Comparing the effects of biosignal-similarity feedback and personality-similarity feedback on empathy and social connectedness

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Comparing the effects of biosignal-similarity feedback and personality-similarity feedback on empathy and social connectedness

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Abstract

Nowadays, people rely much on technology-mediated communication to remotely interact with others. However, compared to offline communication, insufficient nonverbal cues (e.g., eye contact and touch) in online communication could decrease affective feelings (e.g., empathy and connectedness) and accordingly undermine interpersonal relationships. Recent studies found the potential of conveying similar biosignals (e.g., heart rate and skin conductance) as social cues to enhance empathy and social connectedness within dyads (Feijt, de Kort, Westerink, Okel, & IJsselsteijn, 2020; Dam, 2021). Similarly, earlier research reported that simulated feedback about a similarity in personality could increase empathy (Wróbel, Królewiak, & Czarna, 2015). It is still unknown whether the effects of biosignal feedback on subjective feelings were specific enough to make similar biofeedback eligible as a novel cue in remote communication. Regarding this issue, the present study compares the effects of feedback about biosignal similarity on empathy and social connectedness and the effects of feedback about the similarity in personality traits. A two-session study consisting of a lab experiment and an online survey is performed. Each participant was provided with four fixed figures presenting simulated feedback about presumed 'other four participants' with a similar heart rate, dissimilar heart rate, similar personality, and dissimilar personality. The results illustrated significant main effects of the level (similar vs dissimilar) and the type (biosignals vs personality) of similarity. No interaction effects were found between the effects of the two types of similarities. The study evidences the promising potential of implementing biosignals (which do not have to be similar ones) in technology-mediated communication to promote social interaction.

Keywords: biosignals, similarity, personality, empathy, social connectedness, comparison

Contents

1 Introduction

In this digital age, technology-mediated communication (e.g., audio/video conferencing) is essential for us as it meets our needs for remote interaction. It is widely applied in our daily life, and people even rely more heavily on it during the COVID-19 pandemic (Feldmann et al., 2021). However, online communication conveys fewer nonverbal cues (e.g., eye gaze, body posture) than offline communication (Baym, 2015). Compared to verbal cues, nonverbal cues are considered very important for emotional understanding and thus affect people's interpretation of the information about each other in interpersonal interaction (Lamichhane, 2016). Nonverbal communication behaviors are vital to delivering emotional messages. Since understanding the emotions of each other is fundamental to meaningful interpersonal relationships, a lack of nonverbal communication could lead to fewer affective experiences like connectedness, empathy, and liking (Venter, 2017). Hence, with the increased use of technology-mediated communication nowadays, it becomes crucial to develop technologies that portray more nonverbal messages and so support people in establishing satisfying online communication.

Biosignals, also known as physiological signals/parameters, are biological signals that can be continuously measured, such as heart rate (HR), skin conductance responses, and body temperature (Kaniusas, 2012). The changes in biosignals are closely related to our psychological states (Cacioppo, Tassinary, & Berntson, 2007). For example, people's hearts tend to beat fast when they are excited. Therefore, showing biosignals of a person can reveal some information about that one's emotional state (Cacioppo et al., 2007). With the development of wearable technology and the prevalence of wearable devices (e.g., fitness bracelets, breast straps, smartwatches), it has become possible for people nowadays to record and share (only when they give informed consent) their real-time biosignals with others. One way in which this could be

applied would be to include biosignal feedback as an additional nonverbal cue in online interpersonal interaction to help people understand their emotions toward each other.

Recent research found that perceiving simulated feedback about biosignal similarity with another person relates to feelings of empathy and social connectedness with that other (Feijt et al., 2020; Dam, 2021). The findings inspired us to extend the scope of traditional nonverbal cues and make use of other personal data to facilitate technology-mediated communication. Based on its influences on how people feel about each other, we could thereby regard biosignals as potential social cues for future interpersonal communication. Nevertheless, it is still unknown if the perceived similarity of biosignals specifically causes people's enhanced empathy and social connectedness toward each other. In other words, it could be the case that people tend to equally have these 'special' feelings when they receive any types of similar information. For example, previous research by Wróbel et al. (2015) found that the simulated feedback about the similarity in personality increased people's liking and empathetic feelings toward each other. Similar findings were even reported in more random characteristics (e.g., fingerprint, birthday): another study found that people indicated increased compliance when they were presented with bogus feedback about similar characteristics to others' (Burger, Messian, Patel, Del Prado, & Anderson, 2004). Although different kinds of emotional feelings like empathy, social connectedness, liking, and compliance were investigated in different studies, it seems possible that presenting fake feedback about the similarity of other characteristics (e.g., personality, fingerprint, birthday) to people can also improve online communication. Therefore, in order to be able to deploy the promising potential of physiological similarity feedback in technology-mediated communication, our study aims to compare the effects of other types of similarity feedback with that of biosignal similarity feedback. In this chapter, we will first provide

background on empathy and social connectedness, as well as on perceived similarity of physiological signals and personality, before we will describe our research questions in more detail.

1.1 Empathy

The appearance of the term "empathy" can be traced back to a century ago – it was first translated from the German word "Einfühlung" by the psychologist Edward Titchener in 1909 (Stueber, 2019). Regarding the definition of empathy, it varies among different studies, and there is still no consensus about it (Elliott, Bohart, Watson, & Greenberg, 2011; Hall & Schwartz, 2019). It can be summarized as the process of understanding or experiencing the natural states of others. Usually, the word is vividly described as the capacity to "put oneself into another's shoes" (Ioannidou & Konstantikaki, 2008). Despite debates over the definition, there is a general opinion on three main elements of empathy: cognitive empathy, emotional convergence, and empathic responding (Janssen, 2012). According to Janssen (2012), cognitive empathy entails knowing what another person is feeling. It involves two steps: first, being aware of the feeling and then finding out its origin. Cognitive empathy is closely related to empathic accuracy (Janssen, 2012), whether we correctly tell why another person has a certain feeling. Emotional convergence happens when a person can experience another person's emotional state, which relates to automatic emotional mimicry (i.e., imitating others' emotional behaviors like facial expressions) (Janssen, 2012). The third component of empathy is empathic responding, an intention to make compassionate responses to what another person is feeling, which can be regarded as a behavior showing sympathy, referring to "the act or capacity of entering into or sharing the feelings of another" (Decety & Jackson, 2004; Janssen, 2012; Aring, 1958).

As a vital concept, empathy has been researched in interpersonal interaction and human well-being in multiple disciplines (e.g., psychology, neuroscience) (Hall & Schwartz, 2019). For instance, patients declared to be more satisfied and have better patient-clinician relationships when they felt the clinician empathized with them (Montague, Chen, Xu, Chewning, & Barrett, 2013). Perceiving empathy and receiving empathetic responses from another individual can change our attitude toward that person and subsequently influence our emotional experience. In addition, empathy is associated with the psychological state: happier people were found to be more empathetic (Thomas et al., 2007; Bourgault et al., 2015). Also, people are more likely to prefer communications that involve more empathetic interaction as they can feel more happiness and satisfaction (Montague et al., 2013). As empathy plays such an important role in interpersonal interaction, it is worthwhile to investigate empathy in order to support the quality of technology-mediated communication.

1.2 Social connectedness

As humans are "social animals", constructing connectedness with others is an essential need for human beings (Townsend & McWhirter, 2005). Social connectedness is defined as "the experience of belonging and relatedness between people" (Van Bel, Smolders, Ijsselsteijn, & de Kort, 2009a). This sense of belonging with the feeling of closeness could result from successful interaction (Lee & Robbins, 2000; Van Bel, Ijsselsteijn & de Kort, 2008). In other words, there are relations among the quality of interaction, a sense of belonging, and perceived social connectedness. Besides, social connectedness is also strongly related to the feeling of loneliness (Jose & Lim, 2014) and mental health (Seppala, Rossomando, & Doty, 2013). To be specific, high social connectedness is related to less loneliness but more happiness. Therefore, it is not surprising that many people declared to suffer from isolation and even depression during the

pandemic, as it was much harder to socially connect when lockdown measures were in place (Salari et al., 2020). On the other hand, these complaints also reflect the limitation of the existing technology-mediated communication, that is, it cannot sufficiently facilitate the perceived social connectedness. So, investigating how online mediated communication can increase social connectedness could support human well-being.

1.3 Psychophysiological Synchronization (PS)

Psychophysiological synchronization (PS) refers to the synchrony in physiological signals (e.g., in heart rate and skin conductance responses) of two or more people. It is also known as physiological synchronization, physiological synchrony, physiological linkage, physiological coherence, and physiological covariation (Palumbo et al., 2016).

The benefits of PS have been found in different fields. According to previous studies, higher PS was related to better cooperation (Behrens et al., 2020; Romero-Martínez, Rodríguez, & Moya-Albiol, 2019). Researchers found that people performed better in teamwork when their physiological signals were highly aligned. Besides, they also found that in better cooperation, people had more similar physiological signals. Higher synchronized physiological signals are linked to stronger empathetic feelings within dyads (Prochazkova & Kret, 2017; Weber & Quiring, 2019). As understanding the emotions of each other is fundamental to effective communication (Venter, 2017), PS has become a meaningful concept for enhancing positive interpersonal interaction (Palumbo et al., 2016). Indicating the relationship between physiology and psychology, the application of PS is worth considering in social interaction. The favorable impacts of PS on human communications could be expected.

1.4 Perceived similarity

Prior research found that the perceived similarity between oneself and others could positively affect subjective experiences like social connectedness and empathy (Seppala et al., 2013; Batson, Lishner, Cook, & Sawyer, 2005). The findings implied the possibility of using simulated feedback to investigate the effects of similarity. Similarities can be presented and perceived on various attributes, such as similarity in personality, physiology, and even incidental aspects like shared birthdays or fingerprints. These similarities do not have to be naturally present. Studies found that when people are provided with even bogus information about these similarities, they will feel "something special" about each other, which was explicitly mentioned as increased liking, increased compliance, more connectedness, and more empathy (e.g., Wróbel et al., 2015; Dam, 2021; Feijt et al., 2020; Burger et al., 2004).

1.4.1 Biosignal similarity

According to a laboratory experiment by Salminen et al. (2019), researchers found that compared to receiving no biofeedback, people perceived higher levels of empathy when provided with biofeedback, regardless of whether the feedback was about similar or dissimilar biosignals. Although investigating feedback about biosignal similarity is a relatively new research field, a recent exploratory study by Dam (2021) found large effects that informing people of the similarity in biosignals can increase social connectedness and empathy (social connectedness: $d = 1.54$, empathy: $d = 1.24$). In the study, participants watched a video and received simulated heart rate feedback about themselves and of another participant on the video. They were presented with two conditions, one presenting a heart rate trace of the other participant that was similar to their own trace, and the other presenting a dissimilar heart rate trace. The results showed that people had more perceived empathy and social connectedness in a

similar condition than in a dissimilar condition. Similar results were reported in an earlier study by Feijt et al. (2020). In the study, researchers pretended to record the participants' skin conductance and then provided them with either the (bogus) highly or slightly synchronized biosignals with a confederate. As a result, people receiving high synchronization feedback indicated higher empathy and social connectedness about the confederate than those receiving the lower synchronization feedback.

1.4.2 Other types of similarity

As mentioned above, many other types of similarities have been found to be related to interpersonal feelings. We will discuss several situations in which bogus feedback about other similarities resulted in significant changes in affection and attitude.

For instance, Wróbel and colleagues (2015) found that the perceived personality similarity within dyads had a moderate effect on affective experience (d = 0.68). Their study used an emotional movie to evoke emotions, and feedback about the personality similarity was manipulated before sending it to the participants. The results showed that happy people tended to be happier after being exposed to a happy sender with simulated similar personality traits. When exposed to a similar but sad sender, people experienced less happiness. It appeared that people with positive emotions would shift their emotions in the direction of a similar person's (i.e., the one who was believed to have similar personality traits) emotions.

