The effect of sharing heartbeats on physiological linkage

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INTRODUCTION

New technology now enables people to share information at any time, at any place, and with anyone. This form of communication has the potential to be equally or more intimate than face-to-face communication. One way to increase the amount of perceived intimacy is the usage of emoticons (Janssen, IJsselsteijn, & Westerink, 2014). Currently, research is investigating other intimate methods of sharing information, such as heartbeats. These heartbeats are currently predominantly presented visually, as opposed to aurally for example. Furthermore, they are mainly used as a way to garner information, such as when an athlete wants to monitor their performance. Previously, sensing another person's heartbeat was predominantly done by placing one's ear on their chest. This made heartbeat sharing an intimate and connected affair. Would it be possible with current technology to use heartbeats as an extension during communication, and instill some form of connectedness? And how would the heartbeats have to be presented in order to do this most effectively?

Janssen, Bailenson, IJsselsteijn, and Westerink (2010) believe that when the right technology arrives, heartbeat communication could become as useful as any other nonverbal signal. Moreover, it could improve people's ability to recognize others emotions. They postulate that heartbeat information could not only be valuable in situations where emotional cues are lacking, such as during computer-mediated-communication, but also in face-to-face settings when it is difficult to correctly read another person's emotions. They conclude that the intimate nature of heartbeat communication could "open up a future in which we augment our natural emotion communication by new technologies that share bio signals carrying our emotions" (p.78).

Not a lot of studies exist about the communicative values of heartbeat sharing. The studies that do exist often do not discuss why they chose a certain presentation of the heartbeat over another. However, it would seem that the communicative values of hearing or feeling a heartbeat is greater than seeing a visualization of the heartbeat (Janssen et al., 2010; Ueoka & Ishigaki, 2015; Järvelä, Kätsyri, Ravaja, Chanel & Henttonen, 2016). This assumption is made because Janssen et al. (2010) have made use of heartbeats that could be heard and concluded that this physiological signal can be an important communicative tool, while Järvelä et al. (2016) displayed the heartbeats visually and concluded that they had no effect.

These differing results could be explained through the fact that both experiments used a different method to present heartbeats. For this reason, a distinction is made between a *connected*

and *informational* method of sharing heartbeats. Hearing and feeling a heartbeat was initially done through the intimate action of touching another person's chest, therefore we view the sharing of heartbeat through the use of sound or touch as *connected*. In comparison to this we refer to the use of a visual presentation as *informational*. The information related to heartrate cannot be displayed visually without any artificial aid, which could make this manner of presentation feel more unnatural and distant when compared to the *connected* method. Moreover, feeling or hearing a heartbeat could be more intuitively interpretable than monitoring numbers on a display.

We are interested in finding an answer to the following research question: "What are the effects of presenting heartbeat in a connected rather than an informational manner on the occurrence of physiological linkage and its associated effects?" To this end, we will first briefly discuss what heartbeat entails, then we will look at the different ways of presenting heartbeats, and finally we will discuss the phenomenon of physiological linkage in more detail.

THEORY

Heartbeat

Heartbeat describes one complete pulsation of the heart. This cardiac cycle includes the phase of contraction known as systole and of relaxation known as diastole. Heartbeats are interesting as a new way of nonverbal expression because in contrast to other physiological activities, such as electro dermal activity, they can be intuitively interpreted (Järvelä et al., 2016). However, just because people assume intuitively that an elevated heartrate means that someone is experiencing stress does not necessarily mean that this is correct. Heartbeats are not attributable to a single source and therefore it is difficult to translate its underlying meaning (Ravaja, 2004). For example, a fast heartbeat can correspond with emotional arousal and preparation for action (Cacioppo, Tassinary, & Berntson, 2000). In other words, heartbeats can get elevated because people are aroused or because they get a strong emotional reaction such as a feeling of euphoria or being very scared.

For this reason, we do not investigate the absolute values of heartbeats but instead how they influence the other person sensing them. Since Järvelä et al. (2016) saw no communicative value in sharing heartbeats while Janssen et al. (2010) did, we would like to discuss the different ways of presenting the heartbeat.

Presenting the heartbeats in a connected or informational manner

Usually, heartbeats are useful to gather information about one's health which can be used by a doctor. Another interesting *informational* aspect of the heart is that it can be an indicator of how much effort people are putting into a certain exercise (Laukkanen & Virtanen, 1998). To this end, a number of devices have been developed such as a Bluetooth headset which detects heartbeats through a pulse near the ear (Chou, 2006). Another device analyses the heartbeat of athletes to help the audience understand what goes on inside the athlete's body (Bornand, Güsewell, Staderini & Patra, 2013). Furthermore, heartbeat can be analyzed to determine whether a person is dealing with stress (Thayer, Åhs, Frederikson, Sollers & Wager, 2012). These devices present the information related to the heart as a series of numbers. In conclusion, they use the heart as a source of information.

However, it is difficult to attribute the numbers on the monitor to a certain emotion, as there is a lack of context as to which emotion is causing changes in the heartbeat (Slovák, Janssen, & Fitzpatrick, 2012). Furthermore, every physiological activity can be linked to a number of physiological processes which makes it difficult to draw any conclusions from them (Cacciopo, Tassinary, & Berntson,2000). For these reasons, this study focuses on whether sensing someone's heartrate causes a change in emotion. The convergence of these emotions is an underlying effect of a concept called physiological linkage. This phenomenon will be discussed in more depth in the next section.

As opposed to the *informational* aspect, the heart can instill a feeling of *connectedness*. For instance, heartbeats can be soothing such as when a child is resting on its mother's chest while listening to her heartbeat. Originally, hearing or feeling another person's heartbeat was exclusive to physically touching one another. This natural way of sensing a heartbeat is intimate as it dictates that two people are close to one another with either their hand or ear against the other person's chest. This information leads us to believe that heartbeat sharing is primarily an intimate experience. Moreover, intimacy can be seen as equal to felt connectedness (Slovák, Janssen, & Fitzpatrick, 2012).

In order to benefit more from the *connected* and intimate aspect of the heart, there have been a number of developments. For example, an animal bedding structure which includes a device that vibrates was invented. The vibrations of this device aim to mimic a heartbeat and therefore cause the animal to feel soothed and less lonely (Helwig, 2005). Another invention applies this

idea to human infants. This device mimics the sound of heart the baby's mother in order to calm and soothe the baby when the mother is not present (Sedaros, 1999). Lastly, a device labelled "Mobile Feelings" was developed. This invention consists of two egg shaped devices which vibrate. Currently it is not functional yet, but the idea is that by holding the eggs two people can feel bonded to one another while being physically apart (Sommerer & Mignonneau, 2011). The key idea for these devices is that the heart can be a way for people to feel *connected*.

