Behavioural Strategies and their effectiveness in facilitating Psychophysiological Synchronization
a research protocol and literature review

Heitzer, F.

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Behavioural Strategies and their effectiveness in facilitating Psychophysiological Synchronization: a research protocol and literature review

Floyd Heitzer - 0875379
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Thesis is written for MSc. Human-Technology Interaction
Faculty IEIS

First supervisor: Wijnand Ijsselsteijn
Group: Human-Technology Interaction
Second assessor: Milou Feijt
Group: Human-Technology Interaction
Third supervisor: Joyce Westerink
Group: Human-Technology Interaction / Research Phillips

Abstract:

Psychophysiological synchronization is the phenomenon that two or more people have significant overlap or synchronization in the signals emerging from autonomous nervous system activity (e.g., heart rate, skin conductance response). This synchronization of bio-signals has been proven to be correlated with several positive effects, such as empathy, team work ability and the building of trust between therapist and client. In the field of research into psychophysiological synchronization, various methods are being used to facilitate the phenomenon. With some studies finding it difficult to make dyads synchronized when they need it, guidance is needed for determining what behavioural strategies should be used. This report presents a literature search, categorization and examination of different behavioural procedures suggested or used in the field. To do this, two studies are described: a qualitative study set-up and a literature study. In the qualitative set-up participants could freely come up with procedures to synchronize with their interaction partner, while real-time biofeedback was being shown to inform them of their synchronization status. This study could not be performed in full, but trial sessions were done and used for analysis. The biofeedback being shown to the participants was however hard to interpret for them and they had difficulty adjusting to it. Through a literature study we reviewed the procedures currently used in the field. These articles were used to formulate general behavioural strategies. From the eight general behavioural strategies that were found, “conversation”, “psychotherapy-session” and “playing video games” were found to be most effective in facilitating psychophysiological synchronization.

Keywords: Psychophysiological Synchronization, Bio-Feedback, Behavioural Strategies

Summary

Introduction

Any person "experiencing" an emotion, be it anger, sadness or boredom, is in an affective state. The affective state of a person is experienced cognitively, behaviourally, but also physiologically. This is expressed by the body through physiological signals like heart rate and skin conductance. Emotional contagion (or behavioural contagion) is a psychological concept where the affective state of one person influences and triggers another person to adapt and get into a similar affective state. This can be seen for example in an experiment by Weber and Quiring (2019), where participants were more likely to laugh at a video when the partner they watched it with also laughed, they would also rate the video as funnier. The reverse was also true; a partner showing no emotions made the participant less emotional as well. As shows, the affective state changes depending on the affective state of the influencer, this changing affective state also leads to the subsequent physiological state of the body to adapt.

"Psychophysiological synchronization" is a phenomenon where one or more of the physiological signals of one person are, to some degree, in unison with one or more physiological signals of another person, implying that the dyad is in a similar affective state to each other.

Some research into "psychophysiological synchronization" that has been conducted reveals that existence of the phenomenon can indicate positive social interactions. It was found that in blind dates, were people only saw each other for one minute, it was not visual gaze that signified attraction, but instead synchrony in heart rate and skin conductance could predict attraction between partners.(Prochazkova et al., 2019).

A preceding study into psychophysiological synchronization tried to show a link between synchrony and empathy while feedback was given to the participants on the level of synchrony (Laar, 2019), but this experiment was limited by problems to evoke a sufficient level of synchrony to analyse the mediation. Whereas there appears to be sufficient evidence in support of the existence of interpersonal psychophysiological synchrony, the robustness or fragility of this effect, its underlying mechanisms, dyadic behavioural correlates, and the extent to which it can be placed under collaborative control are still very much open questions. So far, in case synchronization was generated, it was very inconsistent. This might be possibly because some behavioral strategies may work better than others or were not executed correctly. This study aims to shed light on these questions. Furthermore, this study investigates if giving feedback can increase understanding between dyads and subsequently increase synchrony.

The following Research question were formulated:

"What behavioural strategies can dyads use to facilitate synchronization between psychophysiological affective states?"

With the following sub-questions:

"How can behavioural strategies that facilitate PS best be used?"

and

"How does the direct feedback affect the behavior and the perception of synchrony of the dyads?"

Qualitative set-up

The basic idea behind the study was to seat two people and mount physiological sensors to their bodies. Using the data, a PS score is calculated and displayed on a computer screen as feedback. Participants are given example tasks to complete that could possibly improve their PS score, or they are asked to formulate their own methods to improve their PS score. They are asked to come up with and complete multiple tasks in a limited amount of time, and they are permitted to use any means available to them, such as a computer or their phones. The research concluded with a brief discussion of what the experiment's participants thought of the experiment.

The dyads often performed breathing exercises, played video games, cooperative and competitive. on the computer or phone and looked up media, such as websites and YouTube videos, on the computer. Participants found it hard to use the feedback shown to them and were often confused regarding the PS scores. Participants mentioned that cooperative tasks and tasks that involved some forms of mimicry were the tasks where they felt most in sync.

Literature study

The literature study consisted of three stages: *The search process stage, The data extraction stage* and *The data analysis stage.*

In the search process stage articles were searched and filtered to obtain a pool of literature suitable for analysis.

The following criteria were used to filter in the literature search

- A PS facilitating behavioural strategy is utilized in the experiment.
- Some sort of ECG or GSR measurements are used in the experiment.
- The participant demographic group being utilized must be able to perform most other PS facilitating behavioural strategies.
- The behavioural strategies being performed must be somewhat replicable in a general setting.
- The PS data collected is between a few participants rather than a large group.
- Too little information regarding the PS facilitating behavioural strategy is present.

A total of 53 articles remained

In the data extraction stage the following variables were extracted from the pool of articles:

- *Presence of PS*
- *Effect*
- *Physiological measurement*
- *Time-frame of behavioural strategy procedure*
- *Data analysis Time-frame*
- *Sample size*
- *Description*
- *Comments*
- *Demographic*

After the analysis was performed there were a couple of procedures that were formulated. They are listed below alongside their success rate in facilitating PS.

Behavioural strategy	**Feature(s) in articles**	**Facilitating PS success percentage**
Conversation	14	94%
Psychotherapy-session	9	100%
Playing video games	8	88%
Imitation tasks	4	75%
Gazing	4	100%
Playing	3	100%
Rhythmic Tasks	3	66%
Miscellaneous tasks	10	NA

"Conversation", "Psychotherapy-session" and "Playing video games" were the three procedures with the most evidence of being successful in facilitating PS. The "conversation" procedure can best be performed by asking the dyad to talk about a shared past experience, preferably one which featured a high level of conflict. The conversation topic does not have to be positive or negative per se. This is an effective procedure to use with people that are very familiar with each other (Couples, Friends, Family etc.). Psychotherapy-sessions works best for dyads that have high therapeutic alliance. Playing video games should most likely be in a cooperative context, where the focus is on the players themselves and less on the environment presented in the game. This can be achieved by choosing a game that does not feature any AI agents in the game and has minimal interaction with other variables.

Several limitations were found in the study. In the qualitative study there were problems with participants being confused with the PS scores. In the literature study there was likely a large publication bias which made comparing behavioural strategies hard. The studies were also hard to use due to many articles not concretely comparing PS levels between baselines and the PS facilitating procedures.