In terms of the similarity in more incidental aspects like names, birthdays or fingerprints, previous research found that providing people with feedback about this kind of similarity also contributed to developing positive attitudes toward others (Burger et al., 2004). When perceiving high incidental similarities such as same first names, shared birthdays, and similar fingerprints, people were more likely to be convinced by that similar person who actually did not exist.

1.5 The present study

The present research aims to compare the effects of feedback about biosignal similarity found in recent studies and the effects of feedback about other similarities found in previous studies on interpersonal interaction. Recent findings regarding the effects of biosignal similarity feedback by Dam (2021) evoke our curiosity about how the strength of these effects compares to those of feedback about other kinds of similarities. It is still unknown whether people have different responses when receiving feedback about different kinds of similarities. People may tend to "feel something different" when they are informed about any similarity between them and another person. Thus, several questions were raised: whether it is feedback about biosignal similarity in specific has this effect, whether feedback about any similarity would have this effect, and how do they compare to each other?

1.5.1 Choices regarding the presentation of similarity

In order to achieve our research goal, we had to make several decisions about a specific biosignal applied to the biosignal similarity, a specific "another characteristic", and feedback about people's own data.

Heart rate vs skin conductance response

In previous studies, two types of biosignals were used: heart rate and skin conductance responses. In order to make a selection, a pilot (see Appendix A) was carried out. Compared to skin conductance response traces, heart rate traces had much more variances (i.e., ups and downs), making it easier to identify the changes in heart rate responses. Moreover, participants were confused about the skin conductance response during the measurement as they had never

heard about it. In contrast, everyone mentioned that heart rate was familiar to them. Therefore, heart rate was selected as the biosignal to manipulate in the study.

Personality vs random characteristics

As the present study aims to compare the effects of presenting biosignal similarity to presenting another similarity, a choice had to be made on which kind of "another similarity" we should use. Compared to totally random characteristics like fingerprints, personality reveals more personal information as it is an essential psychological characteristic. In addition, as our cover story conceives that the study aimed at how people derive emotions based on specific traits, personality is a more scientific choice as it was known to be related to affection (Revelle & Scherer, 2009).

Although only the simulated feedback was used in the study, easy manipulation and presentation were also important arguments to select "another characteristic". In order to avoid potential confounding in the comparison, we tried to ensure that the participants would not be able to check the authenticity of the presented feedback. For example, if we chose to present feedback about fingerprint similarity, it would be too easy for people to check the feedback by directly looking at their fingers. Thus, we did not consider using fingerprints as "another characteristic". Personality traits are usually obtained based on particular measurements (e.g., personality questionnaire), which makes it possible to manipulate the similarity of personality.

Real feedback vs simulated feedback

In the test run (see Appendix A), we tried to present each person with his own HR trace but were unsuccessful in implementing a trustworthy algorithm that would calculate a reliable similar or dissimilar signal based on this. Therefore, we decided to send fixed feedback (i.e., all

participants received the same feedback, and both “your own” feedback and “another participant’s” feedback was simulated) to participants.

1.5.2 Research question and hypotheses

After making the necessary choices, we finally specified the question we wanted to investigate: will people have different feelings about empathy and connectedness when receiving feedback about biosignal similarity compared to feedback about the similarity in personality? To explore the potential differences between these effects, we defined the research question as follows:

What are the differences between the effect of feedback about biosignal similarity on empathy and social connectedness compared to feedback about the similarity in personality attributes?

From the papers mentioned above (Wróbel et al., 2015; Dam, 2021), we found the corresponding effect size of each type of similarity: biosignal similarity (d = 1.24); personality similarity (d = 0.68). Based on this data, two hypotheses come as follows:

H1: The effect of feedback about biosignal similarity on empathy is larger than that of feedback about the similarity in personality attributes.

H2: The effect of feedback about biosignal similarity on social connectedness is larger than that of feedback about the similarity in personality attributes.

By investigating the differences between the effects of the similarity on biosignals and other attributes, we would like to explore the potential of applying biosignal sharing to technology-mediated communication. Further, we expect the findings might shed some light on

including biosignals as nonverbal cues during online conversations to increase the perceived emotional understandings and ultimately improve the quality of remote interpersonal interaction.

2 Method

2.1 Design

The study consisted of a 2 x 2 within-group design. The two independent variables of the feedback given were attribute type (personality vs heart rate feedback) and the similarity level of the feedback (similar vs dissimilar). The dependent variables were empathy and social connectedness. The study included two sessions, the first one being a lab experiment and the second one an online survey. Between the two sessions, there was an interval of two days.

2.2 Participants

56 Participants were recruited from the JFS database from the Human Technology Interaction Group at the Technical University in Eindhoven (TU/e). Among them were 28 females, 26 males, and two persons preferring not to say. Their ages ranged from 18 to 77 (M = 27.60, SD = 15.11), with one person who preferred not to indicate the age. The education level of the participants also varied: most of them had obtained a high school degree (41.1%), and the rest had either HBO (7.1%), Bachelor's (26.8%) or Master's (25%) degree.

We calculated a required sample size of 55 using G*Power 3.1. In G*Power, we used the t-test for dependent means (matched pairs), first to calculate an expected effect size. The calculation was based on the mean difference between the effects of feedback about similar vs dissimilar biosignals found in Dam's study (2021) and the expected mean difference for feedback about similar vs dissimilar personalities based on the reported effect size of Wróbel et al. (2015). Furthermore, the SDs and correlation between similar and dissimilar groups found by Dam (2021) were included. The result was d = 0.51, which resulted in a small sample size. Research showed that effect sizes tend to be smaller in replication studies (Brysbaert & Stevens,

2018). Hence, instead of the calculated effect size of 0.51, we chose a slightly more tentative effect size of 0.4, which was lower than the ones found in previous studies (personality similarity: $d = 0.68$; biosignal similarity: $d = 1.24$). Inserting the effect size of 0.4 with the one-tailed option and the desired power of 0.90, we calculated the sample size of 55. However, in order to allow counterbalanced groups of the same size, eventually 56 participants were recruited.

2.3 Cover story

To ensure that the participants would not know about the real objective of the study, we created a cover story. In the experiment, the participants were told that the study aimed to estimate other participants' emotions based on physiological or psychological characteristics. To make the cover story more credible, we included the Self-Assessment Manikin (SAM) (Bradley & Lang, 1994) and open questions about their subjective emotional experience (Dam, 2021) in the survey. Also, to make the participants believe that they would indeed receive feedback on their own and other participants' data, they were asked to wear heart rate sensors to measure their heart rate while watching an emotional movie clip and then fill in a personality questionnaire during the first session in the lab. Both the measured heart rate and the personality were not analyzed but used to increase the credibility of the cover story.

2.4 Stimulus materials

2.4.1 Mobi-8 device

TMSi-Mobi (TMSi, n.d.) device (see Figure 1), owned by the Human Technology Interaction group of the IE&IS department at the TU/e, was used to measure the heart rate in the lab experiment. The device was connected to a Mobi laptop via Bluetooth. The Phylo (software

to acquire physiological data from Mobi devices (Boschman, 2017)) and HRMonitor (software to calculate heart rate (Boschman, 2018)) applications were run on the Mobi laptop. The measured heart rates were not analyzed after the experiment.

Figure 1. The Mobi8 device with the marker button.

2.4.2 Online questionnaires

In both experiment sessions, Limesurvey was used as a survey platform, and an encrypted Research Drive was used to store anonymized data.

Personality questionnaire

A 15-item personality questionnaire (Short Big Five Inventory, Soto & John, 2017) was used to measure the personality and thus obtain the personality profile of the participants (see Appendix B). All items were rated on a 5-point Likert scale ranging from 1 (completely disagree) to 5 (completely agree). The personality questionnaire results were not analyzed. Similar to the purpose of heart rate measurement, we included this questionnaire only to increase the credibility of the cover story.

2.4.3 Emotional video

A pilot (see Appendix A) was conducted to select a proper movie clip to be presented to experience emotions, and we found that the fragment from the movie “The Champ” evoked the most emotions. Consequently, this movie clip was selected. It also makes our study more comparable to previous studies that used the same movie fragment (Dam, 2021; Feijt et al., 2020).

The video prepared for the experiment consisted of two parts, the first part showing an aquarium with soothing music and the second part extracted from “The Champ” about a boy crying for his dead father. Between the two parts and after the movie clip ends, some instructions were shown on the screen to remind the participants to press the marker button on the MOBI device (see Figure 1).

2.4.4 Simulated feedback

Simulated feedback was presented in four conditions: similar personality feedback (i.e., the feedback illustrated a personality profile of another participant that was similar to the personality profile of the participant), dissimilar personality (i.e., the feedback illustrated a personality profile of another participant that was dissimilar to the personality profile of the participant), similar heart rate (i.e., the feedback illustrated a heart rate trace of another participant that was similar to the personality profile of the participant), and dissimilar heart rate (i.e., the feedback illustrated heart rate trace of another participant that was dissimilar to the personality profile of the participant). The figure used in each condition was fixed, so each participant received the same feedback.

Simulated personality profile

Each participant's personality questionnaire results were presented in a spider chart, of which the dimensions follow the Big Five personality traits (i.e., extraversion, agreeableness, openness, conscientiousness, and neuroticism), and each trait corresponds to three items in the questionnaire. For the feedback about personality, two personality charts created in the pilot (see Appendix A) were presented (see Figure 2). One included a personality score similar to their own (which was shown in the background as a reference), and the other included a dissimilar personality score (again, with their own in the background). All the three personality results, "your personality score", "personality score of Participant 12", and "personality score of Participant 10", were presented in fixed figures.

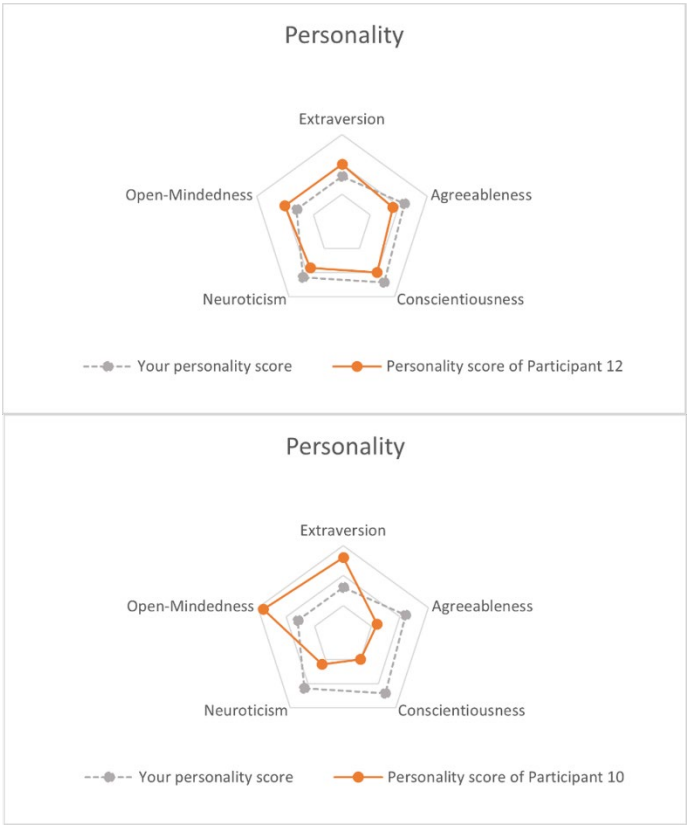

Figure 2. The personality profile – similar condition (the upper graph) and the dissimilar condition (the lower graph).

Simulated heart rate trace

To present the feedback about biosignals, we used two graphs created by Dam (2021) in her study. Both figures included “your response” in the background as a reference. One included a heart rate trace similar to the “your response” trace, and the other contained a dissimilar heart rate trace (see Figure 3). However, all the three heart rate traces, “your response”, “response of Participant 5”, and “response of Participant 17”, were indeed fake and generated based on Dam’s heart rate while watching an emotional movie clip.