Relevant to this study, there is also evidence in the effectiveness with which informational and connected ways of presenting and sharing heartbeats influences feeling connected. For instance, Janssen et al. (2010) hypothesized that hearing another person's heartbeat would create a feeling of intimacy (a concept strongly associated with feeling connected). In their experiment, participants were placed in a virtual reality environment while they heard the sound of a heartbeat. The experimenters were interested in the self-reported intimacy and how far participants distanced themselves from the confederate. Their results confirmed their hypothesis as the participants created a bigger physical distance between one another to compensate for the increase in perceived intimacy. Another study which also made use of the sound of the heart combined with its vibrations, showed that hearing another person's heartbeat intensified a horror movie experience (Ueoka & Ishigaki, 2015).

However, in an experiment where the participants had to sense one another's heartbeat through *informational* rather than a *connected* presentation (using a simple visualization), no such effects were found (Järvelä et al., 2016). In this study, participants were shown four clips while they had the option to engage in text-based chat and they could observe the heartbeat of their co-participant visually. Because of these divergent results, we believe it is important in what manner the heartbeat is presented when two people want to share their heartbeats.

In this research, we want the differences between the informational and connected manner of presenting heartbeat to be substantial. In order to realize this, we have designed a pillow that allows the participants to both feel and hear the heartbeat of their partner while simultaneously holding a pillow close to the chest, which we believe leads to a higher amount of perceived intimacy and therefore connectedness. A pillow was used to increase the intimacy as it is comfortable to hold and it might mimic the feeling of hugging someone and feeling their heartbeat. This design was inspired by the works of Nishimura, Hachisu, Sato, Fukushima and Kajimoto

(2013). They made a device that allows people to watch a movie or play a video-game while still hearing a heartbeat without polluting the experience. The device is displayed in Figure 1.

Figure 1. Pillow device by Nishimura et al. (2013)

Physiological linkage as a manifestation of heartbeat-sharing

The feeling of connectedness that can happen when sharing heartbeats stems from a phenomenon called physiological linkage. This can be described as bodily activities that correspond across two or more individuals. People can adapt mannerism, postures and facial expressions to those of their communication partners (Bargh & Chartrand, 1999). This unintentional process causes the communication partner to subsequently get an increased appreciation for the person that is copying them, which causes people to feel closer and more connected to one another. Physiological linkage through heartbeats was found while observing macaques (Miller, Banks & Kuwahara, 1966). It was noticed that the monkeys who were experiencing distress had the same heartbeats as the monkeys which were observing their troubled expressions.

Similar to the monkeys, this connectedness was also found while observing participants in a conflict situation with their spouses (Gottman & Levenson, 1985). The participants had the same heartbeats when they were partaking in the conflict as when they watched the session on videotape at a later date. Moreover, Preston and de Waal (2002) suggest that people's heartbeat correlated with others when they were empathic for their situation, or in the case of the experiment of Gottman and Levenson (1985): for their own situation. Lastly, when people's heartbeat correlates, it also correlates with their self-reported understanding of the other group member, which is another indication that a correlating heartbeat is closely related to feeling connected (Ekman, Chanel, Järvelä, Krivikangas, Salminen & Ravaja, 2012). However, in these experiments, the similar heartbeats were obtained through feeling connected. In the current experiment, we are interested in the reverse happening, namely whether sensing someone's heartbeat can result in a greater feeling of connectedness.

How to measure physiological linkage

Physiological linkage not only manifests in a feeling of connectedness, but also associates with constructs such as emotional convergence and social presence. Emotional convergence can lead to physiological linkage based on contagion (Bruder, Dosmukhambetova, Nerb, & Manstead, 2012). This contagion can be described as the convergence of emotional states of people through the use of verbal or non-verbal communication (Barsade, 2002). An example of this would be that a smile from one person elicits a smile in another with increased happiness as a result. Moreover, this shared smile would produce similar autonomic activity in both people, such as an elevated heartrate (Ekman, Levenson, & Friesen, 1983). Social presence is defined by Gunawardena (1995) as "the degree to which a person is perceived as a 'real person' in mediated communication" (p.151). Järvelä et al. (2016) state that social presence can be seen as a measure of physiological linkage, as they positively correlate with one another.

Physiological linkage is difficult to measure since we do not have the tools to monitor the bodily activities of the participants accurately. For this reason, we have decided to measure the constructs which relate to it. Firstly, we would like to investigate whether people's emotions converge in order to see whether physiological linkage took place. Secondly, we are interested whether people feel more connected and lastly whether they feel a greater amount of social presence.

Synthesis

We predict that physiological linkage is less likely to occur in the informational condition as this condition is similar to the experiment conducted by Järvelä et al. (2016) who found no heartrate related effects in their study. Subsequently, we hypothesize that physiological linkage is more likely to occur in the connected condition which includes hearing and feeling the heartbeat as this is in line with Janssen et al. (2010) and Ueoka and Ishigaki's (2015) findings. Furthermore, we also view this condition as intimate, since the sound and vibrations are felt and heard through a pillow which is held closely to the chest. This intimacy is related to connectedness which further increases the likelihood of physiological linkage to occur. Lastly, we hypothesize that the connected condition has a higher amount of social presence which in turn leads to a higher amount of physiological linkage. Social presence is thought to be higher in the connected condition because an actual heartbeat can be heard and felt which should make the participants more aware of their co-participants as real and present.

Since we are not measuring physiological linkage directly but rather concepts that it effects this results in the following hypotheses:

H1a: Sharing heartbeats in a connected manner yields more similar variation in emotion than sharing heartbeats in an informational manner.

H1b: Sharing heartbeats in a connected manner yields more feelings of connectedness than sharing heartbeats in an informational manner.

H1c: Sharing heartbeats in a connected manner yields more social presence than sharing heartbeats in an informational manner.

RQ: What are the effects of presenting heartbeat in a connected rather than informational manner on the occurrence of physiological linkage and its associated effects?

METHOD

Design

For this experiment a between subject design was used. The dependent variables are the emotions of the participants, their perceived social presence and connectedness. The independent variable in this experiment is the manner of presentation. A control condition was also implemented, which does not feature any sensing or sharing of heartbeats.