Conclusion

In this report there was a search and examination of various behavioural strategies. To do this, two studies were designed and performed: a qualitative set-up and a literature study. Using clustering, several general behavioural strategies were found, including: gazing, conversation, psychotherapy-session, playing video games, imitation task, playing, rhythmic tasks and miscellaneous tasks. Most evidence for effectiveness in facilitating PS was found for conversation, psychotherapy-session and playing video games. The study found that each behavioural strategy had unique applications and contexts in which they would be most useful. Finally, the study found that dyads had a hard time interpreting bio-feedback and using it to facilitate PS between themselves.

Contents

1. Introduction

The range of human behaviour consists not only of behaviours derived from reason and conscious decision making; they also occur naturally, from the subconscious or by impulse. Infants have no to very little previously learned experiences to draw from when they act, nor are they very deliberate or contemplative in how they should behave. Therefore it is fascinating that babies are naturally inclined to behaviours such as mimicry, gazing and imitation of sounds or faces (Moore, 1977). Humans are naturally appealed by synchrony with others; research shows they are more empathic when others portray similar behaviour as them (Prochazkova & Kret, 2017). This subconscious appeal to synchrony with others is seen in all of human society in situations such as people copying each other's pose when talking to someone, the act of dancing in synchrony to a disco song and, to some extent, yawning (Palagi et al., 2009). In fact, yawning contagion is argued to be related to empathy in baboons, but also in humans (Palagi et al., 2009). This raises an interesting question; can synchronization be artificially facilitated by performing certain behaviours? When individuals synchronize on a behavioural level it is beneficial for creating empathy, but there is more to synchronization of human mental states than just yawning; the synchronization of thoughts, emotions, heartbeats and affective states in general will be touched upon in this report in the form of "Psychophysiological Synchronization".

In this report, the concept of "Psychophysiological Synchronization" (from now on referred to as "PS") will be explored, and an effort will be made to facilitate this phenomenon in an experimental setting in a structured manner. To start, the fundamentals of what PS is and how and why it occurs will be established. The prevailing research, methods and procedures of the PS research field and issues surrounding PS will be explored. The idea of artificially generating PS using certain procedure or behavioural strategies will be introduced and extrapolated upon. Towards the end of the Introduction, we will cover how PS and biofeedback are combined in applications. Three research questions are then formulated that guide the scientific direction of the paper. Two studies are described which were designed to address these questions: a qualitative set-up (which could not be executed in full due to the COVID-19 pandemic and its associated lockdown measures), and a literature review. In the results section there is an attempt at answering the three research questions using information gathered in the studies. Finally, a discussion section is presented where the answers to the research questions are reviewed and summarized, as well as a discussion of limitations of the performed studies, and a consideration of future implications and a conclusion.

1.1. The fundamentals of Psychophysiological Synchronization

1.1.1. Affective States and their physiological basis

The concept of humans feeling and experiencing emotion is called "affect" (Hogg, Abrams, & Martin, 2010). Affect is often contrasted with mood, where affect is the more intense short-term experience, and mood refers to the long-term and generally less intense experience. Affect is further defined by different dimensions: Arousal, valence, and mmotivational intensity (Harmon-Jones et al., 2013). Humans likely evolved affect to help in interacting with stimuli, since affect high in motivational intensity helps to focus the cognitive and behavioural apparatus (Harmon-Jones et al., 2013). In practice this would mean for example, that if a

subject is “fearful”, which is a motivationally high affect, more cognitive resources can be allocated to dealing with the stimuli that caused the fear affect. Being able to concentrate on your source of fear will logically increase your chances of survival. With this we are introduced to the concept that the emotions that we experience can affect our brain and body in significant ways.

Any person experiencing an emotion, be it anger, sadness or boredom, is in an affective state. The affective state of a person is experienced cognitively, behaviourally, but also physiologically (Scollo et al., 2014). The physiological response associated with the affective state can be explained by the three earlier mentioned ways people experience affect. The presence of arousal, for example, is linked to increase in activity in the amygdala of the brain (Balleine, 2005). This is expressed by the body through physiological signals like an increase in heart rate and a change in skin conductance, due to sweating.

1.1.2. Emotional Contagion

Emotional contagion (or behavioural contagion) is a psychological concept where the affective state of one person influences another person’s affective state, and more specifically making the other person’s affective state similar. It is argued that in complex environments, the environments humans live in, simulation is a good strategy for survival (Mafessoni & Lachmann, 2019). This can be seen for example in an experiment by Weber and Quiring (2019), where participants were more likely to laugh at a video when the partner they watched it with also laughed, and they would also rate the video as funnier. The reverse was also true; a partner showing no emotions made the participant less emotionally responsive as well. This shows that the affective state of an individual can influence the affective state of another individual. This changing affective state also leads to the subsequent physiological state of the body to adapt. Emotional contagion can thus lead to two individuals, or a dyad, synchronizing their cognitive, behavioural and physiological state. When this occurs, this is referred to as synchronization (Arizmendi, 2011). In the following paragraphs, there will be a focus on PS, on PS in an experimental context and in eventual applications of PS.

1.1.3. Psychophysiological Synchronization

Psychophysiological synchronization (PS) is a phenomenon where one or more of the physiological signals of one person are, to some degree, in unison with one or more physiological signals of another person, implying that both individuals in a dyad are in a similar affective state. Terminology for this concept is varied, examples include; *Physiological synchronization, Physiological linkage, synchrony, physiological compliance or psychophysiological attunement* (Palumbo et al., 2017) or any combination of these terms and many more. In this report, the term “Psychophysiological synchronization” was chosen with the intention to highlight not only the physiological nature of the synchronization but also the psychological nature of the synchronization. Also, the abbreviation “PS” seems to be universally understood in the field.

According to Palumbo et al. (2017), there are multiple attributes that define PS and how it functions. In the following paragraph some of these attributes will be covered. PS can be stronger or weaker depending on the interaction, this is referred to as the *magnitude* (Palumbo et al., 2017). The magnitude of measured PS can be used to compare groups and give empirical evidence about which group is more strongly synchronizing. Another attribute is *concordance*: PS can be concordant or discordant, such that when arousal levels are moving synchronously in the same direction it is concordant and when it is moving in the opposite direction it is discordant.

1.2. PS in depth

Some research into PS that has been conducted reveals that presence of synchronization can indicate positive social interactions. It was found for example that in blind dates, where people only saw each other for one minute, it was not visual gaze that signified attraction, but instead synchrony in heart rate and skin conductance that predicted attraction between partners (Prochazkova, Sjak-Shie, Behrens, Lindh, 2019). In the first paragraph of the introduction, the fact was mentioned than humans have an innate ability for physical and cognitive synchronization, and how high PS might be related to positive benefits like empathy (Weber & Quiring, 2019) or team performance (Elkins et al., 2009). Without intervention, these suggested benefits of high PS between individuals will only be present in situations where people naturally synchronize with each. Therefore, in situations of significantly lower or even non-existent PS, a method that can facilitate this innate ability of synchrony would be very beneficial. In experiments intended to analyse the effects of PS, researchers have already attempted to create situations where high PS is present between dyads (and control conditions in which PS is not present). These experiment set-ups do not always use the same procedures, however; in fact, when looking at the literature, a huge variety of behavioural strategies are used to create high PS situations in the experiment group. A few examples of such procedures are instructing dyads to gaze in each others eyes without moving or conversing (Ferrer & Helm, 2013), singing (Vickhoff et al., 2013), or playing a competitive or cooperative game (Järvelä, Kivikangas, Kätsyri, & Ravaja, 2014; Ekman et al., 2012).