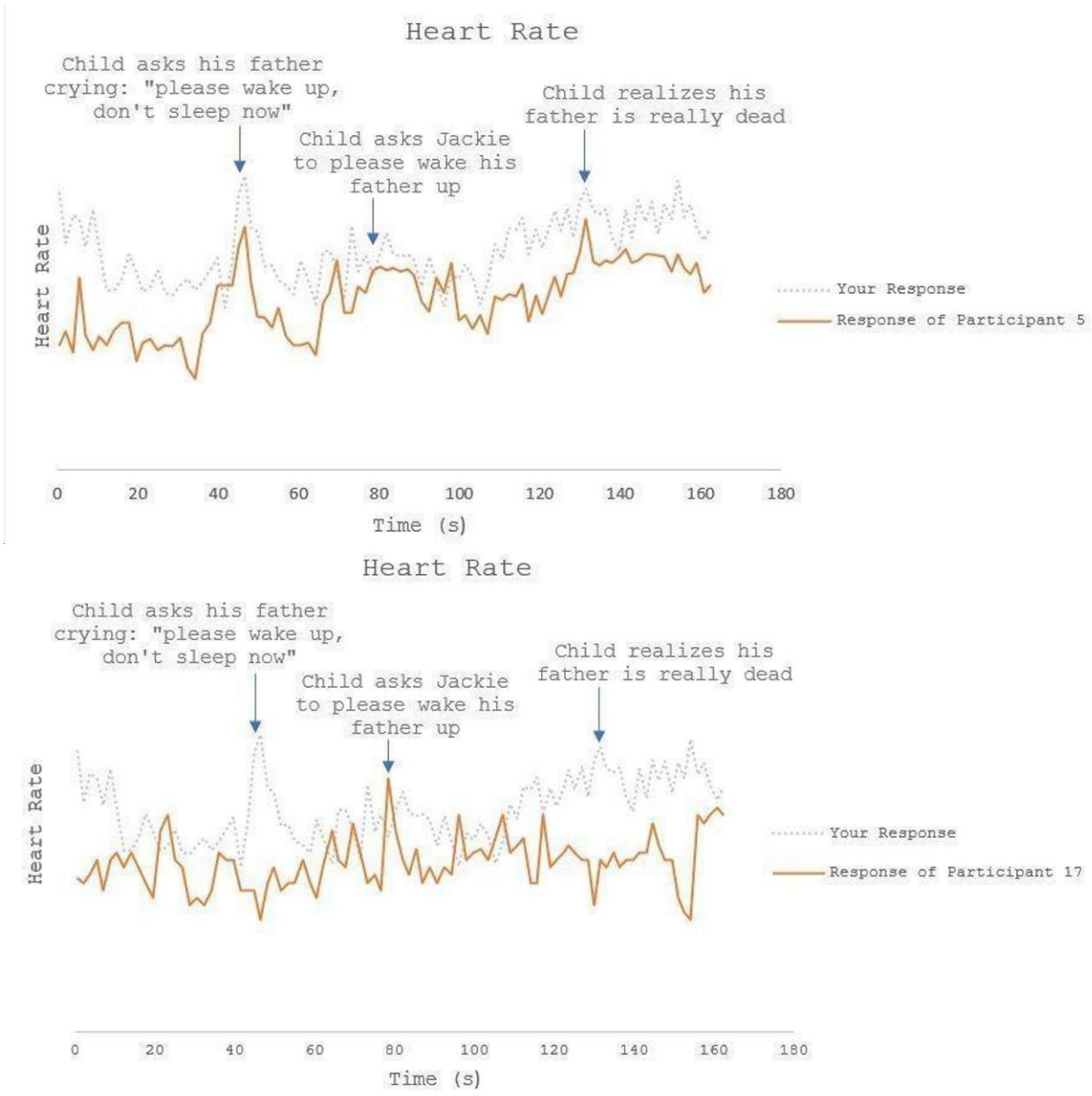

Figure 3. The heart rate responses – similar condition (the upper graph) and the dissimilar condition (the lower graph).

2.5 Measurements

2.5.1 Perceived similarity

To check if the manipulation of the similarity level was successful, we asked participants to rate the similarity between the feedback about their own responses and that of the other participants. An example is: “Please rate the similarity between your heart rate response and that of Participant 17.” The item was rated on a scale from 1 (very different) to 5 (very similar).

2.5.2 Empathy

Following the previous study (Dam, 2021; Feijt et al., 2020), four items were used to measure perceived empathy (See Appendix C). An example is: “I really understand the feelings of Participant 5 about this situation.” All items were rated on a 5-point Likert scale ranging from 1 (completely disagree) to 5 (completely agree).

2.5.3 Social connectedness

Following the previous study by Dam (2021), the perceived social connectedness was measured via three subscales, Shared understandings, Knowing each others’ experiences (Van Bel et al., 2009b) and the Inclusion of Other in Self Scale (IOS).

Shared understandings

Three items were used to measure social connectedness in terms of “Shared understandings” (See Appendix D). An example is: “I feel that Participant 5 and I share experiences.” (Van Bel et al. 2009a). All items were rated on a 7-point Likert scale ranging from 1 (completely disagree) to 7 (completely agree).

Knowing each others’ experiences

Four items were used to measure social connectedness in terms of "Knowing each others' experiences" (See Appendix D). An example is: "I know what Participant 5 feels in this situation." (Van Bel et al. 2009b). All items were rated on a 7-point Likert scale ranging from 1 (completely disagree) to 7 (completely agree).

IOS

The IOS was used to measure social connectedness in terms of the feelings of closeness (Van Bel et al., 2009a) (See Appendix D). Presented with seven Venn diagram-like circle pairs (one circle represents "self" while the other represents "other"), the scale correspondingly ranges from 1 to 7 (Aron, Aron, & Smollan, 1952).

2.5.4 Emotion

The Self-Assessment Manikin (SAM) (Bradley & Lang, 1994) (see Appendix E) was used to measure the emotion of participants. Removing one dimension "dominance" that was not applicable to this study, only "valence" and "arousal level" were assessed. Both dimensions were presented with figures. The figure of the valence dimension showed an unhappy face to a happy face, with the corresponding scale from 1 (very unhappy) to 9 (very happy). The figure of the arousal dimension showed a calm face to an excited face, with the corresponding scale from 1 (very calm) to 9 (very excited). As the SAM was only included to support the cover story, the results were not analyzed.

2.6 Procedure

Figure 4 shows an overview of the procedure. The study includes two parts. In the first part, participants' heart rate was measured while watching a video, after which they completed a personality questionnaire. In the second part, they filled in a survey about the presented

personality profiles and heart rate responses of 'other participants'. Considering that four conditions could be presented in eight sequences, we made eight equal groups to counterbalance the conditions. Subsequently, participants were assigned randomly to these groups.

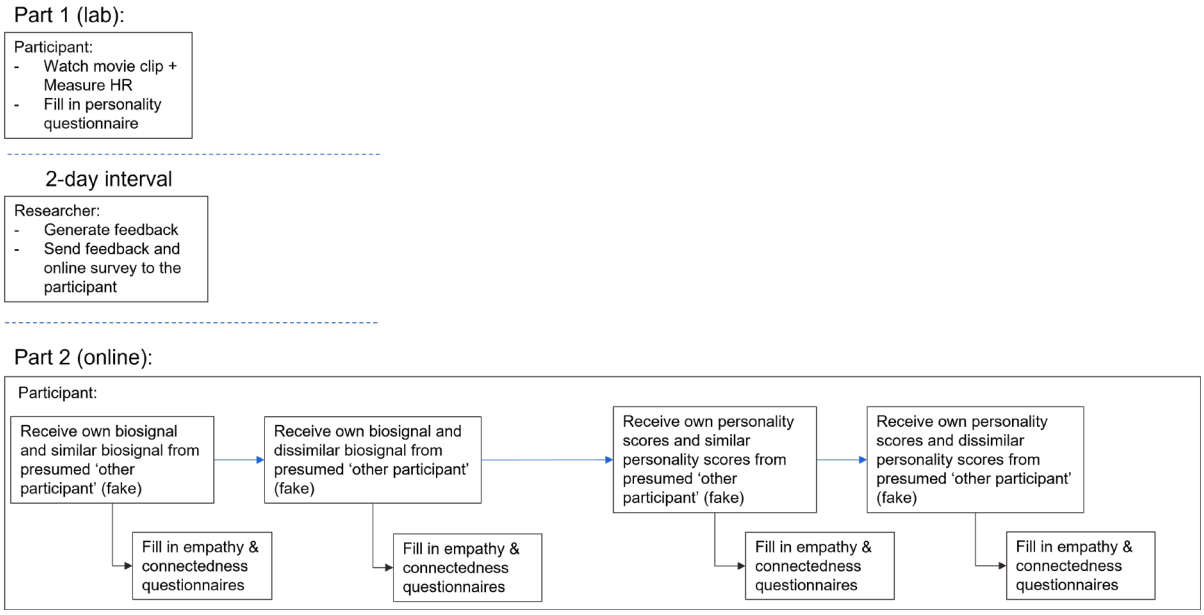

Figure 4. The overview of the procedure (the order of information presented in Part 2 is counterbalanced)

2.6.1 Part 1

The participant was picked up from the waiting area outside the lab, and then they were informed about the cover story and signed the informed consent form (see Appendix F). Then they were asked to put on the heart rate sensors by themselves following the lab instructions (see Appendix G). After the check by the researcher to see if the sensors were correctly attached to the body, the participants started watching the video. During the video, they were instructed to press the marker button on the device to mark the beginning and the end of the emotional movie clip "The Champ". After the movie, they filled in a survey on the lab computer. In the survey, they completed a personality questionnaire (see Appendix B) and answered questions about their

subjective emotional experience with “The Champ”. The questions were the SAM (see Appendix E) and an open question “How would you describe your feelings about the video clip?” (Dam, 2021). A last question concerned if they would give consent to share their heart rate with other participants. This question was included to make the participants believe that their heart rate was recorded and that their heart rate recordings and personality profile would be shared with others if they agreed. In the end, the participants were thanked for participating in the first part and informed that they would receive a survey link for the second part of the study within two working days.

2.6.2 Part 2

After one working day, the participants received the link to the second part, the online survey, via email. The introduction to the survey can be found in Appendix G. All the feedback presented to the participants was simulated by the researcher. In the survey, the participants were presented with (bogus) feedback about the heart rate and the personality of their own and a presumed ‘previous participant’. The participant’s own (bogus) feedback was provided as a reference to support the interpretation of the other’s (bogus) feedback. Each type of (bogus) feedback was presented with two ‘other participants’: one with similar and one with dissimilar feedback in counterbalanced order. The participants received four conditions, similar personality, dissimilar personality, similar heart rate, and dissimilar heart rate, that were introduced as the data ‘retrieved from four other participants and from themselves’. For each type of feedback, participants answered the corresponding questions (i.e., the perceived similarity scores between the responses of their own and ‘another participant’, the SAM, an open question about feelings, revealing and valence of the signal, empathic understanding, IOS, Knowing each others’ experiences, and Shared understandings). The survey ended with questions about demographics,

what they thought was the real objective of the study, whether they believed they received their own and others' data and why not, and which kind of compensation they liked to receive. In the end, the participants were thanked for their participation. They received a debriefing that explained the real purpose of the study and clarified that the feedback presented to them was simulated by the researcher and not real heart rate or personality profile extracted from any participants.

2.7 Data preprocessing and statistical analysis

All the responses to the questionnaire in the second session were exported from Limesurvey and merged into one dataset. In the statistical software package STATA, we recoded variables and generated new variables if necessary for further analyses. A binary variable named "suspicion" was generated to represent whether the participant believed the feedback they received. It was coded as 0 when the participants indicated to believe in all the feedback (i.e., their own heart rate responses, another participant's heart rate response, their own personality score, and another participant's personality score) presented to them. Otherwise, the variable was uniformly coded as 1.