Procedure

Participants were arranged into thirty dyads. For each condition, 10 pairs were used. The participants were always present in the same room and they were instructed to sit at the same table. Informed consent was obtained from all participants before the start of the experiment. Furthermore, they were instructed not to communicate verbally and to try and keep non-verbal communication to a minimum. After the instructions the participants were asked to wear a device that would track their heartbeat, unless they were in the control condition. The participants were randomly assigned to a condition. In each condition they were made to look at the three presented clips while either: holding a pillow, looking at a heartrate visualization on a second screen (see section Apparatus and Materials) or doing nothing extra. The presentation order of the clips were randomized for all dyads. The condition with the pillow is regarded as the connected condition. The pillow supplied participants with tactile feedback of their co-participants' heartbeat. The second screen condition is labelled as the informational condition, in this condition the second

screen gave them visual feedback of their co-participants' heartbeat. After every video clip, the participants filled out a number of self-report questionnaires (see section Survey) which related to their current emotional state. The next clip did not start until both participants were ready to continue. This process was repeated thrice in every condition, once for every clip.

Participants

Sixty students from the Tilburg University participated in the experiment in exchange for course credit. One person was excluded from the dataset as halfway through the experiment they no longer took the experiment seriously and always responded with the left-most option. Since the data consist of couples this resulted in one less dyad for the visual condition. This left 38 women and 21 men in the dataset, with an age between 17-67 years old (M=23.8, SD = 8.4). Every participant either completed or was currently undergoing a college education. Twenty participants were randomly assigned to each of the three conditions.

Stimuli

In this study the stimuli consisted of three video clips, whose duration ranged from 2:42 to 2:52 . The video clips were selected based on three emotions, fear, sadness and happiness. The sad clip can be found here: https://www.youtube.com/watch?v=SU7NGJw0kR8. The clip that is happy can be found here: https://www.youtube.com/watch?v=b0OeM6UUAoI. Lastly, the fearful clip can be found here: https://www.youtube.com/watch?v=ovQk7fd4_Co. Inspiration for these clips came from a research conducted by Gross and Levenson (1995) on the emotions elicited by various clips. After each stimulus, the participants were asked to fill out a questionnaire, more information about this can be found in the section "Survey".

Apparatus and Materials

In both of the conditions that featured the sensing and sharing of heartrate two single-board microcontrollers from the Arduino brand were used. They were equipped with a pulse sensor and were both connected to a different laptop. When placed on the participants' finger, the pulse sensor measured the heartrate by calculating how much infrared light it was able to pick up. Oxygenated and de-oxygenated blood have different optical properties, which makes the reflection of infrared light different during the heartbeat from between the heartbeat. This allows the pulse sensor to monitor how fast the heart is beating.

This information was read with a program called Processing. We made use of an application developed by Y. Gitman (http://pulsesensor.com/pages/processing-visualization). This

application was able to render a visual presentation of heartbeat as displayed in Figure 2. This visual presentation features a picture of the heart that beats with every pulse. In addition to this, a live heartbeat waveform is displayed and the beats per minute are shown in digits. All this information was shown as it was included in the application and it gave intuitively interpretable information to the participants. During the informational condition, these visualizations were displayed on two laptops placed approximately 200 cm in front of each participant. In the connected condition, the heartbeat information which was recorded through processing was translated into a sound which mimics an actual heartbeat. This sound was played through a speaker which we inserted into a pillow. With a high enough volume and level of bass, this caused the pillow to vibrate which not only made it possible to hear the heartbeat but to feel it as well. This device is shown in Figure 3 and 4.

Lastly, the clips were displayed on a projector in front of the experiment room, approximately 2 meters in front of the participants.

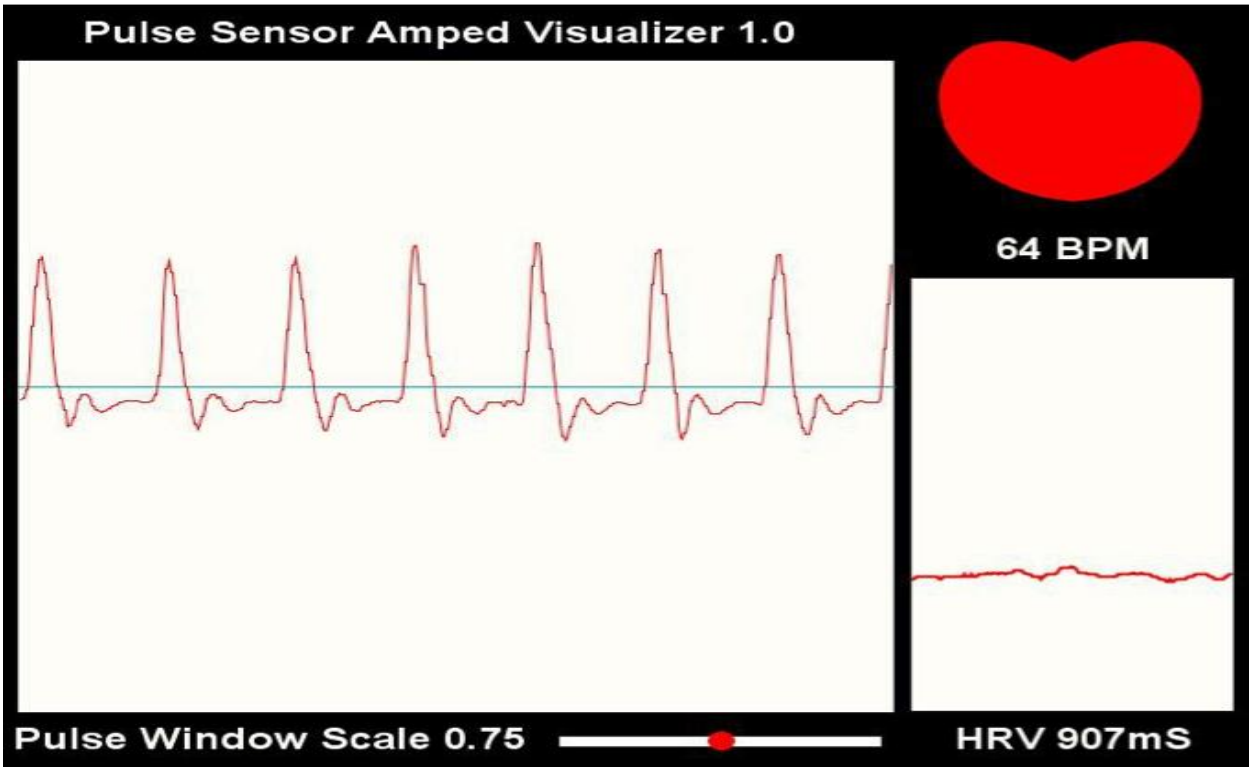

Figure 2. The visual presentation of heartbeat as displayed by Processing.