PS between dyads is still a complex and not very well understood phenomenon. Like mentioned before, many different methods are used in the attempt of facilitating PS with little consensus of what technique is most effective or most consistently useful. Many articles use procedures that do not succeed in facilitating PS, as can be seen in the meta-review of Palumbo et al. (2017). In this review, there were quite a few articles that had no significant findings of PS whilst trying to facilitate it. Similarly, a preceding study into PS that tried to show a mediating link between PS and empathy had significant problems with trying to evoke a sufficient level of PS to analyse the mediation (Van Laar, 2019). Whereas there appears to be sufficient evidence in support of the existence of interpersonal psychophysiological synchrony, the robustness or fragility of this effect, its underlying mechanisms, dyadic behavioural correlates, and the extent to which it can be placed under collaborative control are still very much open questions. So far, in the cases synchronization was evoked, results were very inconsistent. This might be possibly because some behavioural strategies to evoke PS may work better than others or were not executed correctly.

This study aims to shed light on these questions and how to increase the magnitude of PS by performing certain procedures.

The research question for this study thus will be: *"What behavioural strategies can dyads use to facilitate synchronization between psychophysiological affective states?"*

1.3. Interactions and relevance of PS facilitating behavioural strategies

The goals and activities in a social interaction highly determine the experience of the interaction. Tasks such as a "breathing exercise" and "playing a video game" are very different in how a dyad would behave and think about their actions in the process. Even stronger, an activity generalized such as "playing a video game" can be performed in very different manners. In Järvelä et al. (2014) for example the same kind of interaction (gaming) is performed in variations that differ slightly. In the experiment, the game "HEDGEWARS" is played by a dyad in the experiment procedure. The procedure however changes from a cooperative game of to a competitive game and other such variations of playing the HEDGEWARS game. The results of these various conditions influenced the levels of PS to varying degrees. In addition, consider that other studies use entirely different games than "HEDGEWARS" be it other "AAA" video games or self-developed games. A researcher that is tasked to set-up an experiment that features PS must thus not only think about what kind of task the dyads should perform, but also how such a task is implemented in more detail.

There are also some other influencing factors that should be considered when choosing what interaction should be performed to facilitate PS. Different factors make certain procedures less effective or sometimes literally impossible. Individual characteristics of the dyad or a single participant for example are a main factor one should consider. There are many studies that focus on dyads of mothers and infants (e.g., Baker et al., 2015; Ham & Tronick, 2009) but the procedure used by Järvelä et al. (2014) like described above would be impossible for these dyads to complete. If the study is set in a professional setting like a research team (Henning et al., 2009) silly playful behaviour like in Goldstein et al. (1989) would be highly inappropriate and if this was suggested as a serious behavioural strategy would likely be ignored.

To conclude, it is very likely that certain actions can facilitate PS magnitude to some extent. That does not mean however that each behavioural strategy is likely to guarantee effectiveness: it is important to know, especially for researchers, how to best implement these procedures considering different contexts of interactions. Therefor the first sub-question reads: *"How can behavioural strategies that facilitate PS best be used?"*

1.4. Feedback on PS

Sharing data derived from physiological signals of a user, with the user themselves, also known as biofeedback, is a great application of how physiology can be used in applications. The presence of feedback has been shown to have a positive effect on individuals. In the study by Janssen et al (2010), people that were able to hear the heartbeat of a confederate reported higher levels of intimacy. The effect was as strong as the effect of gazing on intimacy. The study even states that *"Heartbeats are shown to be a powerful intimate nonverbal cue" (p. 78)*. PS might have the same potential to be used as feedback in various different contexts. Providing feedback on PS could be established in the following way: an application that has access to the physiological data from two individuals can calculate the intensity of the dyad's PS, online and in real-time. Collecting physiological data (Data) from dyads using physiological measurement devices (Acquisition Device), processing the data, calculating PS scores (processing module)

and presenting the scores as feedback (Feedback) creates a closed feedback-loop as seen in Figure 1 (Choi et al., 2020).

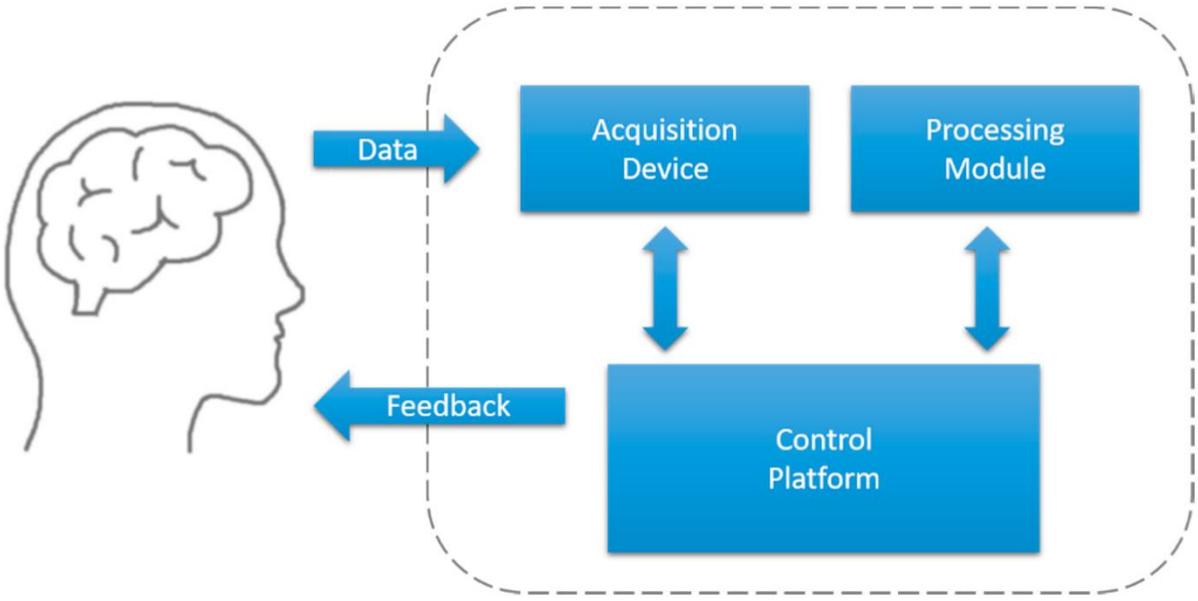

Figure 1 A closed feedback loop template

Providing PS feedback can possibly aid in facilitating PS alongside the aforementioned behavioural strategies. If a dyad sees that a certain behavioural strategy is working and improving their PS score, they might become more confident in the interaction. This works the other way around as well, if PS scores stay low for the dyad, they might be incentivized to try something different or to be more committed in the behavioural strategy they were performing.