Looking into the prepared data, we first checked the variable "suspicion". Suspicion could be a big issue for this study because it could directly influence the validity of participants' responses to the questions regarding the feedback. Half of the participants did not (totally) believe the feedback presented to them in the second session was their own or others'. To avoid potential confounding caused by participants' suspicion, we removed their records from the dataset before performing quantitative analyses. Within the remaining records, we checked the internal consistency of the items used to measure the dependent variables. The computed Cronbach's alphas showed that the reliability of empathy (α = 0.82) and social connectedness in

terms of “Shared understandings” (α = 0.90) and “Knowing each others’ experiences” (α = 0.92) were all good and acceptable. The corresponding items were respectively averaged to generate the final scores for each dependent variable among the four conditions.

In order to see if the similarity manipulation was successful, we first checked the normality assumption of the perceived similarity scores. The results showed that the assumption was met when presenting feedback about the personality, whereas it was violated when presenting feedback about the heart rate. Hence, a paired t-test was performed on the similar and dissimilar personality feedback, and a non-parametric Wilcoxon signed-rank test was performed on the similar and dissimilar heart rate feedback.

Before the main analyses, we checked the assumptions of running linear mixed models (LMMs) for dependent variables: the normality assumption and the homoscedasticity among the four conditions. As a result, all dependent variables are normally distributed, while heteroscedasticity was found in two dependent variables: empathy and IOS. Despite the violations, we still used LMMs to perform analyses because LMMs have been found to be robust to unequal residual variances (Schielzeth et al., 2020). No outliers were found in each dependent variable among the four conditions. After checking the assumptions and outliers, we finally performed the LMM for every dependent variable to investigate the effects of similarity on empathy and social connectedness. Additionally, the effects of the covariates, gender, age, task order, and familiarity were added to the model to control their influence.

As for the responses from the other half of the participants who indicated that they did not believe the feedback presented to them, we exploratively analyzed the open questions about why they did not believe the feedback to gain an understanding of the reasons why they did not.

3 Results

3.1 Movie clip check

Checking the answers to the question “How would you describe your feelings during the video clip about the child?”, most of the participants (48 out of 56) expressed their sadness. They used words and phrases like “sad”, “felt for him”, “emotional”, “sorry”, “sympathized”. A few participants also mentioned that they were confused about the context while watching the video. Several participants pointed out that the video was staged, and the boy performed well. Overall, the selected video effectively evoked emotions, which met our expectations.

3.2 Manipulation check

Before investigating the effects of similarity on empathy and social connectedness, we conducted a paired t-test and a non-parametric Wilcoxon signed-rank test to individually check if the similarity manipulations of personality and heart rate worked. The statistically significant differences between similar feedback and dissimilar feedback were found in the personality manipulation ($t(111) = 16.92$, $p < 0.001$) and the heart rate manipulation ($z = 9.16$, $p < 0.001$). Participants reported higher perceived similarity of personality profile for the similar condition ($M = 3.43$, $SD = 0.87$) than the dissimilar condition ($M = 1.68$, $SD = 0.76$), and higher perceived similarity of heart rate trace for the similar condition ($M = 4.04$, $SD = 0.73$) compared to the dissimilar condition ($M = 2.04$, $SD = 0.63$). In other words, both similarity manipulations were successful.

3.3 Effects on dependent variables

Several LMM analyses were performed for the various dependent variables. Each model included seven covariates: gender, age, the order of feedback (i.e., showing personality first vs

showing heart rate first), the order of personality feedback (i.e., showing similar personality first vs showing dissimilar personality first), the order of heart rate feedback (i.e., showing similar heart rate first vs showing dissimilar heart rate first), the familiarity of personality measurement, and the familiarity of heart rate measurement.

3.3.1 Empathy

The LMM found a large positive effect of receiving similar feedback on perceived empathy ($\beta = 0.39$, $p < 0.001$, $d = 1.07$). Also, people scored higher on perceived empathy when they received the heart rate feedback of another person than when they received the personality information about another person, although the effect was small ($\beta = 0.15$, $p = 0.011$, $d = 0.41$). Descriptive statistics of the four conditions are illustrated in Table 1 and Figure 5. Meanwhile, no significant interaction between the similarity and the type of feedback was found ($\beta = -0.019$, $p = 0.752$). In other words, there were no significant differences between the effect of different feedback similarities (i.e., the difference between similar and dissimilar heart rate responses vs the difference between similar and dissimilar personalities) on perceived empathy. Therefore, the results cannot support *H1: The effect of feedback about biosignal similarity on empathy is larger than that of feedback about the similarity in personality attributes.*

Table 1

Descriptive statistics of the measured empathy for all conditions.

Condition	Empathy			
	Mean	*SD*	95%CI	Range
Similar personality	3.13	0.17	2.77-3.48	1.75-5
Dissimilar personality	2.31	0.12	2.07-2.56	1-3.25

Similar heart rate	3.41	0.10	3.20-3.62	2-4.25
Dissimilar heart rate	2.68	0.13	2.41-2.95	1.5-4

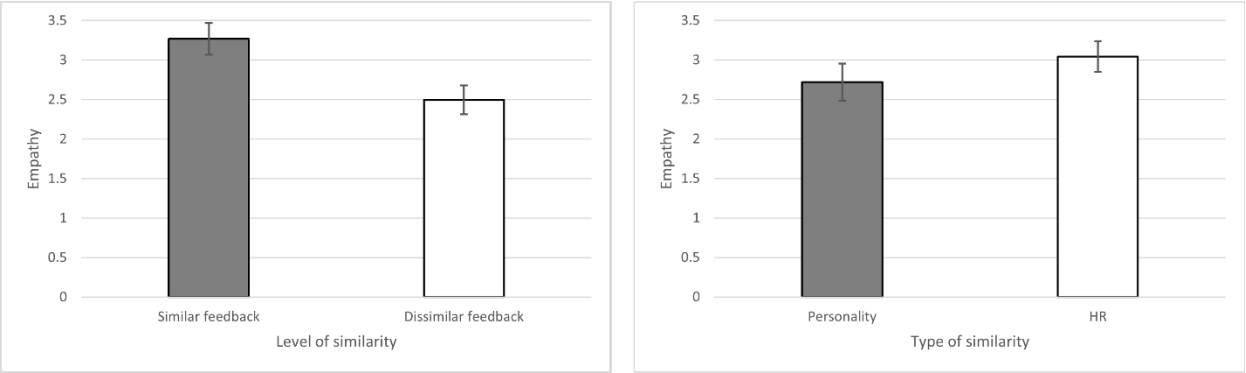

Figure 5. Means and confidence intervals on the dependent variable empathy for the two factors – the level of similarity and the type of similarity. Significant differences were between the similar and dissimilar feedback, and between the feedback about personality and HR.

As for the effects of covariate factors, only the order of personality feedback significantly had a moderate effect on empathy (β = -0.24, p = 0.03, d = 0.64). Descriptive statistics of the two orders can be found in Table 2.

Table 2

Descriptive statistics of the scores on empathy for four conditions based on two personality orders.

Condition	Empathy			
	Mean	*SD*	95%CI	Range
Similar personality first				
Similar personality	2.75	0.78	2.38-3.12	1.75-4

Dissimilar personality	2.14	0.63	1.84-2.45	1-3.25
Dissimilar personality first				
Similar personality	3.92	0.65	3.42-4.42	3-5
Dissimilar personality	2.67	0.5	2.28-3.05	2-3.25

3.3.2 Social connectedness

Shared understandings

People indicated to feel more social connectedness in terms of "Shared understandings" when they were presented with similar feedback than dissimilar feedback, and this effect was large ($\beta = 0.85$, $p < 0.001$, $d = 1.47$). Besides, people tended to give higher scores on perceived shared experience when receiving the heart rate feedback of another person compared to receiving the personality information about another person, but the effect was small ($\beta = 0.27$, $p = 0.006$, $d = 0.40$). Descriptive statistics of the four conditions are presented in Table 3 and Figure 6. No interaction effects between the similarity level and the similarity type of feedback were found on perceived social connectedness in terms of "Shared understandings" ($\beta = 0.059$, $p = 0.545$).

Table 3

Descriptive statistics of the measured social connectedness in terms of "Shared understandings" for all conditions.

Condition	Shared understandings			
	Mean	*SD*	95%CI	Range
Similar personality	4.25	0.25	3.73-4.77	1-6.67
Dissimilar personality	2.65	0.22	2.20-3.11	1-5.33

Similar heart rate	4.94	0.18	4.57-5.31	3-6.33
Dissimilar heart rate	3.10	0.20	2.69-3.51	1-5

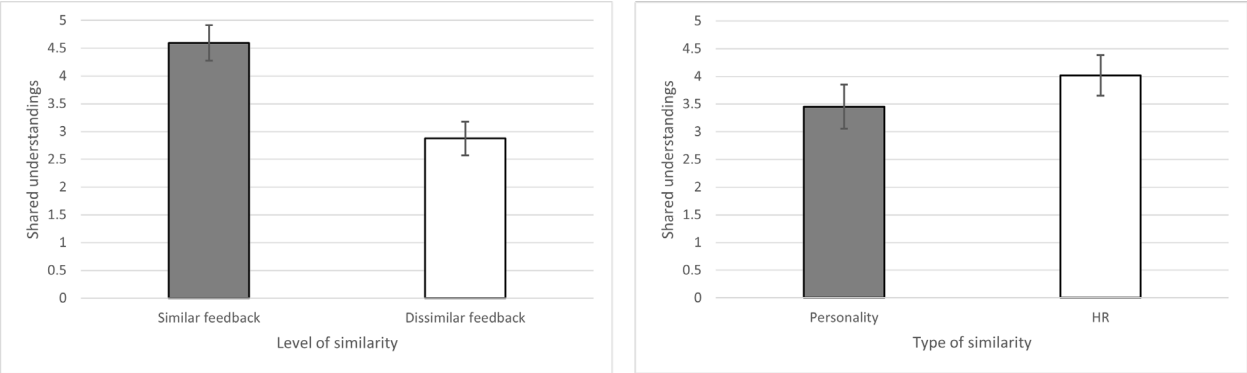

Figure 6. Means and confidence intervals on the dependent variable social connectedness in terms of "Shared understandings" for the two factors – the level of similarity and the type of similarity. Significant differences were between the similar and dissimilar feedback, and between the feedback about personality and HR.

Similar to the finding in the LMM on empathy, we found that the order of personality feedback was the only covariate having a significant and medium-sized effect on social connectedness in terms of "Shared understandings" ($\beta = -0.39$, $p = 0.023$, $d = 0.49$). Descriptive statistics of the two orders can be found in Table 4.

Table 4

Descriptive statistics of the scores on social connectedness in terms of "Shared understandings" for four conditions based on two personality orders.

Condition	Shared understandings			
	Mean	*SD*	95%CI	Range

Similar personality first				
Similar personality	3.79	1.29	3.17-4.41	1-5.67
Dissimilar personality	2.30	1.18	1.73-2.86	1-5.33
Dissimilar personality first				
Similar personality	5.22	0.88	4.54-5.90	3.67-6.67
Dissimilar personality	3.41	0.81	2.78-4.03	2.33-5

Knowing each others' experiences

People tended to have more social connectedness in terms of "Knowing each others' experiences" when presented with similar feedback than dissimilar feedback. The effect was large ($\beta = 0.57$, $p < 0.001$, $d = 0.84$). Also, people reported higher scores on the social connectedness in terms of "Knowing each others' feelings" when receiving the heart rate feedback of another person compared to receiving the personality information about another person. The effect was small ($\beta = 0.22$, $p = 0.022$, $d = 0.31$). Descriptive statistics of the four conditions are illustrated in Table 5 and Figure 7. No interaction effects between the similarity level and the similarity type of feedback were found on perceived social connectedness in terms of "Knowing each others' experiences" ($\beta = 0.046$, $p = 0.902$).

Table 5

Descriptive statistics of the measured social connectedness in terms of "Knowing each others' experiences" for all conditions.