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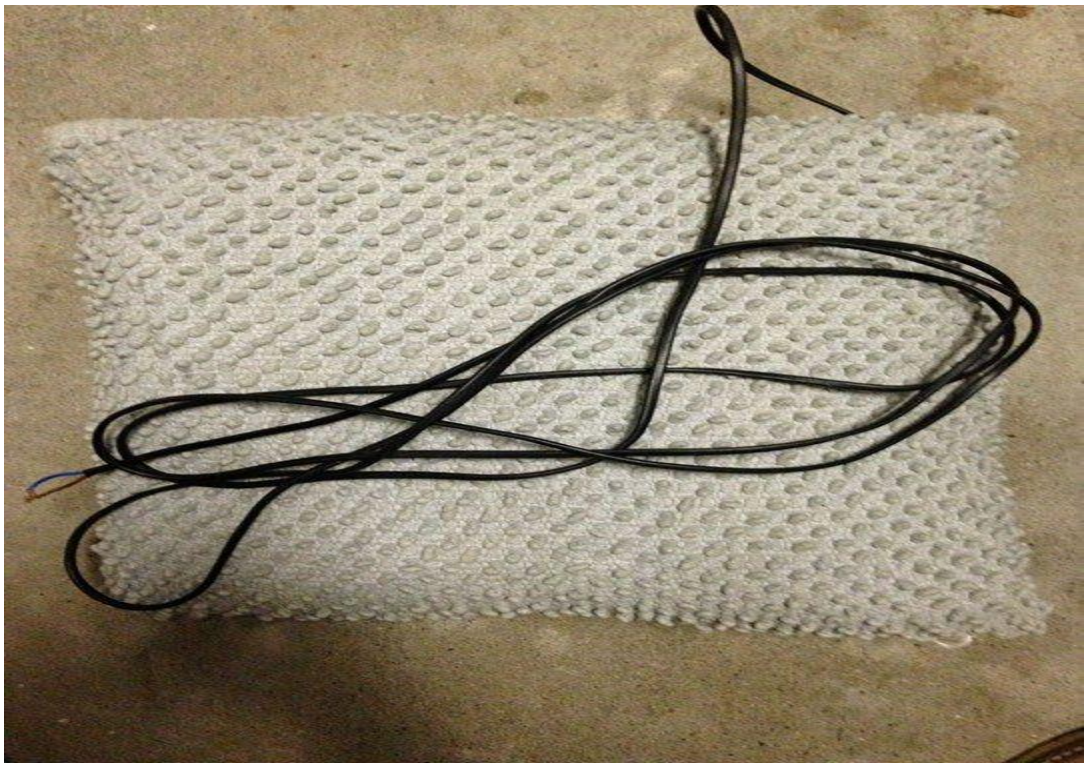

Figure 3 . The pillow device that was used during the connected condition

Figure 4. The speaker that was placed inside the pillow to mimic the sound and movement of the heart

Survey

Measurement of physiological linkage

Since it is very difficult to directly measure physiological linkage, it was measured through a number of constructs which are associated with physiological linkage. These constructs are emotion, connectedness and social presence. The full questionnaire can be found in appendix 1.

Measurement of emotion

In order to measure emotion we asked the participants to fill in a questionnaire which featured 5 emotions on a 7-point Likert scale to assess whether the participants felt happy, sad or fear as these emotions were affiliated with the clips that were displayed during the experiment. Furthermore, we asked the participants whether they were relaxed or tense as we were interested if the measurement of heartrate made them feel either comfortable or uncomfortable. The participants were asked to indicate their emotional state four times. The first time in order to establish a baseline and all subsequent times occurred after they had watched a clip. Afterwards, the differences in emotion between each participant of each pair were observed. In other words, we looked at the absolute differences between the participants that formed a pair together for each perceived emotion. This resulted in three absolute differences, as the baseline measurement was discarded because no sensing or sharing of heartrate took place until the first clip was being viewed. This resulted in fifteen numbers for every pair, three for each emotion.

Measurement of connectedness

Connectedness was measured by providing the participants with four statements, with a Cronbach's alpha of .85, which they could agree or disagree with through a 7-point Likert scale. The participants were asked to fill in these statements three times, once after every clip. The four statements were inspired by those found in the research conducted by Harms and Biocca (2004). These are the statements that were used in the experiment:

- "I felt emotionally connected to the other person"
- "I got an impression of the emotional state of the other person"
- "My emotional state was influenced by the emotional state of the other person"
- "I got the impression that my emotional state was similar to the emotional state of the other person"

Measurement of social presence

Similar to the way connectedness was measured, the participants were given four statements, which had a Cronbach's alpha of .86, to agree or disagree with through a 7-Point Likert scale. Moreover, these statements were also asked three times, once after every clip. They were also inspired by statements that were found in the research conducted by Harms and Biocca (2004). The statements related to social presence are the following:

- "I was conscious of the other person"
- "The other person was conscious of me"
- "I had attention for the other person"
- "The other person had attention for me"

Additional questions of the survey

The participants were also asked a number of other questions, which were not necessarily related to the main question at hand but could still provide interesting information. Firstly, basic questions about their gender, age and education level (completed or current) were asked. Secondly, the participants were asked to share whether they knew one another as we felt that this could be a confound to the experiment. Moreover, the participants were posed a number of questions related to heartbeats, as we were interested to see what they thought about the experiment instead of how it made them feel. Lastly, the participants were asked to state whether they knew what the experiment was about, as knowledge about the experiment could influence the results.

RESULTS

Covariation of emotion

The first hypothesis states that the *connected* manner of presentation would yield a more similar variation in emotion than sharing heartbeats using the *informational* method. In order to determine whether the assumptions are correct we look at the differences in emotion between each participant of each pair. A repeated measures ANOVA was conducted to compare the effects of the manner of presentation and the clips which conveyed a different emotion on the amount of covariation of emotion in the *connected*, *informational* and control condition. The results can be found in Table 1. In order to make the table more readable, only the total means and standard deviations are displayed as opposed to the information regarding each clip.

Condition	Emotion				
	Happiness	Sadness	Fear	Tense	Relaxed
Connected	1.23 (1.07)	0.97 (0.96)	1.30 (1.18)	1.67 (1.40)	1.80 (1.35)
Informational	1.00 (1.77)	1.15 (0.77)	1.07 (1.07)	1.37 (1.21)	1.37 (1.04)
Control	1.07 (1.20)	0.87 (1.01)	1.40 (1.40)	1.70 (1.24)	1.60 (1.45)

Table 1. Means and standard deviations in parentheses of the absolute differences for every emotion and every condition.