In one study that applied PS feedback (Wikström et al., 2017) a set-up is described were dyads of participants are connected to a system that observed their facial expressions and measured EEG, ECG, and EDA. These measurements were used to quantify parts of their affective and physiological state such as "Arousal", "Mood" and "Activation". The system then calculated a score representing PS (expressed in a percentage) based on these measurements and displayed the score on a screen alongside the other quantified factors. Participants were encouraged to look at the feedback and try to get the sync score as high as possible by doing things, which was approached as some sort of game. This experiment resulted in various participants trying out the system and seeking to establish PS with their team partner. This report will try to investigate if giving feedback can increase understanding between dyads and subsequently increase synchrony. Therefore, the following sub question is formulated:

"How does the direct feedback affect the behavior and the perception of synchrony of the dyads?"

1.5. Goals of this report

The main goal of this report is to collect and document effective behavioural strategies that facilitate PS. Researchers at the TU/e had trouble actively generating psychophysiological synchronization between people using movie clips (Laar, 2019). This study tries to address these issues and answer the question whether, to what extent and in what ways physiological synchronization can be generated. The results are thus directly useful for researchers trying to

create psychophysiological synchronization between participants by providing them with a swath of useful behavioural strategies. To add to this, researchers can use the exploratory findings as basis to create hypotheses for more confirmatory research. This study also goes further in applying synchrony to technology by using a direct feedback loop to inform users of their synchronization level. Providing insights into how people react to feedback in depth can help us understand if the direct feedback loop can help facilitating synchrony.

On a larger scale, the knowledge gained in this study could be used to create better implementations of psychophysiological synchronization in applications and other systems designed to evoke empathy or facilitate interactions.

Society will mainly benefit from this research through the increased understanding of Psychophysiological Synchronization, how it can be more easily evoked and the effect feedback has on people.

The following Research question was formulated:

"What behavioural strategies can dyads use to facilitate synchronization between psychophysiological affective states?"

With the following sub-questions:

"How can behavioural strategies that facilitate PS best be used?"

and

"How does the direct feedback affect the behavior and the perception of synchrony of the dyads?"

To answer these questions two studies were designed and performed (to some extent). Due to the limits on research brought by the COVID-19 crisis the second sub-question can only be answered by using data from the initial pilot tests. The main research question and first sub-question will be answered using analysis results from the pilot tests and by performing a meta-analysis by utilizing past literature as research data.

The next section of the report will be split up into two studies. The first study will describe a qualitative research set-up that was aimed to generate and test a large number of improvised behavioural strategies that could potentially serve the purpose of facilitating PS. This qualitative research set-up could not be performed in full due to limitations regarding the COVID-19 situation. Before study 1 is reported, the trial sessions that were performed to help design and test study 1 are summarized and analysed. The second study describes a meta-analysis which has the aim of using past literature to find and evaluate different behavioural strategies to generate and facilitate PS. The results of the meta-analysis are shown in the results of study 2.

2. Study 1 – Qualitative Set-Up

In this study, an attempt is made to answer what behavioural strategies can be used to facilitate PS are and which ones are effective. To accomplish this a study was designed with the aim of being exploratory in nature and focussing on qualitative research methods. The design process

consisted of creating a basic concept of the study and then iterating on that basic concept. The iteration was done by performing trial sessions with each new trial session introducing or removing features of the study.

2.1. Methods

2.1.1. Design of trial sessions

The basic concept of the study was to seat two participants and attach physiological sensors to their person. Using the data, a PS score is calculated and used as feedback, which is shown on a computer screen. The participants are given example tasks to perform that might improve their PS score, or are asked to come up with their own strategies to increase their PS score. They are asked to come up with and perform several tasks for a short period of time and are allowed to use any means available such as a computer or their phones. The study ends with a small discussion about what the participants thought of the experiment.

The design and results of the trial sessions are written below. The first trial session featured the initial concept of the qualitative set-up, and was performed to test the design of the study. Observations from the sessions were written down by the experiment leader and summarized. All participants were grouped in dyads. A total of ten participants were used, all participants were students recruited from the TU/e. The relationships of these participants ranged from somewhat familiar to close friends.

2.1.2. Trial sessions

Session 1 & 2

The Heartrate synchronization programme has two variables to create a score from: correlation and covariance. In session 1 the correlation option was used.

It was chosen to display the correlation of both participants' heartbeats as the PS score. The session started with a suggestion to try some breathing exercises. The dyad also performed an imitation task. Session 1 concluded with the dyad looking up funny videos on YouTube as was suggested by one of the participants. In the end the dyad wound up watching two videos together. Session 2 had roughly the same set up as session 1, only this time more time was spent using covariance between the bio-signals as a basis to generate a PS score rather than correlation between the bio-signals. They performed breathing exercises like the first dyad. They also tried to play several games including a guessing game against the computer. They then had a conversation regarding a tournament they were going to attend on a later date. In the discussion both participants were very sceptical about the shown feedback. They did not see any results that would suggest that there were moments of synchrony generated by their actions. They also argued that moments of high scores of synchronies were likely related to signal noise of the sensors, which occurs when moving your body in a significant way.

Session 3

To address the issue of the unstable fluctuations in the PS score, a window size of 30 seconds was chosen rather than one of 8 seconds. The participants tried breathing exercises on suggestion from the experiment leader. They suggested out of their own volition to stare in silence out of the window for a while. Another task they came up with is with looking at their heartbeat data that was shown on the computer screen. Finally, they looked up 2 songs to listen to; one with a slow, soothing sound and one more rhythmic heavy metal sound and watched some funny YouTube videos. In general, it was agreed upon that the process of watching but also discussing the YouTube videos brought them the most perceived synchronization. It seemed that there was improvement in regards to the massive fluctuation of the synchronization

score being displayed, although the participants still noted that there was some pretty significant fluctuation especially in the latter moments of the two-minute segments.

Session 4

The fourth session introduced the skin conductance sensor to the experiment. Participants were asked to put these sensors on their fingers in addition to their ECG sensors. The two skin conductance signals of the dyad were processed into a skin conductance PS score. The ECG PS score as well as the GSR PS score were both shown to the participants using the in-house developed graphical user interface programme (details on the programme are described in the next section). In the first half of the experiment the two scores were shown in addition to an average of the two scores. In the 2nd half of the experiment the two PS scores were displayed in addition to a bar which showed the maximum of either of the two scores (thus if the ECG PS score was the higher of the two scores, it was displayed). The dyads did a breathing exercise and played a couple of computer games. On suggestion of the experimenter, the participants also recalled a positive shared experience and discussed it. They then also did some games that required physical touch. In the discussion section they explained that they did not really pay attention to the synchronization scores that were displayed on the computer screen, even though they were told multiple times in the experiment to keep their eye on the scores. They said that they did not understand the point of the scores and why they were displayed. They also told that the scores did not reflect their own feelings in how synchronized they were. They also told that they did not really notice any difference between they displayed average synchronization score and the maximum synchronization score. As answer as to what activities they thought caused the most synchronization they answered that it was the sharing of positive shared experience, and the games that required physical touch.