Condition	Knowing each others' experiences			
	Mean	*SD*	95%CI	Range
Similar personality	4.13	0.30	3.51-4.74	1-6.75

Dissimilar personality	3.01	0.25	2.49-3.53	1-5.25
Similar heart rate	4.58	0.23	4.11-5.05	1.75-7
Dissimilar heart rate	3.44	0.22	3.00-3.88	1-5.25

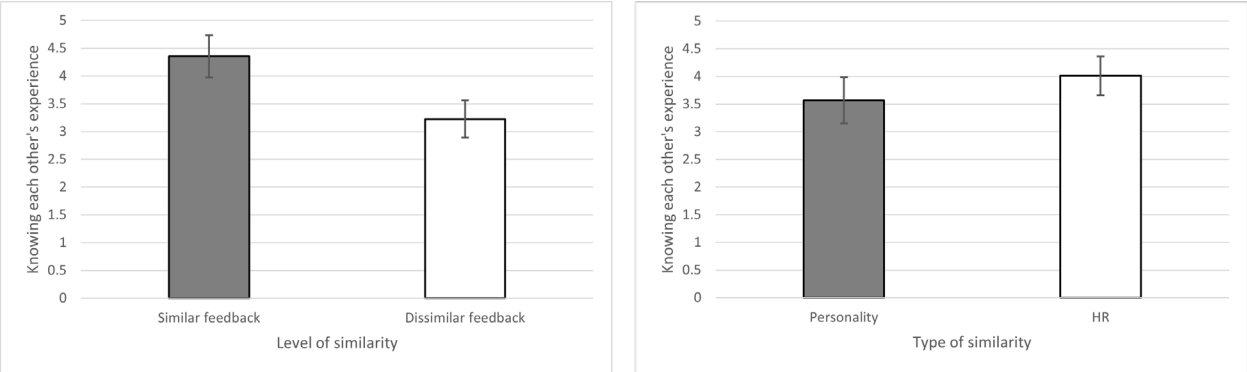

Figure 7. Means and confidence intervals on the dependent variable social connectedness in terms of "Knowing each others' experiences" for the two factors – the level of similarity and the type of similarity. Significant differences were between the similar and dissimilar feedback, and between the feedback about personality and HR.

Looking into the effects of covariates, we found a negative effect of age on social connectedness in terms of "Knowing each others' experiences" (β = -0.047, p = 0.032).

IOS

Similar to the findings in the other two subscales of social connectedness, the participants scored higher on the scale IOS when receiving similar feedback than dissimilar feedback. The effect was large (β = 1.06, $p < 0.001$, d = 1.63). The participants gave higher scores on the scale IOS when receiving the heart rate feedback of another person compared to receiving the personality information about another person. The effect was small (β = 0.26, p = 0.01, d =

0.34). Descriptive statistics of the four conditions are illustrated in Table 6 and Figure 8. There were no interaction effects between the similarity level and the similarity type of feedback on the scale IOS (β = 0.074, p = 0.460).

Table 6

Descriptive statistics of the scores on the scale IOS for all conditions.

Condition	IOS			
	Mean	*SD*	95%CI	Range
Similar personality	4.21	0.31	3.58-4.85	1-7
Dissimilar personality	2.29	0.17	1.94-2.63	1-4
Similar heart rate	4.93	0.23	4.46-5.40	2-7
Dissimilar heart rate	2.68	0.22	2.23-3.13	1-5

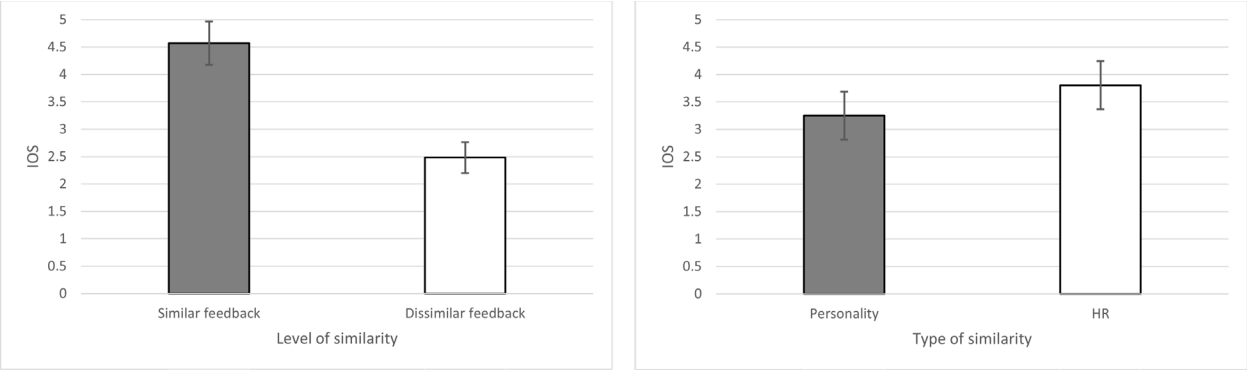

Figure 8. Means and confidence intervals on the dependent variable IOS for the two factors – the level of similarity and the type of similarity. Significant differences were between the similar and dissimilar feedback, and between the feedback about personality and HR.

Regarding the effects of covariates, the order of personality feedback was found to significantly affect the scale IOS (β = -0.63, $p < 0.001$, d = 0.77). Descriptive statistics of the two orders can be found in Table 7.

Table 7

Descriptive statistics of the scores on social connectedness in terms of the scale IOS for four conditions based on two personality orders.

Condition	IOS			
	Mean	*SD*	95%CI	Range
Similar personality first				
Similar personality	3.47	1.39	2.80-4.14	1-6
Dissimilar personality	1.89	0.74	1.54-2.25	1-3
Dissimilar personality first				
Similar personality	5.78	0.83	5.14-6.42	4-7
Dissimilar personality	3.11	0.60	2.65-3.57	2-4

3.4 Restricted covariate models

According to the LMMs involved with all covariates, we did not find significant interaction effects between the two types of similarities. In order to avoid potential risks of overfitting problems in the LMMs, we excluded non-significant covariates from the corresponding model and then respectively ran a restricted covariate model for each dependent variable. From the results, the significance of all previously found effects remained, except for the effect of age on social connectedness in terms of "Knowing each others' experiences". The covariate age turned out to be non-significant in the restricted covariate model for the variable "Knowing each others' experiences".

To sum up, without risks of overfitted results, the main effects of the level and the type of similarity on empathy and social connectedness were still significant. However, we did not find significant interaction effects on empathy or social connectedness between these two factors.

3.5 Open questions

3.5.1 Qualitative analysis of questions regarding suspicion

Although half of the participants declared their suspicion about the presented feedback as they did not believe that the feedback they received was retrieved from their own or other participants', only a small proportion (about 10%) of them was also right about the real aim of the study.

Regarding the authenticity of the personality profile, 13 participants doubted their own personality results, and 17 participants doubted another participant's results. As for presenting the feedback on heart rate response, 17 participants doubted their own heart rate data, and 10 doubted another participant's data. At the end of the second session of the study, some participants answered the reasons why they were skeptical about the corresponding feedback. Based on these answers (see Appendix H), four themes were generated on the provided arguments for not believing their data: relevant knowledge, subjective feelings, distrust of the procedure, and distrust of feedback figures.

Relevant knowledge – people seemed to know something about their own heart rate and/or personality. These understandings could influence their trust in the feedback. Looking through the reasons for suspicion, some participants mentioned that their heart rate was "usually lower than the average", thus they doubted the high relation to another person's heart rate in the condition with a similar heart rate trace. Regarding the authenticity of the personality profile,

some participants indicated that they remembered their answers to the personality questionnaire in the first session. Several participants mentioned the personality they believed that they had, for example, one replied, “I am usually neurotic, conscious and not extravert”.

Subjective feelings – people usually believe in their judgment of their own emotions. Looking into the suspicion about “your own heart rate response”, we found that many people described their subjective feelings of heart rate as “calm at the time”, “did not feel emotional”, and “did not respond much”.

Distrust of the procedure – people indicated their doubt about the experimental procedure in the answers. For example, more than one participant mentioned that the video was too short to evoke emotions, and one participant doubted that the personality test was too brief to give a correct estimation of one’s personality.

Distrust of feedback figures – as the feedback figures were simulated, participants also held distrust about the bogus figures. They described the figures as “fake graph”, “too similar to be real”, “seemed simulated”, “exact opposite of mine”, and so on.

3.5.2 Emotional interpretation of the feedback

From the answers to the question “Based on his/her heart rate response, how do you think Participant X was feeling while watching the video?”, all the participants indicated that the person having a similar heart rate felt sad, empathized, emotional, and agreed with them. Meanwhile, most participants declared that the person with a different heart rate did not get as emotional as they did. They described the participant as “not very moved”, “calmer than me”, “relatively insensitive”, and so on. There was a clear difference between the answers in the two conditions, which showed that the participants did perceive that the person with similar heart rate

responses had similar feelings. In contrast, the person with different heart rate responses was perceived to have distinct feelings.

As for the answers to the question regarding personality, the difference between the answers to the two conditions was not as straightforward as using the heart rate response in the feedback. The explanations were varied and mixed. It seems that some participants tended to analyze others' feelings based on certain personality traits. For example, one participant described the person having a similar personality as "A bit sad because he/she is quite conscientious and open-minded, this might perhaps indicate empathy. However, he/she might not be extremely sad because of a lower neuroticism score.", whilst one participant explained the feelings of the person having the dissimilar personality that "I think that a higher open-mindedness could relate to higher empathy, but lower conscientiousness to lower empathy. Taking this into account I think that the person still feels sad about the video, but not super sad." Participants regarded others in either the similar or the dissimilar personality condition as sad but not very much. These answers did not show apparent differences between different levels of similarity in personality-based feedback.

4 Discussion

4.1 Effects of feedback of between-person similarity on empathy and social connectedness

Our study aimed to investigate if differences between the effects of similar and dissimilar feedback on perceived empathy and social connectedness would vary among different types of shared attributes. The results showed statistically significant differences in the effects on empathy and social connectedness for different levels of similarity. Besides, significant differences were also found between the effects of different types of the presented feedback on perceived empathy and social connectedness. Against our expectations, no interaction between the type of feedback and the similarity of feedback was found. In other words, the differences between the effects of dissimilar and similar biosignals on empathy and social connectedness do not significantly differ from the differences between the effects of dissimilar and similar personalities on empathy and social connectedness.

4.1.1 Effects of the level of similarity on empathy and social connectedness

The simulated heart rate traces used for the feedback on heart rate were the same as Dam (2021) used in her study. Thus, our procedure presenting different heart rate feedback to the participants could be regarded as a replication of previous research. The results indicate that similar feedback is positively related to perceived empathy and social connectedness. The findings are in line with the ones found in previous research that a perceived similarity in feedback about personalities and biosignals serves to enhance feelings of empathy and social connectedness (Wróbel et al., 2015; Dam, 2021; Feijt et al., 2020).

4.1.2 Effects of the type of similarity on empathy and social connectedness

We found significant effects of the feedback type on empathy and social connectedness. To be specific, people perceived more empathy and social connectedness when receiving feedback about biosignals than personality attributes. Although the effects have a smaller effect size than those found in the level of feedback similarity, the findings seem to affirm the promising potential of using biofeedback to facilitate interpersonal interaction. In prior research, including biosignals in communication was viewed as capable of increasing affective feelings like intimacy (Janssen, Bailenson, Ijsselsteijn, & Westerink, 2010). However, empirical evidence corroborating the differences between the effects of sharing different information (e.g., biosignals and personalities) in interpersonal interaction is scant. To our knowledge, little research explored how the effects of varying feedback differ on people's emotional feelings. Therefore, our findings on the positive impacts of showing biosignals on empathy and social connectedness compared to showing personality (irrespective of similar or dissimilar feedback) are fairly new in this research area. From the findings, we can infer that the effects of presenting biofeedback on perceived subjective feelings are indeed not arbitrary but specific. Thus, we could expect to make use of it and apply shared biosignals in technology-mediated communication to help people understand the emotions of each other.