If a main effect of condition is found, the post hoc test Tukey HSD is used to see whether the conditions differ significantly from one another.

Covariation of happiness

For the covariation of the emotion happiness, no statistically significant interaction was found between the kind of clip and the manner of presentation of heartbeats, $F(4, 52) = 0.20$, $p = .94$, partial $\eta^2 = .015$. Furthermore, the main effect of the different clips showed no statistically significant difference in mean covariation of happiness between the various clips, $F(2, 52) = 0.17$, $p = .84$, partial $\eta^2 = .007$. Lastly, the main effect of condition showed that there was no statistically significant difference in mean covariation of happiness between the manners of presentation of heartbeats $F(2, 26) = 0.29$, $p = .75$, partial $\eta^2 = .022$.

Covariation of sadness

Regarding the covariation of the emotion sadness, no statistically significant interaction was found between the kind of clip and the manner of presentation of heartbeats, $F(4, 52) = 1.23$, $p = .31$, partial $\eta^2 = .086$. Furthermore, the main effect of the different clips showed no statistically significant difference in mean covariation of sadness between the various clips, $F(2, 52) = 0.43$, $p = .65$, partial $\eta^2 = .016$. Lastly, the main effect of condition showed that there was no statistically significant difference in mean covariation of sadness between the manners of presentation of heartbeats $F(2, 26) = 0.64$, $p = .53$, partial $\eta^2 = .047$.

Covariation of feeling fear

A statistically significant interaction was found between the kind of clip and the manner of presentation, $F(4, 52) = 2.75$, $p = .04$, partial $\eta^2 = .175$. There was a statistically significant difference between the conditions during the presentation of the scary clip, $F(2, 26) = 7.22$, $p = .01$, partial $\eta^2 = .282$. The covariance of fear was statistically significantly greater in the control condition ($M = 2.40$, *SE*

= 0.38) than in the *informational* condition (*M* = 0.67, *SE* = 0.40, *p* = .01). Furthermore, the covariance of fear during the scary clip was not significantly different between the *connected* condition (*M* = 1.40, *SE* = 0.38) and the *informational* condition (*M* = 0.67, *SE* = 0.40, *p* = .39). The *connected* (*M* = 1.40, *SE* = 0.38) and control conditions condition (*M* = 2.40, *SE* = 0.38, *p* = .17) were also not significantly different. No statistically significant differences between the conditions were found during the sad clip ($F(2, 26) = 0.74$, $p = .49$, partial $\eta^2 = .054$) or during the happy clip ($F(2, 26) = 0.03$, $p = .97$, partial $\eta^2 = .002$).

Covariation of being tense

No statistically significant interaction was found between the kind of clip and the manner of presentation of heartbeats, $F(4, 52) = 0.34$, $p = .85$, partial $\eta^2 = .026$. Furthermore, the main effect of the different clips showed no statistically significant difference in mean covariation of being tense between the various clips, $F(2, 52) = 0.63$, $p = .54$, partial $\eta^2 = .023$. Lastly, the main effect of condition showed that there was no statistically significant difference in mean covariation of being tense between the manners of presentation of heartbeats $F(2, 26) = 0.40$, $p = .67$, partial $\eta^2 = .030$.

Covariation of being relaxed

No statistically significant interaction was found between the kind of clip and the manner of presentation of heartbeats, $F(4, 52) = 0.99$, $p = .42$, partial $\eta^2 = .071$. Furthermore, the main effect of the different clips showed no statistically significant difference in mean covariation of being relaxed between the various clips, $F(2, 52) = 0.65$, $p = .53$, partial $\eta^2 = .024$. Lastly, the main effect of condition showed that there was no statistically significant difference in mean covariation of being relaxed between the manners of presentation of heartbeats $F(2, 26) = 0.65$, $p = .53$, partial $\eta^2 = .048$.

Connectedness

The second hypothesis states that the *connected* condition would yield more feelings of connectedness than sharing heartbeats in an *informational* manner. The participants were asked a series of questions to measure whether they felt connected to one another.

A repeated measures ANOVA was conducted to compare the effects of the manner of presentation and the clips which conveyed a different emotion on the amount of perceived connectedness in the *connected, informational* and control condition. There was no statistically

significant interaction between the kind of clip and the manner of presentation of heartbeats, $F(4, 112) = 1.54$, $p = .20$, partial $\eta^2 = .052$. The main effect of the different clips showed a statistically significant difference in mean connectedness between the various clips, $F(2, 112) = 3.41$, $p = .04$, partial $\eta^2 = .057$. The main effect of condition showed that there was a statistically significant difference in mean connectedness between the manners of presentation of heartbeats $F(2, 56) = 4.59$, $p = .01$, partial $\eta^2 = .141$. The marginal means for the connectedness score were 4.14 ($SE = 0.17$) for the sad clip and 3.75 ($SE = 0.16$) for the scary clip, a statistically mean difference of 0.40, 95% CI [0.01, 0.79], $p = .049$. No statistically significant differences were found between the sad ($M = 4.14$, $SE = 0.17$) and the happy clips ($M = 3.79$, $SE = 0.14$, $p = .13$) or the scary ($M = 3.75$, $SE = 0.16$) and happy clips ($M = 3.79$, $SE = 0.14$, $p = 1.00$). The means and standard deviations are shown in Table 2.

	Clip			
Condition	Scary	Sad	Happy	Total
Connected	4.06 (1.18)	4.04 (1.03)	3.74 (1.00)	3.95 (0.69)
Informational	3.17 (1.09)	3.87 (1.27)	3.18 (0.89)	3.41 (0.79)
Control	4.01 (1.39)	4.53 (1.51)	4.27 (1.32)	4.33 (1.27)

Table 2. The means of connectedness (and the standard deviation in parentheses) for every fragment and every condition including the total means per condition.

The post hoc test Tukey HSD is used to see whether the conditions differ significantly from one another. According to the post hoc test, the means of the control condition ($M = 4.33$, $SD = 1.27$) are significantly higher than the means of the *informational* condition ($M = 3.41$, $SD = 0.79$, $p = .03$). No significant differences were found between either the *connected* ($M = 3.95$, $SD = 0.69$) and *informational* ($M = 3.41$, $SD = 0.79$, $p = .19$) conditions or the *connected* ($M = 3.95$, $SD = 0.69$) and control conditions ($M = 4.33$, $SD = 1.27$, $p = .42$).

Social presence

The third hypothesis states that sharing heartbeats through a *connected* manner would result in a greater feeling of social presence than sharing heartbeats through an *informational* manner. Similar to the construct related to connectedness, we asked the participants four questions concerning social presence.