Session 5

The final pilot test session was aimed at finalizing the experiment. A questionnaire was introduced with the aim of refocussing the participants' attention to the PS scores shown on the computer (this questionnaire can be found in Appendix A). The questionnaire requires the individual to note down after each 2-minute experiment how well the PS scores reflected how in-sync they felt with their partner on a 6-point Likert scale. The results of the questionnaire would be useful in post-discussions, but are not considered vital data for the experiment. The questionnaire's main point was to make sure participants would keep an eye on the PS scores on the screen. The two participants were in all other manners set-up in the same was as the previous participants. After installation and instructions, they performed several tasks including a breathing task, an imitation task, playing tic-tac-toe on a piece of paper and a conversation about past experiences. In the feedback session the participants said that the feedback was sometimes off, but that there were moments when the results on screen lined up with expectations. It was also noted that the participants were more aware of the results on screen overall.

Conclusion

The dyads often performed breathing exercises, played video games, cooperative and competitive. on the computer or phone and looked up media, such as websites and YouTube videos, on the computer. Participants found it hard to use the feedback shown to them and were often confused regarding the PS scores. Participants mentioned that cooperative tasks and tasks that involved some forms of mimicry were the tasks where they felt most in sync.

2.2. Results

Based upon the trial sessions, a qualitative research-set up was drawn up. This section describes the methods section of a hypothetical research set-up that could be used in future studies to explore which behavioural techniques evoke PS.

2.2.1. Design

This study is of exploratory nature and will use qualitative behavioural strategies to gather data and analyse it. The participants will be asked to come up with different methods to improve psychophysiological synchronization with one another. Data is collected from measurement devices that generates a synchronization score in real time. The data and score are shared with the participants while performing the task. The experiment will be discussed with the participants were they then proceeding can elaborate on their thoughts during the activities. The video, physiological data, synchronization score, and insights and judgements from the participants are then analysed, from with conclusions are drawn and a discussion is initiated.

2.2.2. Participants

Participants will be dyads, recruited via the "JFS proefpersonenbank" database. For the study to be effective there should be some homogeneity among the dyads, however the participants should not be completely homogenous since the findings should be generalizable over the larger population. Preferably the dyads are familiar with each other to some extent since this increases the likeliness synchronization occurs (Gonzalez-Liencres et al., 2014). Their will be a maximum total amount of 30 dyads recruited, or 60 participants, with a buffer of 5 dyads.

Sample Justification

According to guidelines by Dworkin (2012) for qualitative research, their is no perfectly suited answer to what the sample amount should be for a qualitative research project. They however do give the rough estimate of 30 samples for an accurate representation of a population, which in the case of this experiment would translate to 30 dyads. In this research however it is only worth performing 30 experiment sessions if each session gives either new insights into the research question or validates earlier findings found in other sessions. Thus, if after a couple of sessions several behavioural strategies have been performed with very little diversity in their form, and these behavioural strategies have been validated in latter sessions to a satisfactory extent, there is really no need to perform more sessions. For this reason, a minimum of 10 sessions is set to gather data and insights. Hereafter the rough results are evaluated. When the information gathered is equivalent across the sessions, it would follow that further sessions would likely supply redundant information. In this case, the data for analysis would suffice and the experiment would be stopped. If the information gathered is very diverse, further sessions might reveal more interesting information, thus the experiment is continued with additional sessions until there is a lack of interesting new data. As the experiment can't be prolonged forever, a maximum of 30 sessions will be set, as suggested by Dworkin (2012).

2.2.3. Materials & Measurements

Materials

Two TMSi Mobi8 devices, two sets of ECG electrodes, and two GSR sensors are used.

Several computer programmes will be used to gather and analyse data and video in the experiment which includes:

Phylo: a program that connects with and gathers data from MOBI devices. The collected data will then be saved and utilized in the other concurrently running computer program.

HRsync: a program that performs a simple algorithm on two real time heart signals and gives as output a synchronization score.

GSRsync: a program that performs a simple algorithm on two real time skin conductance signals and gives as output a synchronization score.

Graphical user-interface program: a custom build program was made for this experiment (see Figure 2). This program is directly linked to the HRsync and GSRsync programmes and requires data from both programmes to function. The computer program provides a graphical visualization of the synchronization scores. It can show the Heartbeat Synchronization score, the skin conductance synchronization score, The average of the two synchronization scores and the maximum of either synchronization score. The visualization bar will be displayed in a different colour depending on how high the score is (Red bar for low scores, yellow bar for medium score and green bar for high scores). Using the menu different bars can be hidden, for when the experiment requires it. The program also includes a timer which activates when the "Start Timer" button is pressed. When the timer is activated, the displayed time counts down from "120 seconds left" to "0 seconds left". Furthermore, all the bars displaying the visualized synchronization scores are hidden for 30 seconds upon activation of the timer. When the timer reaches "0 seconds left" the program stops displaying new information and shows a screen which states the time is up. It also gives a numerical average of the synchronization scores over the 120 seconds.

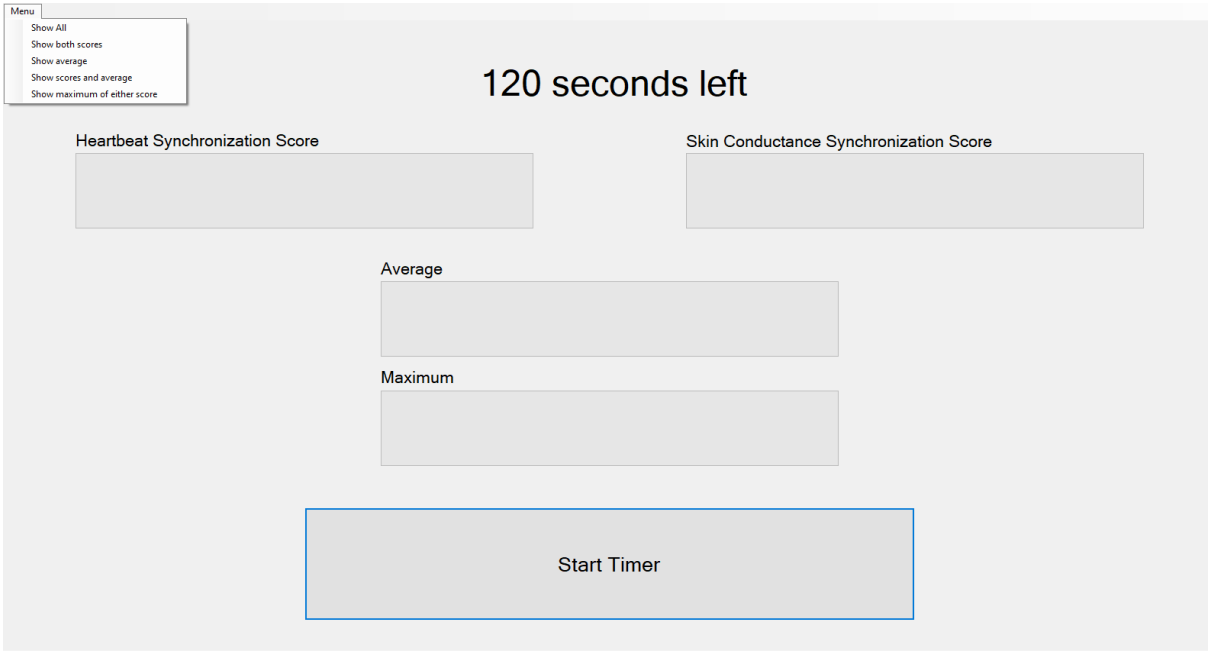

Figure 2: The interface of the GUI programme

Further materials such as games, laptops or the participants' mobile phones will be used to facilitate the partaking in different activities.