4.1.3 Interaction effects between the level and the type of similarity on empathy and social connectedness

We did not find sufficient evidence in our dataset to conclude significant interaction effects between the level and the type of similarity on empathy and social connectedness. Therefore, both hypotheses (*H1: The effect of feedback about biosignal similarity on empathy is larger than that of feedback about the similarity in personality attributes*; *H2: The effect of*

feedback about biosignal similarity on social connectedness is larger than that of feedback about the similarity in personality attributes) are rejected. In other words, the effects of the similarity level and the similarity type are independent of each other on perceived empathy and social connectedness. It is acceptable as this study is one of the first to investigate the effects of perceived similarity using more than one type of feedback. We came up with the hypotheses based on evidence that the effect sizes of the effects in emotional experiences differed in different similarity types. However, the effect sizes we referred to were extracted from only two previous studies, which might not be supportive enough. Also, the two attributes had to be presented in two different forms: the simulated personality feedback was presented in five dimensions following the Big Five personality traits; the simulated biosignal feedback was presented as a continuous trace along the time axis. This unavoidable difference leads to "unstandardized" feedback manipulations, which might influence how individuals perceive the two types of similarities, thus affecting their feelings about empathy and social connectedness. Furthermore, different feedback manipulation could make it difficult to compare the effects of the similarity level and the effects of the similarity type, thereby influencing the significance of the interaction effects between these two factors.

Another reason for this non-significant interaction could be the small sample size in this study. The expected sample size was decreased since half of the participants did not totally believe the feedback they received. Although we still found significant main effects, interaction effects might be not robust enough to exist in our dataset.

4.2 Effects of covariates

The analyses found that the presenting order of personality significantly affected empathy and two subscales of social connectedness, "Shared understandings" and IOS. The directions of

the three effects were consistently negative. Participants tended to perceive lower empathy and social connectedness in terms of “Shared understandings”, and lower social connectedness in terms of IOS when they saw a similar personality first compared to the condition when they saw a different personality first. As for the reasons, we think that anchoring effects might play a role because people rely much on the information offered before their judgment (Furnham & Boo, 2011). In our case, people might regard the first personality feedback as an anchor. After giving tentative scores on the corresponding scales for the first personality, people tended to answer the following question about the other condition based on their last impression of the first condition. However, we noticed that this potential anchoring effect did not exist in different orders of biosignal feedback. It might have something to do with the feedback manipulation. In the previous section regarding feedback manipulation, we have introduced that differences between similar and dissimilar biosignal feedback were shown by two different traces, whilst differences between similar and dissimilar personality feedback were in two different five-dimensioned shapes. It might be easier for people to tell the difference between the two shapes shown in the spider chart than to distinguish two curves with various ups and downs. When differences between similar and dissimilar feedback are perceptible (with a significant difference in perceived similarity) but not very evident, it could be the case that regarding similar or dissimilar feedback as an anchor would not affect answers to perceived empathy and social connectedness, thus the biosignal feedback order did not have significant covariate effects. In addition, people believe that it is much less possible to have highly similar biosignals than to have a highly similar personality to another person. This thought could make people more tolerant of differences presented in the biosignal feedback of two individuals. It could be the case that

people tended to give neutral answers when seeing the first biosignal feedback as they had expected some differences in biosignals in advance.

4.3 Implications

The current study shows that when one is fed back personal data about another person, a similarity with one's own data has a positive effect on empathy and social connectedness. Moreover, the size of these effects does not differ between biosignals-based feedback and personality-based feedback. But compared to personality feedback, showing biosignal feedback has a positive effect on empathy and social connectedness. Part of our results aligns with the previous findings in this field that found positive effects of similar feedback on empathy and social connectedness (Wróbel et al., 2015; Dam, 2021; Feijt et al., 2020). The unanticipated finding that people perceived more empathy and social connectedness when they received biosignal feedback than personality feedback extends earlier work in this field. By distinguishing the effects of biosignal and personality feedback, the findings seem to prove the special significance of biofeedback for interpersonal communication. We suppose this finding could be due to people's different thoughts about biosignals and personality traits. People usually associate physiological signals with emotions to interpret their biosignals (Slovák, Janssen, & Fitzpatrick, 2012). People believe that biosignal exchange is closely associated with affective connectedness (Slovák et al., 2012). In contrast, it was underlined by some participants mentioning that personality is a relatively fixed trait (more stable than biosignals) and will not have transient changes as emotion varies. From these understandings, we could thereby infer that biosignals are believed to have a closer relationship with emotions than personality. Our findings that biosignals-based feedback has a more positive effect on subjective feelings than personality-based feedback reveal the potential of implementing shared biosignals in communication to

enrich empathic interaction. One of the motives for this study was the general issue of lacking nonverbal cues in technology-mediated communication and its negative consequences on emotional understanding in interpersonal interaction. Based on our findings, we proposed that showing biofeedback in online communication could provide more emotional understanding to optimize affective communication and enhance connectedness. This application could add value to interpersonal interaction. Additionally, if we want to include biosignals as novel nonverbal cues in our daily remote interaction, people's attitudes towards biosignal sharing should be regarded as a big issue. Two aspects can be discussed here. One is about difficulties in understanding biofeedback. The relation between a psychological state and physiological signals is usually not specific (Fairclough, 2009; Liu, Dabbish, & Kaufman, 2017). In other words, it is complex to understand biofeedback since certain physiological information cannot be precisely matched to a particular psychological state (e.g., the increase in heart rate could be interpreted as being either furious or surprised). Therefore, biosignals-based feedback can be a too ambiguous cue for participants to understand the emotions of others, which might undermine effective communication. In our study, some participants declared their uncertainty when trying to understand the presented biosignal feedback. They used many words like "not sure", "maybe", and "no idea" in their interpretations of the ups and downs in the heart rate traces. This uncertainty could decrease people's acceptance of receiving biosignal cues in online communication. The other aspect that might influence people's attitudes is their subjective feelings about sharing biosignals. People believe that biosignals can expose their actual mental state, while sometimes they want to hide it. In the lab, a few participants mentioned that they felt insecure wearing heart rate sensors. This fact might result in people's discomfort feelings and even becoming unwilling to share biosignals with others (Liu et al., 2017). In a word, it is crucial

to investigate a proper and generalized approach to conveying biosignals in practical technology-mediated interaction.

4.4 Limitations

In the present study, about half of the participants indicated that they had some sort of suspicion about the experiment. This fact subsequently led to a smaller sample size, which could be regarded as a considerable limitation for our study. Participants who did not believe at least one feedback were excluded from the dataset for the statistical analysis. As a result, only half of the sample was analyzed, which could be argued that the sample size in this study is inadequate and lowers the statistical power of the findings. However, at the same time, we did detect strong effects with such a small sample.

Another limitation exists in the experimental procedure. We used heart rate sensors and the MOBI device to measure each participant's heart rate in the lab. Some participants reported that the measurement made them feel uncomfortable and uneasy. These feelings might affect their own heart rate feedback interpretations and understandings.

The last limitation of this current study is that we presented very little information to the participants. Our findings were based on a precondition that everyone knew nothing about each other but only another person's heart rate trace or personality results. Although it is appropriate for our controlled experiment, in practical technology-mediated communication, people must have more information about each other (e.g., seeing each other's faces, hearing each other's voices) rather than only receiving feedback about a certain similarity with another person. We can expect people to have a higher level of interaction in real online communications, and thus our findings regarding the effects of feedback about similarities might be accordingly affected.

4.5 Recommendations for future research

The most important issue that needs to be addressed in follow-up research is how to increase people's trust in the feedback presented to them. It is crucial to conduct a similar study with more credible feedback. Future research should take into account the reasons for suspicion mentioned by participants in this study. For example, some people pointed out that the dissimilar personality figure was too extreme to be humanoid. Therefore, less extreme scores for dissimilar personality feedback are recommended in future studies.

In the pilot, we noticed that people tended to doubt the feedback they received, even when they were presented with their own real heart rate feedback and personality score. Among the reasons for suspicion, uncertainty about the feedback was mentioned several times. As people were unsure about the authenticity of the feedback presented to them, they were very likely to indicate their suspicion when asked about it. In order to decrease the suspicion caused by the uncertain feeling, we suggest future research to investigate if visualizing the feedback (e.g., displaying real-time heart rate trace) to the participants during the measurement could decrease the feeling of uncertainty. In terms of the unease feelings during the biosignal measurement mentioned by several participants, other wearable devices like smartwatches could be used in further research. Moreover, compared to measuring with the heart rate sensors and the MOBI device, measuring with smartwatches is more meaningful for practical use in everyday circumstances.

5 Conclusion

The present study compared the effects of similarity in biosignal versus personality feedback on empathy and social connectedness. It was motivated by the increasing complaints about insufficient nonverbal cues conveyed in technology-mediated communication (Baym, 2015). This limitation could accordingly undermine the quality of interpersonal interaction. As wearable technology develops, prior research introduced the promising potential of presenting biosignal feedback to facilitate online communication (Feijt et al., 2020; Dam, 2021). This study was designed to determine if the effects of similarity feedback on empathy and social connectedness vary between biosignals versus personality data. We found two main effects. Similar to prior results, the similarity level (similar vs dissimilar) of attributes does positively affect empathy and social connectedness with another person. In addition, biosignal feedback has a more positive effect on empathy and connectedness than personality feedback. However, no significant interaction was found, implying that the similarity/dissimilarity effect is equally large for biosignals-based feedback and personality-based feedback. Following the two main effects, we expect our findings to help determine that applying biofeedback to interpersonal communication would be of added value. We hope the study could shed some light on introducing shared biosignals, which do not have to be similar ones, as nonverbal cues in future technology-mediated communication to improve people's emotional connections and help build satisfying interpersonal relationships.

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Appendix A. Pilots

Before the start of the formal experiment, three pilot studies were conducted. The first pilot aimed to choose which physiological signals (i.e., heart rate or skin conductance) and which emotional movie clip (i.e., “Lion King”, “the Decent”, “the Champ”, or “Bridge to Terabithia”) to use in the experiment. The second pilot tested if people could distinguish between similar and dissimilar results from ‘other participants’. The last one was a trial of the formal experiment to find out if the procedure was practically feasible, if the cover story was credible and if the study was comprehensible.

Pilot 1 Selecting the biosignal and the movie clip

In order to decide the type of biosignal and the content of the video used in the experiment, three participants were invited to the first pilot. Their heart rate and skin conductance were measured while watching a video collection including four emotional movie clips (respectively taken from four movies). Each of the movie clips was previously found to evoke the viewers’ emotions (Carvalho, Leite, Galdo-Álvarez & Gonçalves, 2012; Gross & Levenson, 1995; Overbeek, van Boxtel & Westerink, 2012). Between every two clips, there was a one-minute aquarium video to make sure that the biosignal was back to the baseline before the next clip started. The biosignals of the three participants while watching four movie clips were demonstrated in Figure 9 and Figure 10.

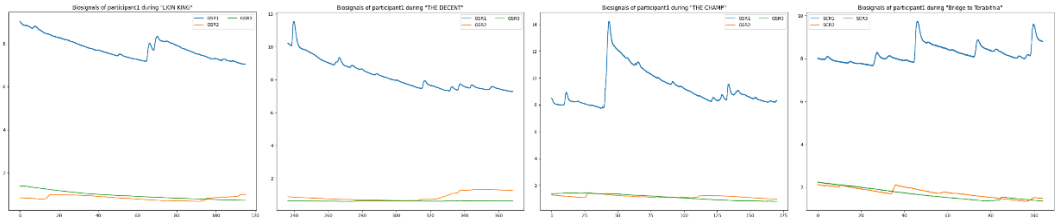


Figure 9. Skin conductance responses of the three participants while watching the four movie clips.