A repeated measures ANOVA was conducted to compare the effects of the manner of presentation and the clips which conveyed a different emotion on the amount of perceived social presence in the *connected, informational* and control condition. There was no statistically significant interaction between the kind of clip and the manner of presentation of heartbeats, $F(4, 112) = 0.27$, $p = .90$, partial $\eta^2 = .009$. The main effect of the different clips showed no statistically significant difference in mean social presence between the various clips, $F(2, 112) = 2.43$, $p = .09$, partial $\eta^2 = .042$. The main effect of condition showed that there was a statistically significant difference in mean social presence between the manners of presentation of heartbeats $F(2, 56) = 4.11$, $p = .02$, partial $\eta^2 = .128$. The means and standard deviations are displayed in Table 3.

	Clip			
Condition	Scary	Sad	Happy	Total
Connected	4.51 (0.86)	4.59 (0.64)	4.74 (0.73)	4.61 (0.62)
Informational	3.82 (1.17)	4.09 (0.94)	4.07 (0.92)	4.00 (0.77)
Control	4.46 (1.22)	4.58 (1.12)	4.86 (1.11)	4.63 (0.94)

Table 3. The means of social presence (and the standard deviation in parentheses) for every fragment and every condition, including the total means per condition.

Furthermore, the post hoc test Tukey HSD is used to see whether the conditions differ significantly from one another. According to post hoc test in the Repeated Measures ANOVA, the means of perceived social presence are significantly higher in the *connected* condition ($M = 4.61$, $SD = 0.62$) than those in the *informational* condition ($M = 4.00$, $SD = 0.77$), $p = .05$. Moreover, the means of the control condition ($M = 4.63$, $SD = 0.94$) are significantly higher than those in the *informational* condition ($M = 4.00$, $SD = 0.77$, $p = .04$). No significant differences were found between the *connected* ($M = 4.61$, $SD = 0.62$) and control conditions ($M = 4.63$, $SD = 0.94$, $p = .996$).

DISCUSSION AND CONCLUSION

Summary of the results and links to previous work

This study we have set out to answer whether the manner of presentation has an effect on physiological linkage. The results indicate that the first hypothesis cannot be confirmed. We did not find that the emotions of the participants in the *connected* condition were more closely related than those in the *informational* condition. Furthermore, both conditions did not differ significantly

from the control condition. This means that displaying the heartrate had no influence on the emotional state of the participants, only the clips themselves caused a variation in emotion. Subsequently, the emotions of the participants did not converge over the course of the experiment.

Additionally, we expected to find a higher amount of perceived connectedness in the *connected* condition compared to the *informational* condition. Instead we measured a significantly higher amount of felt connectedness during the control condition. Perhaps this can be explained through the results found by Janssen et al. (2010). In their research, participants compensated for the intimate nature of heartbeat sharing by physically distancing themselves from the other participants. In this research, it is possible that participants were overwhelmed by the intimate nature of sharing their heartbeat. Subsequently, since they perceived the intimacy as misplaced, they felt less connected to their partners. This occurred during the conditions that featured heartbeat sharing and not in the control condition. However, we asked the participants whether they perceived the sharing of heartbeat as intimate and on average they did perceive it as intimate, but not overwhelmingly so.

Finally, the third hypothesis can partially be confirmed. The participants did perceive a higher amount of social presence in the *connected* condition compared to the *informational* condition. However, the results of the *connected* condition did not differ significantly from the control condition. These results show that the *connected* condition did not increase the amount of perceived social presence. Instead, the *informational* condition has a negative effect on whether people feel social presence. This manner of presentation seems to offer no communicative value because if it did people would be more aware of one another. Seeing the lines that formed the others person's heartrate did not invoke a higher amount of social presence in the participants. Perhaps this manner of presentation is too clinical and informative and not associated with another human being. In this study, we have previously compared the *informational* condition to a distant condition, which these results uphold. Furthermore, we stated that the *connected* condition could be perceived as an intimate experience, which is not supported by the results concerning social presence.

In conclusion, we tried to measure physiological linkage indirectly by measuring the covariance of emotions, the perceived social connectedness and the perceived social presence. Since only the third hypothesis was partially confirmed we can state that the presentation method of heartbeat sharing does not have an effect on physiological linkage.

Limitations and alternative explanations

For this experiment, we have made more use of our friends in the control condition than in the other two conditions. The reason for this being that the control condition took less time as we did not have to set up any of the heartrate apparatus and such an experiment could be more easily conducted in between two other experiments that were planned some time before. This could have had a negative effect on the internal validity of the experiment. Moreover, our friends usually had some connection to one another which could have skewed the results of their felt connectedness or social presence. However, to counter this we have made a division of the data between people who knew one another beforehand and those who did not. Analyzing the data in this manner did not produce a different result. We feel that this is still a limitation to take into account as there were only two people who took part of the control condition who did not know one another.

Another aspect that has a negative effect on the internal validity is the fact that different rooms were used to conduct the experiment. The experiments were conducted at the University of Tilburg and we did not have exclusive access to a room. This caused some experiments to be conducted in a hotter classroom or the apparatus might have been set up in differing locations every time.

A final aspect that could have led to a lower internal validity is the response bias. Asking people for their emotional state can lead to people lying as they can be hesitant to admit that they are scared or sad. Moreover, it is possible that people are not aware precisely which emotions and the intensity of these emotions they are currently experiencing.

In addition to a higher internal validity, the experiment requires a higher external validity. The majority of the participants were female and were students of the University of Tilburg. In future research a broader target group would be recommended in order to increase the external validity.

Another limitation of the experiment is similar to the limitation found in the experiment conducted by Järvelä et al. (2016). In that experiment the visual presentation of the heartbeat was difficult to see and was distracting from the clips that were shown. In this experiment, we displayed the visual heartrates on two screens, one in front of each participant, while we displayed the clips on a projector in the front of the classroom. This set up could have made it difficult for the participants to focus on both the movie clips and the visual presentation of their partners' heartbeat. This could have been a confound for a decrease in felt social presence as people became less aware

of their partner's heartbeat.

It is possible that we found that the sensing and sharing of heartbeat does not result in a convergence of emotions because heartbeats are not attributable to a single source which makes it difficult to translate its underlying meaning (Ravaja, 2004). People can have an idea what the heartbeat of another person is communicating, but it does not necessarily have to be correct. In the current experiment, this could have resulted in participants being unsure what the heartbeat of their partner was telling them.

