Based on the overall lower heart rate and fewer spikes I do think this participant might have felt less emotion/sympathetic towards the boy

On average stayed quite constant, does not vary as much

I think participant 17 was distracted. It doesnt seem to make an impact on participant 17

He was feeling even more emotionnal than the last participant and also more than me.

I find this one a bit harder. The person seems to respond very differently to emotions. However, I do think that the fact that his/her heartbeat drops instead of rises still means that the person experiences comparable emotions, yet just responds differently. I think this because this person has a rise in heartbeat where I had a decrease, which is at the moment that the child asks whether Jackie can wake up. So: a different physical reaction but comparable feelings.

The moment the child asks Jackie to please wake his father up is the biggest increase in the heart rate of P17. Very different from me. I think P17 might have felt a bit upset during the whole video and not per see increasingly upset during certain key moments. Her/his heartrate is a bit higher at the end of the video than at the beginning, meaning that P17 gradually felt more upset.

I would say a similar response to mine. Not too emotional, but a bit indiferent

Probably not very touched by the clip, not many spikes

He/She seems to be calm

Pretty calm, does this participant has a soul?

I think they were feeling pretty neutral and calm. Even at the critical moments, they did not spike up.
Participant 5 had a slower heart rate when watching video but still recognized one of the more emotional moments, while the other two highlights did not make much an impression on him.

Maybe a bit less involved or sad than me

I think participant 5 was feeling quite neutral based on the heart rate feedback

Pretty calm due to the stability of the heart rate and it being lower than my own. Also the participant did not really seem to react on certain phrases or events happening, which also gives the feeling the participant felt pretty calm whilst watching the video.

I think this participant was not much moved by the video

I think participant 5 was not very emotionally invested in the child, though the peak around the interaction with Jackie suggests that they were more easily invested with her. Perhaps the fact that she was an attractive woman played a role. Furthermore, their interest seemed to mostly drop off near the end, though they were slightly more excited when it was almost finished.

He felt a little less sad compared to me

I think he/she was feeling sad during while the child asked Jackie to pleas wake his father up. His/her overall emotion was maybe a bit compassionate than mine.

I think he was almost calm and probably unhappy when he watched the video clip.

It seems that I considered myself as the kid and my HR is increased when the kid was crying, but participant 5 considered himself as jakkie or at least he shocked when the kid was asking for help.

His/her emotion is quite stable, changes when realizing the father is dead, and maybe feeling blank towards the end of the video

Pretty calm or normal. There's a slight spike when the child asks Jackie to wake his father up.

I see that during 80th second, the participant really got sad, and he anticipated (spike in heart rate) something good to happen for the child. At the 124th second, the participant also got a confirmation that the father is dead. So, he is really sad.

I think this participant was feeling more neutral and was not very excited about the video. However, I wouldn't know how to explain the peak at the point where the child asks Jackie to wake his father up. Maybe the participant felt with the child as he/she/they might have thought that at this point the child becomes more desperate.

Quite stable

I think participant 5 felt more emotion during the part when the kid asks jackie to wake his father up. I also feel like participant 5 was not majorly influenced by the strongly emotional scenes.

Also emotional based on the peak at arrow number two, but has an easier time of letting go of those feelings

Keeping strong, I guess. However when child asks father to wake up, he shows his true emotions.

The participant looked more neutral and felt more when the little boy was asking for help.
i think participant 5 was sad and emotionaly affected.

Quite uncalm, because there are a lot of peaks and valleys.

Calm, not really affected by the video

It seems that participant 5 had a lower response at the crucial moments on the video. It seems that he was calmer and not as emotional.

The opening of the scene has got attached to the participant. He/she has a pattern of deep breaths during the scenes (broader peaks). The participant is emotional while watching the video.

i think we have the heartdrop in a different part of the video, i would assume they already know the story or what's coming in the beginning so they felt worse/touched when the child asks jackie to wake his father up. also even their high wasnt as high as mine.

It looks like participants felt the most for the child the moment he asks Jackie to wake up his father.
In the first and third "moments" his or her heartbeat dropped. It seems like a reaction to the scene. But there are several moments that there are drops in his heart rate, so it does not seem that these moments did more or less to him or her compared to the other moments in the video.

There is one clear peak when the child asks Jackie to please wake his father up. This seems to show that the participant is affected by this. In the remainder of the measurement the heart rate of this participant is quite stable, so he/she seems not to be affected that much.

He still felt the pain of the child but not as much

It seems the participant was rather unfazed by the video, or more at peace
Since the average heart-rate feedback of this participant is a bit lower I think he/she was a bit more relaxed while watching the video. Also, the heart rate of participant five shows a clear peak when the child asked Jackie so the participant probably did feel sad at that moment.

I don't know

More neutral. The overall base rate is lower. Maybe this suggest less emotional investment, or just a lower heart rate. The heart rate does not seem to gradually go up during the video, so i think less emotionally investment.

The difference between the two heart rates is surprisingly intense. A much more stable heart rate is depicted with fewer peaks than mine. What this tells me is that apparently, (s)he was more emotionally stable compared to me during the video, and the small number of peaks, as well as the fact that they are not that sharp, means that even though at some points (s)he was moved a little bit by an act/saying, it wasn't that strong.

Apparently less than me since there aren't that many apparent peaks

He/she has a better heart :-) Seems to be less affected

a bit more stable then I was during watching

Somewhat calmer, but without knowing his/her standard heart rate, there is not really a way to tell.

sad, but not overcome with sadness

Indifferent

I think participant 5 was less touched by the video, because his hart rate is more constant. Only the one peak where the child asks Jackie to wake his father up, i think was a touching moment for him.

The heart rate is quite varies quite a lot over time, which would make me think that they were also feeling some kind of emotion. My guess would be that this would also be a sad emotion based on the content of the video

The person was not that much emotionally connected to the clip like i did.

I think he was feeling pretty calm, since his heart rate does not really make big spikes

I personally felt pretty calm, and this person has a lower heart rate, and during the video the average did not raise a lot. So I think this person felt pretty calm as well.

It looks like this participant was feeling even more neutral as it stays very constant. and that they were most strongly reacting to the child asking jackie to wake his father up.

The graph goes down at 2 of the highlighted moments, in comparison to my own heartrate. However it spikes more at the second highlighted moment. Overall the graph is more flat, however I don't know what to make of this and cant reasonably assume his feelings based on this. Maybe slightly less active?