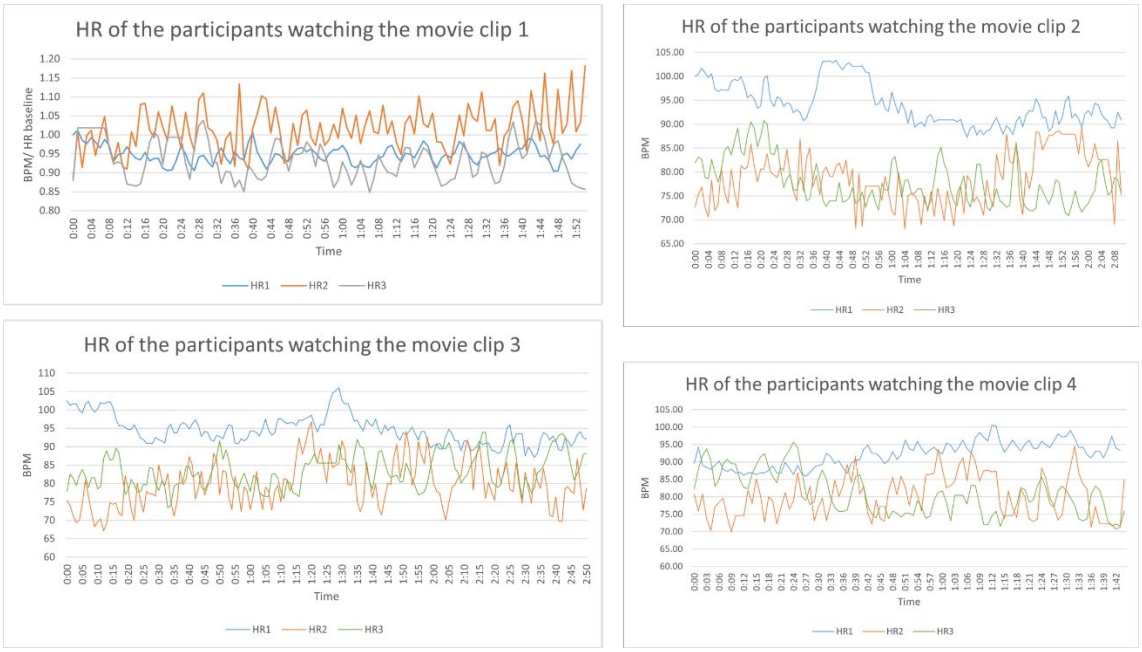


Figure 10. Heart rate responses of the three participants while watching the four movie clips.

According to Figure 9 and Figure 10, the changes in the participants' heart rate were much more evident than the skin conductance (i.e., more peaks and valleys through the curves). Besides, in the pilot, every participant felt nothing about the skin conductance, whereas they indicated that the heart rate was more intuitive and comprehensible for them. Combing the curves of the two biosignals and the feedback from the participants, we therefore chose HR as the physiological characteristic to manipulate in the study.

Regarding the selection of the emotional movie clip, we observed that one participant was close to tears while watching the movie clip 1 (i.e., “Lion King”), and even cried while watching the movie clip 3 (i.e., “the Champ”). According to the subsequent interview, two participants said the movie clip 3 was the most impressive clip. Considering the three heart rate traces illustrated in Figure 10 (from “the movie clip 1” to “the movie clip 4”: “Lion King”, “the Decent”, “the Champ”, and “Bridge to Terabithia”), the tendency of the curves of “the movie clip 3” seemed more consistent than the other three: there was a big peak in the middle of the movie clip.

In conclusion, we finally chose heart rate to be presented as the biosignal feedback and the movie clip extracted from “the Champ” to be played as the emotion-evoking video.

Pilot 2 Checking the two similarity manipulations

In the second pilot, we presented either similar and dissimilar heart rate, or similar and dissimilar personality to six participants and asked them to score the perceived similarity between the similar and dissimilar feedback on a scale from 1 (very different) to 5 (very similar). The similarity manipulations of the two attributes were based on the corresponding algorithms.

To manipulate the personality feedback, we added and subtracted a certain number of points for each personality questionnaire item to create a personality score that is either similar or dissimilar. As for the simulated heart rate response, we used an unusual heart rate response (which was taken from the first pilot) and participants’ own heart rate response to generate the two versions of ‘other participants’’ data. To be specific, a certain percentage was respectively multiplied by the unusual HR and the original one to create a heart rate trace that is either similar or dissimilar.

The perceived similarity ranged from 1 to 2 for the condition with dissimilar personality, and 4 to 5 for the similar one. As for the heart rate, the participants scored 1 to 2 for the condition with dissimilar heart rate response, and 3 to 4 for the similar one. We could say that the similarity manipulation was successful as all the participants scored higher similarity for the similar feedback than the dissimilar one.

Pilot 3 Test run

11 participants were involved in the test run of the whole procedure. To check the suspicion, we created four questions (e.g., “During filling out the questionnaire I believed that I was presented with my own heart rate response. Yes/No”) were added at the end of the second questionnaire. Surprisingly, nine participants answered at least one “no”, which meant that almost no participants believed in the feedback presented to them. To deal with this issue, we decided to replace the personalized feedback with the fixed ones. The personality feedback was extracted from the two participants who declared no suspicion. As for the fixed feedback of the heart rate, we used the ones created by Dam (2021) in her study.

Appendix B. Personality questionnaire

I am someone who... (1 Strongly disagree ~ 5 Strongly agree)

1. __ Tends to be quiet.

2. __ Is compassionate, has a soft heart.

3. __ Tends to be disorganized.

4. __ Worries a lot.

5. __ Is fascinated by art, music, or literature.

6. __ Is dominant, acts as a leader.

7. __ Is sometimes rude to others.

8. __ Has difficulty getting started on tasks.

9. __ Tends to feel depressed, blue.

10. __ Has little interest in abstract ideas.

11. __ Is full of energy.

12. __ Assumes the best about people.

13. __ Is reliable, can always be counted on.

14. __ Is emotionally stable, not easily upset.

15. __ Is original, comes up with new ideas.

Appendix C. Empathy measure

(1 Strongly disagree ~ 5 Strongly agree)

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

I feel as if I am on the same wavelength as Participant X.

I do not understand how Participant X thinks.

I can feel with Participant X in this situation.

Appendix D. Social connectedness measure

Shared understandings

(1 Strongly disagree ~ 7 Strongly agree)

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.

Knowing each others' experiences

(1 Strongly disagree ~ 7 Strongly agree)

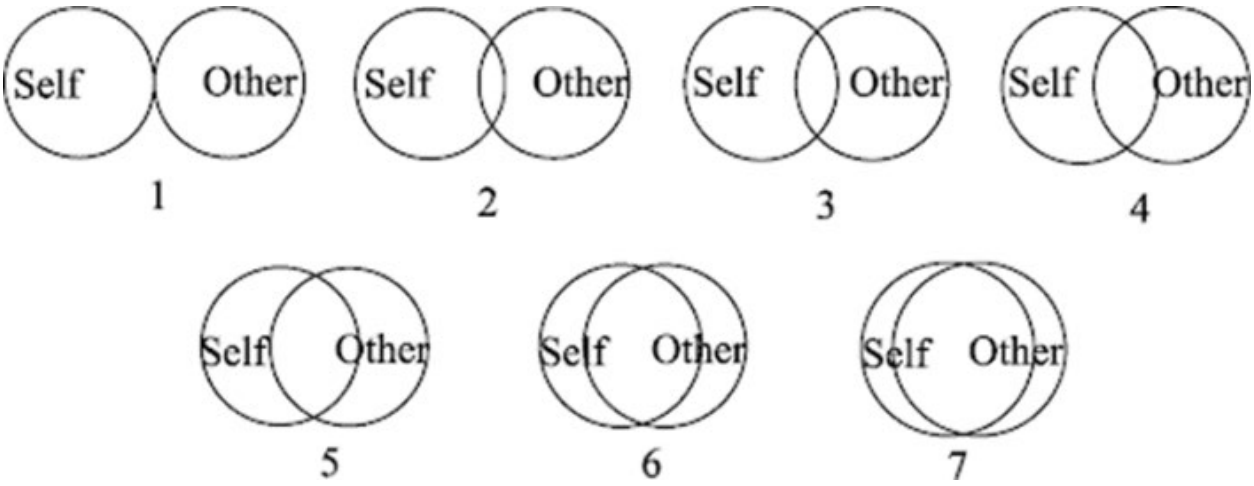
I know what X feels in this situation.

I know what X thinks in this situation.

I feel that X knows what I think in this situation.

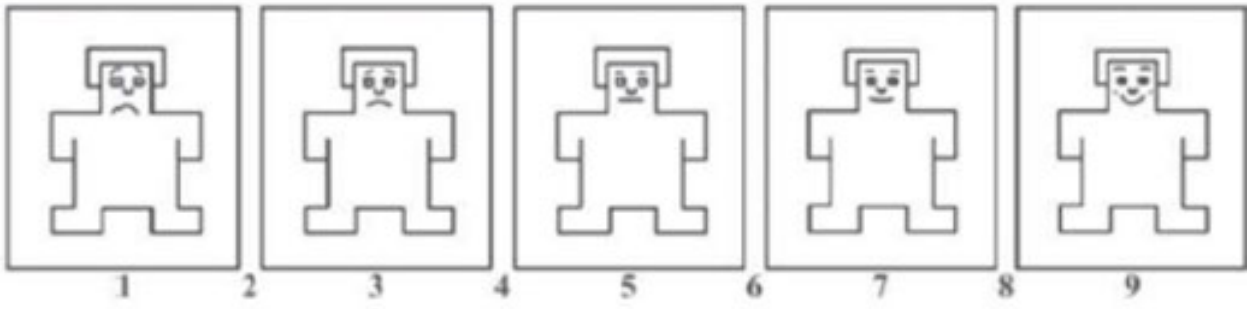
I sense that X knows what I feel in this situation.

Inclusion of Other in Self scale (IOS)

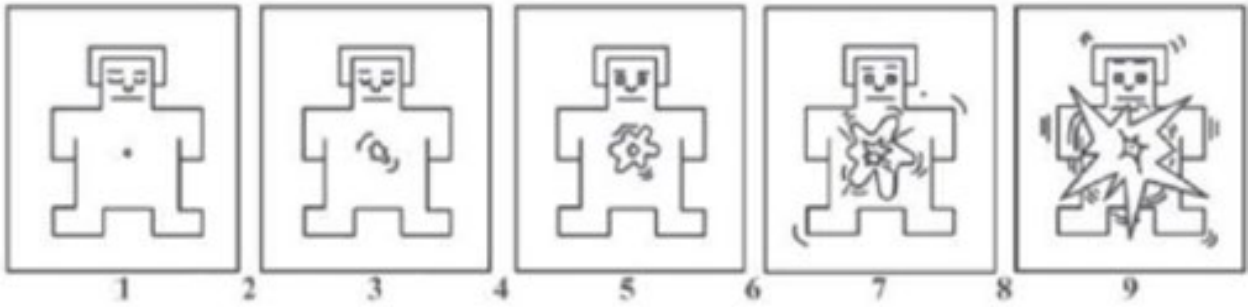


Appendix E. Self-Assessment Manikin

(1 Very unhappy ~ 9 Very happy)



(1 Very calm ~ 9 Very excited)



Appendix F. Informed consent form

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Information form for participants

This document gives you information about the study "Deriving emotions from personality and biosignal feedback". Before the study begins, it is important that you learn about the procedure followed in this study and that you give your informed consent for voluntary participation. Please read this document carefully.

Aim and benefit of the study

The aim of this study is to measure how people estimate others' emotions based on physiological or psychological characteristics.

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

Procedure

This study consists of two parts with an intervening period of approximately two days. In the first part, you will come to the HTI General Purpose Lab at the TU/e. In the lab, you will watch an emotional video, while your heart rate is being measured. Then, you will fill in several questions on your emotions during the movie and a personality questionnaire.
Afterwards, the researcher will analyze your physiological response and answers on the personality questionnaire and generate visual feedback of both the results.
In the second part, your will receive an email with a LimeSurvey link to a survey. In this survey, you will receive feedback on your and others' heart rate response and personality results. We will ask you to answer some questions about the information we provided.