As an alternative explanation, it could be possible that sharing heartbeats in general is a negative experience, as this study has found a high feeling of connectedness and social presence during the control condition. In this case, a connected design would mitigate some of this negativity as the level of connectedness is similar to the control condition.

Finally, an alternate explanation for not finding a significant difference in emotional convergence in the various conditions could be that the emotional response was dictated too highly by the movie clips themselves. Perhaps the clips already made people feel a certain way leaving no room for the sharing and sensing of heartbeat to have any influence on the emotions of the participants.

Future work

For future studies it is recommended that the experiments take up a longer amount of time. This gives the participants the time to adjust to the new form of communication which could provide more meaningful results. Moreover, we recommend that more professional and accurate devices are used. With such equipment, it would also be possible to store the heartrate data and analyze whether physiological linkage occurred, circumventing the need to ask people to report their own feelings. In the current experiment, the devices were self-made and therefore not fine-tuned to provide accurate displays of heartbeats. Instead these devices provided an estimation of the participants' heartrate, which was appropriate for the intuitive interpretation we were interested in. Additionally, we recommend using clips that do not already result in a strong emotional response, as this could overwrite the influence of the sharing and sensing of the heartbeat.

An interesting way of conducting this experiment could be with the use of virtual reality. Making use of virtual reality would assist with a few things. For example, participants would be unable to look at one another and could not communicate verbally as they would be wearing headphones. The participants would not need to watch a clip but could instead either play a game

or just sit in a virtual room. The informational condition would display the heartrate somewhere on the overlay of the program so that participants would always see it no matter where they looked. Sensing the heartbeat of another person without knowledge of what they are currently experiencing could produce interesting results, as during the current experiment, the participants were always aware of what the other person was experiencing, as they were watching the same clip. Finally, it would matter less if the experiment was conducted in various rooms.

Conclusion

In conclusion, this study shows that with the current experimental setup, the manner of presentation of heartbeat does not influence physiological linkage, nor does it influence the construct that are associated with it such as the convergence of emotions, connectedness and social presence. Perhaps in the future when people will be more familiar with the idea of sharing their heartbeats and an application is invented which enhances the experience, the communicative value of sensing someone's heartbeat would become apparent.

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APPENDIX 1

Questionnaire for the connected and informational condition, the control condition used the same questionnaire with exclusion of the questions related to heartrate. The questionnaire was conducted in Dutch.

Koppel - Koppelnummer

Participant - Participantnummer

Conditie - Conditie

- ❍ Gescheiden (1)
- ❍ Samen (2)
- ❍ Met beeldscherm (3)
- ❍ Zonder beeldscherm (4)

Info 1 - Vul onderstaande vragen in.

Geslacht - Wat is uw geslacht

- ❍ Vrouw (1)
- ❍ Man (2)

Leeftijd - Wat is uw leeftijd

Opleiding - Wat is uw hoogst afgeronde of huidige opleiding?

- ❍ Basisonderwijs (1)
- ❍ Voortgezet onderwijs (2)
- ❍ Middelbaar beroepsonderwijs (MBO) (3)
- ❍ Hoger beroepsonderwijs (HBO) (4)
- ❍ Wetenschappelijk onderwijs (WO) (5)

Bekend met ander? - Kent u de persoon waarmee u aan het onderzoek deelneemt?

- ❍ Ja (1)
- ❍ Nee (2)

Mate van bekendheid - Indien u de andere persoon kent, beschrijf dan hieronder de aard van uw relatie.

- ❍ Vriendschappelijk (1)
- ❍ Romantisch (2)
- ❍ Professioneel (3)
- ❍ Anders: (4) _____

Baseline emotie - Hieronder wordt u kort bevraagd over uw gemoedstoestand.

baseline emo - U voelt zich momenteel

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Blij (1)	❍	❍	❍	❍	❍	❍	❍
Verdrietig (2)	❍	❍	❍	❍	❍	❍	❍
Bang (3)	❍	❍	❍	❍	❍	❍	❍
Gespannen (4)	❍	❍	❍	❍	❍	❍	❍
Ontspannen (5)	❍	❍	❍	❍	❍	❍	❍

Start film 1 - info U gaat nu naar het eerste fragment kijken. De experiment leider zal het fragment starten.

Vragen verbonden f1 - Geef aan in hoeverre deze stellingen accuraat waren tijdens het kijken van het filmpje.

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Ik voelde me emotioneel verbonden met de andere persoon (1)	❍	❍	❍	❍	❍	❍	❍
Ik kreeg een indruk van de emotionele toestand van de andere persoon (2)	❍	❍	❍	❍	❍	❍	❍
Mijn emotionele toestand werd beïnvloed door de emotionele toestand van de andere persooon (3)	❍	❍	❍	❍	❍	❍	❍
Ik had het gevoel dat mijn emotionele toestand aansloot bij die van de andere persoon (4)	❍	❍	❍	❍	❍	❍	❍

Vragen hartslag f1 - Geef aan in hoeverre deze stellingen accuraat waren tijdens het kijken van het filmpje.

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Ik besteedde aandacht aan de hartslag van de ander (1)	❍	❍	❍	❍	❍	❍	❍
Ik werd beïnvloed door de hartslag van de ander (2)	❍	❍	❍	❍	❍	❍	❍
Ik had het gevoel dat ik kon communiceren met de ander door middel van de hartslaginformatie (3)	❍	❍	❍	❍	❍	❍	❍
Ik besteedde meer aandacht aan het filmfragment dan aan de hartslag van de ander (4)	❍	❍	❍	❍	❍	❍	❍
Ik heb informatie gehaald uit de hartslag van de ander (5)	❍	❍	❍	❍	❍	❍	❍
Ik vond het storend om de harstlaginformatie van de ander te krijgen (6)	❍	❍	❍	❍	❍	❍	❍
Ik vond het delen van de hartslaginformatie intiem (7)	❍	❍	❍	❍	❍	❍	❍

Emo na f1 - Tijdens het kijken van het fragment voelde u zich

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Blij (1)	❍	❍	❍	❍	❍	❍	❍
Verdrietig (2)	❍	❍	❍	❍	❍	❍	❍
Bang (3)	❍	❍	❍	❍	❍	❍	❍
Gespannen (4)	❍	❍	❍	❍	❍	❍	❍
Ontspannen (5)	❍	❍	❍	❍	❍	❍	❍

Social pres f1 - Geef aan in hoeverre deze stellingen accuraat waren tijdens het kijken van het filmpje.