Measurements

Data that is used in this experiment can mostly be categorized as qualitative. However, there are some measurements used in the experiment that need to be discussed more thoroughly. These include the physiological signals measured from the participants and the calculated synchronization scores.

Synchronization scores

There are four scores that are calculated in the experiment:

Heart rate Synchronization score (SS_{HR}):

To measure the heart-rate of the dyads, two mobi-devices are used connected to a laptop via a server. The signal is collected using two sets of ECG electrodes, each with three electrodes. Two are used to capture the heart rate and one is used as a ground electrode.

The computer programme HRsync, created by the HTI group of Eindhoven University of Technology (Boschman, 2018), uses the collected data to calculate the Heart rate synchronization score. The programme uses the following formulate in the process:

$$r_t = \frac{\sum(IBI_{1k} \cdot IBI_{2k}) - \frac{1}{N} \cdot \sum IBI_{1k} \cdot \sum IBI_{2k}}{\sqrt{\left(\sum {IBI_{1k}}^2 - \frac{1}{N} \cdot (\sum IBI_{1k})^2\right) \cdot \left(\sum {IBI_{2k}}^2 - \frac{1}{N} \cdot (\sum IBI_{2k})^2\right)}} \; [-]$$

Where N is the number of IBI's taken into the calculation. IBI1 and IBI2 are the inter-beat-intervals from the first and second participant. The IBI value is updated each second.

GSR Synchronization score (SS_{gsr}):

$$r_t = \frac{\sum(GSR_{1k} \cdot GSR_{2k}) - \frac{1}{N} \cdot \sum GSR_{1k} \cdot \sum GSR_{2k}}{\sqrt{\left(\sum {GSR_{1k}}^2 - \frac{1}{N} \cdot (\sum GSR_{1k})^2\right) \cdot \left(\sum {GSR_{2k}}^2 - \frac{1}{N} \cdot (\sum GSR_{2k})^2\right)}} \; [-]$$

Average Synchronization score (SS_{AVG}):

An average synchronization score was calculated using both SS_{HR} and $SS_{GSR.}$ The purpose of this score is to combine the information of both measured bio signals into one easily understandable number for the participants. SS_{AVG} would arguably also be more reflective of PS than one of the other scores on their own, since it is the average of both levels of measured synchronization.

The average synchronization score was calculated within the GUI programme. It was calculated by using the equation.

$$SSavg = \frac{SSHR + SSGSR}{2}$$

Maximum Synchronization score (SS_{MAX}):

An average synchronization score was calculated using both SS_{HR} and $SS_{GSR.}$ This again, has the purpose of this score was to combine the information of both measured bio signals into one number for the participants. SS_{MAX} has a different approach in that it gives as feedback the highest levels of synchronization measured. Different measurement tools can measure different kind of factors of the affective state (Wikström et al., 2017), and thus some measurement tools will not be able to catch activation (or inhibition) of certain affective state factors. So, when one measurement does signify there is PS and another signifies there is no PS, the one that says there is PS should be looked at since the other measurement tool might not be able to measure the PS properly in that instance, therefor $SS_{max.}$

The maximum synchronization score was calculated within the GUI programme. It was calculated by using the equation.

$$SSmax = \max(SSHR, SSGSR)$$

2.2.4. Setting and Procedure

Setting

The setting of the experiment consists of two rooms: An observer room and an experiment room. The materials necessary for the experiment are situated on a table in the participants' room. Two chairs are placed next to each other but at an angle so participants can more easily interact with each other. The chair placement is easiest at the corner of a table. But its possible to place the chairs at the angle while both chairs on one side of the table. In the participant room, several cameras are placed at multiple angles, with at least one camera being aimed at the computer screen which displays the synchronization score. There needs to be space in the room and on the table for participants to perform their interactions. The observer room features a computer connected to the cameras and at least a table and three chairs.

Procedure

Two participants are seated in a room in front of a laptop and measurement devices. After the participants are seated, they will be asked to fill in a consent form. The participants are then briefed about the concept of "psychophysiological synchronization" and what will be expected of them during the study; they are also handed a questionnaire each. The experiment leader then instructs the dyad how to put on the heart rate and skin conductance measurement devices; the participants then put on the measurement devices. The experimenter starts up the data gathering, data processing and GUI programmes and checks if they are working appropriately and are receiving data from both sensor devices. He will also turn on the cameras and start recording. In the experiment dyad are instructed to come up with behavioural strategies that would facilitate PS between the two of them. They are allowed to use any of the materials available to them in the experiment room. When a behavioural strategy is thought up and decided, the dyad will press the "start timer" button on the GUI screen. Hereafter the dyad will perform this behavioural strategy for 2-minutes total. After 30 seconds of performing the behavioural strategy the GUI will show the dyad their two PS scores and PS score average,

participants are supposed to keep an eye on the feedback throughout the experiment. After two minutes the GUI indicates that time is up and shows the total average PS score of the 2-minute time span. Participants will then each answer the question on the questionnaire provided to them. This process is then repeated about 10 times until 30-minutes has passed. The experiment leader is largely free to step in and give suggestions the dyad of behavioural strategies that can be performed to possibly facilitate PS. This can be done as initial behavioural strategy to perform to familiarize the participants with the process, but can also be done when participants are having a struggle to come up with novel behavioural strategies to perform. The experiment leader will give suggestions based on what behavioural strategies have not been performed often as of yet in this and other experiment sessions. The experiment leader will keep an eye on the experiment in another room which has access to the live recordings of the experiment. After the 30 minutes have passed the participants are instructed to detach the sensor devices from their bodies. The questionnaires are collected and the experiment leader and two participants retreat to the observer room. In the observer room the participants are seated and an audio recording is started, this starts the post-discussion section of the experiment and will last for about 15 minutes. In this phase, the participants will be queried about their thoughts about the experiment. The experiment leader can utilize the video recordings of the 30-minute experiment to give the participants something to reflect on. The discussion section is largely free flowing and can be suited to what the experiment leader found most interesting of the experiment; however, the following general questions should be asked: “What was the behavioural strategy that you felt most synchronized with your partner?”, “What in general meet you feel synchronized with you partner?” and “Did you feel the feedback was an accurate representation of how synchronized you felt at each moment?”. Finally, a recording of the discussion is saved and if possible, linked to the relevant video sections.

2.2.5. *Analysis*

The purpose of the analysis on the data collected by the experiment is to give an informed answer based on empirical evidence to the research question and its subsequent sub-questions.

The qualitative nature of the study makes it hard to perform quantitative statistical tests on the data. Below is described how each question will be approached using qualitative analytical methods.

What behavioural strategies can dyads use to facilitate synchronization between psychophysiological affective states?