Corona regulations

Please note that there is a strict Covid-19 protocol for research conducted at the HTI Laboratories. At the time of writing, all researchers and participants must adhere to the protocol of September 13, 2021. Be aware that these protocols may change, and that the information here presented may be incomplete. The protocol includes disinfecting your hand when arriving at the lab spaces, and providing your name and phone number. This information is stored by the lab coordinators for 30 days, and will be used to inform you when you may have been in contact with a person that later tested positive. During the experiment, and depending on the nature of the experiment, the protocol may for example include wearing a face mask. You can only participate when you are either fully vaccinated (meaning that the last vaccination is received at least two weeks before your participation to the experiment) or tested negatively for the virus no longer than 48 for hours before the experiment. If you have any corona related symptoms, then please cancel your participation to the experiment.

Risks

The study does not involve any risks, detrimental side effects, or cause discomfort.

Duration

The study will take 40 minutes in total to complete: the first part of the study takes about 20 minutes and the second part of the study takes about 20 minutes.

Participants

You were selected because you were registered as participant in the participant database of the Human Technology Interaction group of the Eindhoven University of Technology or because you were personally invited.

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Voluntary

Your participation is completely voluntary. You can refuse to participate without giving any reasons and you can stop your participation at any time during the study. You can also withdraw your permission to use your data up to 24 hours after they were recorded. None of this will have any negative consequences for you whatsoever.

Compensation

After completing both parts of the study, you can choose to receive a reimbursement of €7.50 (plus an additional €2.00 if you do not study or work at the TU/e or Fontys Eindhoven) or 1 course credit + €2.50. To receive this compensation, your name and bank account (IBAN) will be required, and to receive the course credit will require your TU/e student number. These data will be temporarily stored on the main researcher's TU/e SurfDrive (in combination with a Cryptomator that encrypts the files locally to the researcher's computer), and will be deleted when payment is completed. Please note that you will only receive payment after completion of the entire study, that is, after completing both the first part in the lab as well as the second part that is performed online.

Confidentiality and use, storage, and sharing of data.

All research conducted at the Human-Technology Interaction Group adheres to the Code of Ethics of the NIP (Nederlands Instituut voor Psychologen – Dutch Institute for Psychologists), and this study has been approved by the Ethical Review Board of the department.

In this study, personal data (email addresses, participant database ID, bank details, TU/e student number), demographic data (age, gender, level of education) and experimental data (heart rate signal and responses to questionnaires) is collected. The personal data will be separately stored in the password protected SurfDrive. The demographic and experimental and thus anonymized data will be used for research. 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 that is only accessible by selected HTI staff members. No information that can be used to personally identify you will be shared with others.

The physiological response and personality questionnaire results will not be distributed and will only be available for 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 an online data repository. The anonymized data set collected in this study and that will be released to the public 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. At the bottom of this consent form, you can indicate whether or not you agree with the use of your data for future research within the Human Technology Interaction group.

No video or audio recordings are made that could identify you.

Further information

If you want more information about this study, the study design, or the results, you can contact Yinan Zheng (contact email: y.zheng4@student.tue.nl).

If you have any complaints about this study, please contact the supervisor, Joyce Westerink (j.h.d.m.westerink@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.

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Informed consent form

DERIVING EMOTIONS FROM PERSONALITY AND BIOSIGNAL FEEDBACK

- I have read and understood the information of the corresponding information form for participants.

- I have been given the opportunity to ask questions. My questions are sufficiently answered, and I had sufficient time to decide whether I participate.

- I know that my participation is completely voluntary. I know that I can refuse to participate and that I can stop my participation at any time during the study, without giving any reasons. I know that I can withdraw permission to use my data up to 24 hours after the data have been recorded.

- I agree to voluntarily participate in this study carried out by the research group Human Technology Interaction of the Eindhoven University of Technology.

- I know that no information that can be used to personally identify me or my responses in this study will be shared with anyone outside of the research team.

- I
  - ☐ do
  - ☐ do not

  give permission to make my anonymized recorded data available to others in a public online data repository, and allow others to use this data for future research projects unrelated to this study.

Certificate of consent

I, (NAME) .....
want and provide consent to participate in this study.

_____ _____

Participant's Signature Date

Appendix G. Participant Instructions

Lab instructions

Instructions

Please keep wearing your face mask during the procedure.

How to wear the sensors:

First cleanse the parts of your skin where you will put the sensors with an alcohol prep pad, and then stick the electrodes on in the positions indicated in *Figure 1*:

Step1: Place the red electrode on the soft tissue just below the lower rib on the left side of the body.

Step 2: Place the black electrode on the soft tissue just below the right collarbone near the shoulder.

Step 3: Place the green electrode on top of the left collarbone near the shoulder.

To make sure the electrodes stick well, please press them firmly after sticking them on the corresponding positions. Please try to keep still as much as possible after the sensors are attached.

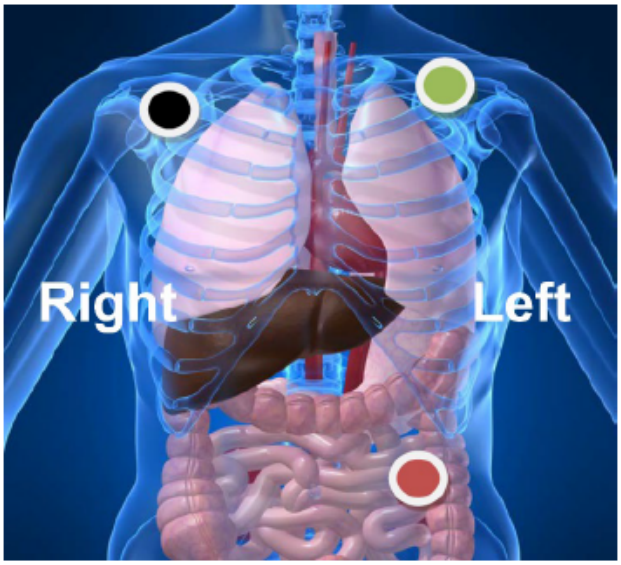

Figure 1 Sticker electrode positions for ECG.

Figure 2 Marker button on the device

Where is the marker button:

See *Figure 2*

During the video, please do not move the Mobi device.

Introduction to the second survey

In the first part of the study, you watched an emotional video clip about a child while your heart rate was being measured, and you completed a personality questionnaire. Afterwards, the researcher has analyzed heart rate data and personality scores collected from other participants in this study so far, and the computer has randomly assigned four participants to be presented to you.

In this survey, we would like to know how you estimate these other participants' emotions based on their heart rate responses during the video clip and their personality scores. To give you an indication of how heart rate responses and personality scores can look like, we also show your own results as a reference. This can help to interpret the other participants' emotions since you know how you felt while watching the video clip.

Appendix H. Representative reasons for suspicions

(The italics in parentheses are the themes we have summarized.)

On the previous page, you indicated that you did not believe you were presented with your own heart rate response during the questionnaire. Could you explain why not?

Based on my experience my heart rate is usually lower than the average. (*Relevant knowledge*)

The video part was too short to get in the emotions. (*Distrust of the procedure*)

I feel when I was watching the clip, I didn't react much about it. (*Subjective feelings*)

Because we thought I was calm at the time. (*Subjective feelings*)

The graph looks too arbitrary. (*Distrust of feedback figures*)

On the previous page, you indicated that you did not believe you were presented with another participant's heart rate response during the questionnaire. Could you explain why not?

The first comparison was too similar to be real. (*Distrust of feedback figures*)

On the previous page, you indicated that you did not believe you were presented with your own personality score during the questionnaire. Could you explain why not?

Based on my previous personality test, I scored really low on neuroticism and higher on open-mindedness. (*Relevant knowledge*)

I do not think that survey accurately measures my personality as it was way too short for that. (*Distrust of the procedure*)

I am usually neurotic, conscious and not extravert. (*Relevant knowledge*)

On the previous page, you indicated that you did not believe you were presented with another participant's personality score during the questionnaire. Could you explain why not?

The emotions and qualities were way too extreme and not human at all. (*Distrust of feedback figures*)

Appendix I. Summary

The study aims at investigating the potential differences between the effects of feedback about the similarity in biosignals on empathy and social connectedness and the effects of feedback about the similarity in personality traits. Although technology-mediated communication is prevalent in this digital era, people are aware of its limitations in delivering nonverbal cues. Compared to traditional offline communication, the conveyed nonverbal cues in online communication are often considered insufficient for people to experience affective feelings like connection, empathy, and liking, factors that are vital to interpersonal interaction (Venter, 2017). Recent research found the promising potential of applying biofeedback, especially (bogus) similar biofeedback, in mediated communication to enhance interpersonal interaction (Salminen et al., 2019; Dam, 2021). Besides, according to an earlier study, informing people about the (bogus) similarity in personality attributes with someone else could increase liking and empathetic feelings (Wróbel et al., 2015). These similar findings regarding the effects of feedback about a certain similarity on people's subjective feelings inspired the researcher to compare the effects of different types of similarity.

The researcher came up with a research question: What are the differences between the effect of feedback about biosignal similarity on empathy and social connectedness compared to feedback about the similarity in personality attributes? According to the effect sizes reported in previous studies by Wróbel et al. (2015) and Dam (2021): biosignal similarity (d = 1.24); personality similarity (d = 0.68), the researcher hypothesized that *the effect of feedback about biosignal similarity on empathy is larger than that of feedback about the similarity in personality attributes (H1)*; *the effect of feedback about biosignal similarity on social connectedness is larger than that of feedback about the similarity in personality attributes (H2).*

In order to answer the research question, the researcher used a 2 x 2 within-group design. The design contained two independent variables (similarity type and similarity level), each with two levels (biosignals-based feedback vs personality-based feedback. similar feedback vs dissimilar feedback). Two dependent variables were empathy and social connectedness. Fifty-six participants were recruited. To make sure that participants would not find out the true purpose of the study, a cover story was made. The participants were told that the objective of the study was to investigate how people estimate others' emotions based on feedback about their biosignals and personality traits. In the study, all feedback presented to the participants was not real but simulated. The study consisted of two sessions with a two-day interval. The first part was a lab experiment. In the lab, participants watched an emotional video while measuring their heart rate by a MOBI device (Boschman, 2017), and then they completed questionnaires including a personality test. The second part was an online survey including different feedback (similar biofeedback, dissimilar biofeedback, similar personality, dissimilar personality) and questionnaires about the two dependent variables. The presenting order of feedback was counterbalanced. Following Dam's study (2021), four items were used to measure perceived empathy, and three subscales ("knowing each other's experiences", "shared understanding", and inclusion of other in self (IOS) scale) were used to measure social connectedness.

Half of the participants doubted the feedback they received. To avoid potential confounding, the researcher excluded their data from the dataset for the quantitative analysis – linear mixed models (LMMs). An LMM including independent variables and covariates (gender, age, task order, and familiarity) was performed for each dependent variable. The results showed that no interaction effects between two factors (the type of similarity and the level of similarity) were significant, which means that the two hypotheses were rejected. However, both main

effects were significant. The effects of the similarity type were small, while the effects of similarity level were large. Compared to dissimilar feedback, similar feedback increased empathy and social connectedness. The results align with the findings reported in previous studies. Additionally, biosignals-based feedback was found to relate to more empathy and social connectedness than personality-based feedback. The findings of the main effects of the type of similarity extend previous findings in this field, as prior research only investigated the effects of the similarity level of feedback. Moreover, the promising potential of applying biosignals to enhance interaction was affirmed.

Before deploying the promising potential of biofeedback in practice, it is necessary to perform more research in this novel area in the future. According to answers from the participants who doubted the feedback, most of them mentioned uncertainty about their biosignals. Hence, the researcher recommends future studies to investigate if visualizing biosignals to the participants during the measurement could decrease the feeling of uncertainty. Besides, some participants mentioned their uneasy feelings with heart rate measurement by the MOBI device. Other wearable devices like smartwatches are recommended to measure biosignals in the following research.

To conclude, this present study affirms that feedback about similar attributes can increase empathy and social connectedness. Moreover, biosignals-based feedback indeed has specifically positive effects on empathy and social connectedness compared to personality-based feedback.Therefore, biofeedback is a very promising nonverbal cue that can be used in technology-mediated communication to compensate for the insufficient traditional nonverbal cues and thus facilitate better social interaction in the future.