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Ik was me bewust van de andere persoon (1)	❍	❍	❍	❍	❍	❍	❍
De andere persoon was zich bewust van mij (2)	❍	❍	❍	❍	❍	❍	❍
Ik had aandacht voor de andere persoon (3)	❍	❍	❍	❍	❍	❍	❍
De andere persoon had aandacht voor mij (4)	❍	❍	❍	❍	❍	❍	❍

Start film 2 info - U gaat nu naar het tweede fragment kijken. De experiment leider zal het fragment starten.

Vragen verbonden f2 - Geef aan in hoeverre deze stellingen accuraat waren tijdens het kijken van het filmpje.

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Ik voelde me emotioneel verbonden met de andere persoon (1)	❍	❍	❍	❍	❍	❍	❍
Ik kreeg een indruk van de emotionele toestand van de andere persoon (2)	❍	❍	❍	❍	❍	❍	❍
Mijn emotionele toestand werd beïnvloed door de emotionele toestand van de andere persooon (3)	❍	❍	❍	❍	❍	❍	❍
Ik had het gevoel dat mijn emotionele toestand aansloot bij die van de andere persoon (4)	❍	❍	❍	❍	❍	❍	❍

Vragen hartslag f2 - Geef aan in hoeverre deze stellingen accuraat waren tijdens het kijken van het filmpje.

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Ik besteedde aandacht aan de hartslag van de ander (1)	❍	❍	❍	❍	❍	❍	❍
Ik werd beïnvloed door de hartslag van de ander (2)	❍	❍	❍	❍	❍	❍	❍
Ik had het gevoel dat ik kon communiceren met de ander door middel van de hartslaginformatie (3)	❍	❍	❍	❍	❍	❍	❍
Ik besteedde meer aandacht aan het filmfragment dan aan de hartslag van de ander (4)	❍	❍	❍	❍	❍	❍	❍
Ik heb informatie gehaald uit de hartslag van de ander (5)	❍	❍	❍	❍	❍	❍	❍
Ik vond het storend om de harstlaginformatie van de ander te krijgen (6)	❍	❍	❍	❍	❍	❍	❍
Ik vond het delen van de hartslaginformatie intiem (7)	❍	❍	❍	❍	❍	❍	❍

Emo na f2 - Tijdens het kijken van het fragment voelde u zich

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Blij (1)	❍	❍	❍	❍	❍	❍	❍
Verdrietig (2)	❍	❍	❍	❍	❍	❍	❍
Bang (3)	❍	❍	❍	❍	❍	❍	❍
Gespannen (4)	❍	❍	❍	❍	❍	❍	❍
Ontspannen (5)	❍	❍	❍	❍	❍	❍	❍

Social pres f2 - Geef aan in hoeverre deze stellingen accuraat waren tijdens het kijken van het filmpje.

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Ik was me bewust van de andere persoon (1)	❍	❍	❍	❍	❍	❍	❍
De andere persoon was zich bewust van mij (2)	❍	❍	❍	❍	❍	❍	❍
Ik had aandacht voor de andere persoon (3)	❍	❍	❍	❍	❍	❍	❍
De andere persoon had aandacht voor mij (4)	❍	❍	❍	❍	❍	❍	❍

Start film 3 info - U gaat nu naar het derde fragment kijken. De experiment leider zal het fragment starten.

Vragen verbond f3 - Geef aan in hoeverre deze stellingen accuraat waren tijdens het kijken van het filmpje.

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Ik voelde me emotioneel verbonden met de andere persoon (1)	❍	❍	❍	❍	❍	❍	❍
Ik kreeg een indruk van de emotionele toestand van de andere persoon (2)	❍	❍	❍	❍	❍	❍	❍
Mijn emotionele toestand werd beïnvloed door de emotionele toestand van de andere persooon (3)	❍	❍	❍	❍	❍	❍	❍
Ik had het gevoel dat mijn emotionele toestand aansloot bij die van de andere persoon (4)	❍	❍	❍	❍	❍	❍	❍

vragen hartslag f3 - Geef aan in hoeverre deze stellingen accuraat waren tijdens het kijken van het filmpje.

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Ik besteedde aandacht aan de hartslag van de ander (1)	❍	❍	❍	❍	❍	❍	❍
Ik werd beïnvloed door de hartslag van de ander (2)	❍	❍	❍	❍	❍	❍	❍
Ik had het gevoel dat ik kon communiceren met de ander door middel van de hartslaginformatie (3)	❍	❍	❍	❍	❍	❍	❍
Ik besteedde meer aandacht aan het filmfragment dan aan de hartslag van de ander (4)	❍	❍	❍	❍	❍	❍	❍
Ik heb informatie gehaald uit de hartslag van de ander (5)	❍	❍	❍	❍	❍	❍	❍
Ik vond het storend om de harstlaginformatie van de ander te krijgen (6)	❍	❍	❍	❍	❍	❍	❍
Ik vond het delen van de hartslaginformatie intiem (7)	❍	❍	❍	❍	❍	❍	❍

emo na f3 - Tijdens het kijken van het fragment voelde u zich

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Blij (1)	❍	❍	❍	❍	❍	❍	❍
Verdrietig (2)	❍	❍	❍	❍	❍	❍	❍
Bang (3)	❍	❍	❍	❍	❍	❍	❍
Gespannen (4)	❍	❍	❍	❍	❍	❍	❍
Ontspannen (5)	❍	❍	❍	❍	❍	❍	❍

social pres f3 - Geef aan in hoeverre deze stellingen accuraat waren tijdens het kijken van het filmpje.

	Zeer mee oneens (1)	Mee oneens (2)	Een beetje mee oneens (3)	Niet eens en niet oneens (4)	Een beetje mee eens (5)	Mee eens (6)	Zeer mee eens (7)
Ik was me bewust van de andere persoon (1)	❍	❍	❍	❍	❍	❍	❍
De andere persoon was zich bewust van mij (2)	❍	❍	❍	❍	❍	❍	❍
Ik had aandacht voor de andere persoon (3)	❍	❍	❍	❍	❍	❍	❍
De andere persoon had aandacht voor mij (4)	❍	❍	❍	❍	❍	❍	❍

Info vermoeden - Vul tot slot onderstaande vragen in:

vermoedens check - Heeft u een idee van waar het experiment over gaat, of wat er onderzocht wordt?

❍ Ja (1)
❍ Nee (2)

Vermoedens beschrijf - Indien u dat heeft, probeer dat dan zo uitgebreid mogelijk te beschrijven.

contactgegevens - Indien u op de hoogte gehouden wilt worden over dit onderzoek, vult u dan hieronder uw e-mailadres in.

Afsluiting info - Hiermee is een einde gekomen aan het experiment. Hartelijk dank voor uw deelname.