To answer this question, we need to analyse the collected data, with as end result a list of behavioural strategies that resulted in a PS response in the experiment on a consistent basis. This means that the behavioural strategy should be performed at least a couple of times before we can make an accurate assessment of the effectiveness of the behavioural strategy. In the experiment, behavioural strategies are performed in two-minute segments. These segments will be extracted from the 30-minutes lasting experiment. The recording, synchronization scores, post-discussion quotes and other data connected to the two-minute segments are grouped into a single data block. By looking at all data points in such a data block we can assess whether PS is present and to what extent. Each data block thus represents a single performed behavioural strategy, and all data blocks together represent all performed behavioural strategies in the

experiment. Noting down all the behavioural strategies that successfully facilitated PS as a final answer to the research question would not be very satisfactory. The list of behavioural strategies would not only be very long, but the behavioural strategies would also have a lot of overlap making the list to broad and not generally applicable. Therefor we will apply "content-based" clustering on the data blocks. The content that is clustered are the behavioural strategies that are performed in each two-minute segment. This will result in clusters of data blocks, with each cluster representing a generalized form of a behavioural strategy. Clusters that include only (or mostly) data blocks that have no signs of PS are therefor generalized behavioural strategies that likely do not evoke PS in any circumstance, and should therefor be excluded from the final results. Clusters should include all data blocks, even the blocks that do not show signs of PS facilitation. This is so further examination of the behavioural strategy is possible by for example asking "In what context is there PS when the behavioural strategy is performed and what context is there no PS?". The final answer to the question will be a list of clusters or generalized behavioural strategies that have proven to be successful methods of facilitating PS, by featuring many data blocks that show signs of PS.

"How can behavioural strategies that facilitate PS best be used?"

This question will be answered by utilizing the clusters of data blocks, that were made to answer the previously discussed main research question. Each cluster will be analysed more in depth and the individual data blocks will be examined more closely and compared to each other. Data blocks which feature high effectiveness in facilitating PS are contrasted to data blocks that mention low effectiveness in facilitating PS.

"How does the direct feedback affect the behaviour and the perception of synchrony of the dyads?"

To approach this question, a comparison needs to be made between interactions of dyads with and without the presence of direct feedback. The comparison should include variables mentioned in previous sections such as recorded behaviours, displayed synchronization scores and subjective input from the participants gathered in the discussion section of the experiment. It is established that each behavioural strategy recorded was performed for 2-minutes as measured by the GUI programme. In the first 30 seconds the participants were not shown any direct feedback. Then after the 30 seconds without feedback there was a 90 second period, during the performance of the behavioural strategy, that feedback was shown. The comparison to answer the sub-question should therefor be between the 30 seconds of the recordings without feedback and the 90 seconds of the recordings with feedback. Comparing the behaviours is straightforward since there is a very clear divide between the two sections. However, when the GUI starts providing feedback is where the most interesting contrast in behaviour is expected to be, as the introduction of new information will likely affect the participants. Comparing synchronization scores is not as straightforward, since the scores are based on the physiological data of the last 30 seconds of the experiment. This implies that the first instance of the displayed PS score taking into account only data of the section without feedback is at the 30 second mark, whereas the first instance of the displayed PS score taking into account only data of the section with featured feedback is at the 60 second mark. Comparing these two instances, in addition to any changes in between and after these two instances, will give a good insight into how direct feedback affects the measured PS of dyads.

3. Study 2 - Literature Study: Methods

To answer the research questions formulated in the beginning of the report, data will be collected from the past literature. This data is intended to replace the data that would otherwise have been gathered in the original study. This study will consist of three stages:

1. *The search process stage,* where past literature is searched for, checked and filtered for future usage.

2. *The data extraction stage,* where the collected and filtered past literature is investigated and data is extracted from its contents.

3. *The data analysis stage,* where the extracted data is analysed by clustering it and comparing and contrasting it with the other data.

The stages will be described below in further detail.

3.1. Search process stage

The goal of the search process stage is to collect as many relevant articles as possible that would contain information regarding PS facilitating behavioural strategies and other findings that would aid in the data analysis section. Articles are searched for using various methods. To start previous meta-studies that cover facilitation of PS are used to gather articles by utilizing the literature they have already gathered for their analysis. In this case the review of Palumbo et al. (2017) and its library of collected articles is used as starting point. The study covers articles revolving around PS, which all use some kind of method of facilitating PS generation. Other methods of acquiring new articles of interest were searching in a scholar database more specifically Google Scholar. Table 1 contains the terms that were used in the search query, each term had to include both the keywords “Psychophysiological” and “Synchronization” or it is synonyms or some specific phrasing.

Psychophysiological	Synchronization
Physiological Psychophysiology Physiology	Synchrony Attunement Linkage Contagion Covariation
Other: Interpersonal physiology	

Table 1 Search terms for every keyword.

Specifically, the search was constrained to articles that were published after the publication of Palumbo et al (2017), since most relevant articles would already be included in that paper. Finally, articles that are found by recommendation of outside sources are included as well.

Whilst searching and accessing articles that might relate to providing new insights, the articles must also be filtered. Including all articles that are found using above mentioned methods will result in a sizable collection of irrelevant articles. In the search process the articles have to meet the following requirements before being evaluated further:

- *Has to clearly be about PS between human participants.*
- *Has to be a published and peer-reviewed scientific article*

While searching there will be articles that do not contain any information regarding PS in the title or abstract. If this is the case these articles were excluded from analysis.

If the article fulfills the initial criteria its full text and reference is collected. The article will then be further evaluated and scrutinized. The following criteria are used to judge whether the article is suited to be used in the final analysis. These are mostly based on what would have been replicable in the original setting of the experiment, since this study is aimed at replacing the data generated in the qualitative set-up study.

- *A PS facilitating behavioural strategy is utilized in the experiment.*
  As this study is aimed at collecting and analysis different PS facilitating behavioural strategies, articles that do not utilized any specifically mentioned behavioural strategies likely not contribute much to answering the research questions. This also includes any articles that only use "resting state" when collecting data to measure PS, this is since resting state is by definition not supposed to elicit any response, so any significant synchronization is likely to be noise.

- *Some sort of ECG or GSR measurements are used in the experiment.*
  As stated by Laar (2019), the measurement used by a study to detect PS is relevant. As the original study was set to use ECG and GSR as measurement tools. Utilizing behavioural strategies that are only effective with specific measurements might make the effects of PS not replicable, which is the main goal of this report.

- *The participant demographic group being utilized must be able to perform most other PS facilitating behavioural strategies.*
  To make general conclusions about what kind of behavioural strategies are useful for a general dyad of participants, there have to be restrictions placed on articles that feature demographics performing behavioural strategies that are not suitable for a general dyad of participants. Most notably are articles featuring mother-infant dyads performing procedures that only mother-infant dyads can perform. Articles featuring mother-infant dyads can still be included but the procedures performed must thus also be suitable for a more general dyad of participants.

- *The behavioural strategies being performed must be somewhat replicable in a general setting*
  The behavioural strategies that are interesting and worthwhile should be performable in a general setting, in the case of this paper a general psychology lab. Behavioural strategies that require complex structures or other obscure settings are hard to replicate and make the behavioural strategies hard to compare to behavioural strategies to are widely generally applicable.

- *The PS data collected is between a few participants rather than a large group.*
  PS synchronization between a group is an interesting topic in off of itself, but however goes beyond the scope of the report. The behavioural strategies used might only be effective in group situations and should therefor not be used as evidence when considering what behavioural strategies are effective in interpersonal situations between dyads.

- *Too little information regarding the PS facilitating behavioural strategy is present.*
  If there is little to no information reported in the article about the PS facilitating behavioural strategy, there will be little added value to include the article in the selection. In such cases, the article will be excluded from further analysis.

After these constraints were applied a total of 53 articles remained in the pool for the data extraction part of the analysis. Below a flowchart is presented with how the final pool of articles was collected (figure 3).

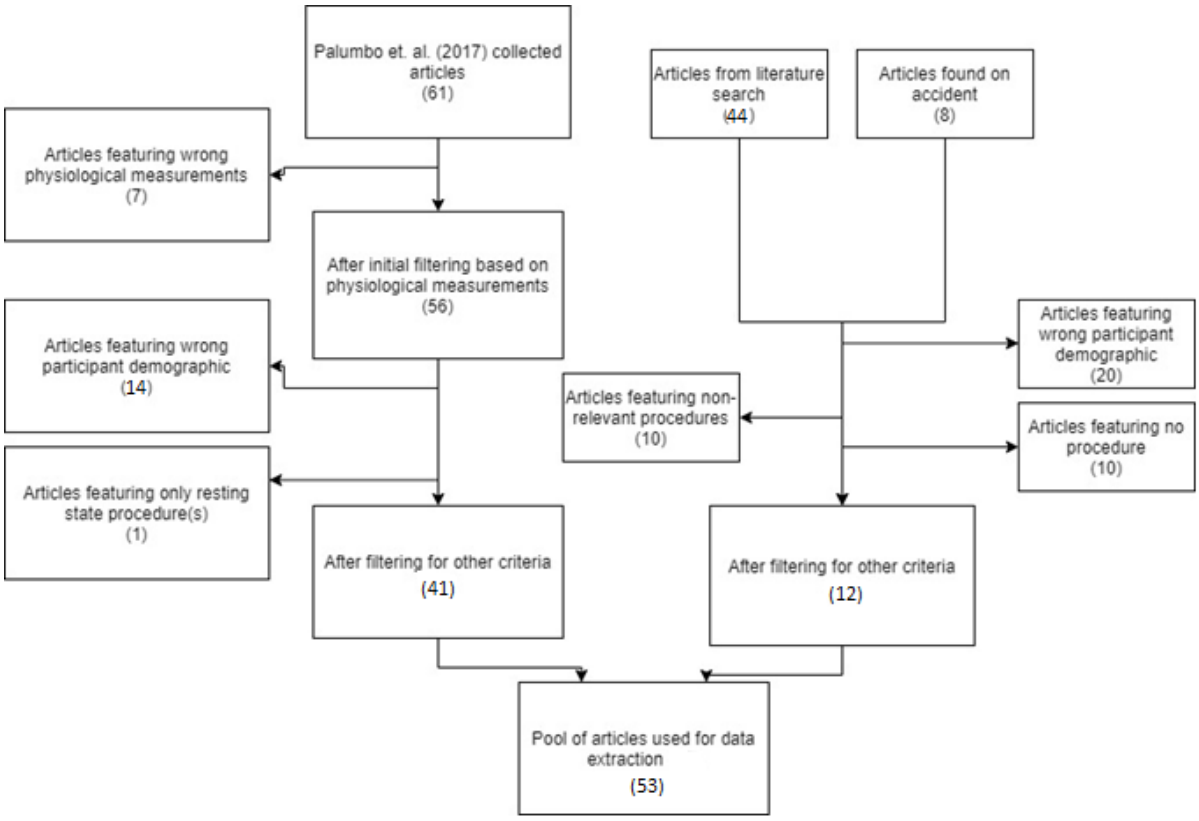

Figure 3 Flowchart of literature review

3.2. Data Extraction

The results of the search process will contain a selection of literature which is suited for this experiment. The literature will then be examined in more detail and important information is extracted to be used as data in the analysis. For each PS facilitating behavioural strategy in an experiment, the appropriate data connected to that usage of the PS facilitating behavioural strategy is extracted and grouped. This means in practice that in a paper where both a gazing procedure and a gaming procedure are performed, data linked to the gazing procedure is collected and grouped together in one data entry, and data linked to the gaming procedure is grouped in another data entry.

Whilst reading the paper the following elements are noted down specifically:

Presence of PS: Most relevant is whether the behavioural strategy performed was actually successful in facilitating PS. This metric is a binary evaluation of whether PS was successfully attained using the facilitating behavioural strategy. This evaluation is gathered by analysing included tables with effects or looking in the results section for mentions of whether PS was achieved.

Effect: When there is a presence of PS stated in the article, the next step is by looking into the quantified effect the behavioural strategy had in facilitating PS. This is preferably the effect size relative to a baseline test, however when no baseline has been performed the effect size relative to a test which used a different PS facilitating behavioural strategy is also useful.

Physiological measurement: Each experiment described in an article will utilize the measurement of physiological signals to derive PS rates. Each physiological measurement that is used is noted down, these included HR, IBI, SC and other measurements derived from

measuring either the heartbeat or the galvanic skin response. It is relevant to note down each measurement used

Time-frame of behavioural strategy procedure: The total time-frame where the PS facilitating behavioural strategy is uninterruptedly-performed and completed. In a 30-minute experiment where a gazing procedure is performed 5 times for 2-minutes, the time-frame of the procedure noted down is 2 minutes.

Data analysis Time-frame: The time-frame that is used to derive some sort of PS levels for the dyads' interactions. This time-frame differs from the procedure timeframe since this time-frame is not concerned about the procedure itself, but the time-frame which is used to calculate the levels of PS. If PS is calculated after the procedure the timeframe might be long, however if the PS is calculated in real-time the Timeframe will likely be much shorter. These facts are relevant when analysing since it has to be checked how PS was calculated.

Sample size: For sample size, the number of dyads that partook in the procedure that is analysed are recorded. This implies not the number of dyads or participants mentioned in the complete article, but specifically the procedure that was meant to facilitate PS.

Description: A snippet of the article is taken and recorded describing the behavioural strategy that was used in the procedure of the article's experiment. When a snippet of the article is too long or a snippet can't be used for another unspecified reason, a short summary is written in this data entry instead. The description is included to provide evidence and context when the behavioural strategies are described.

Comments: These are quotes directly taken from the article that provide important insight into facilizing PS and the PS facilitating behavioural strategies. Also, general conclusions made by the authors of the article are noted down. These comments provide evidence and context for when the behavioural strategies are analysed more thoroughly later in the analysis.

Demographic: In this data entry, the main demographic of the study is recorded. This includes mainly the age-groups of the participants (if specified) but depending on the study, the most important characteristic of the demographic is highlighted. Other kind of demographics group centre around, for example, relationship status or gender. It is important to keep track of these bits of information as it will help in answering what kind of behavioural strategies are effective in what different kind of situations.

3.3. Analysis

The data analysis stage consists of performing an analysis on the extracted and filtered data entries. This analysis has as goal answering the research questions formulated in the introduction of this paper. As a reminder, the literature study is aimed to create data set to replace the data which would be gathered in the qualitative set-up. This means that the actual analysis of the data will actually be roughly the same, although some questions will be harder to tackle. Below is explained how each question is tackled.

What behavioural strategies can dyads use to facilitate synchronization between psychophysiological affective states?

As described in the data analysis section of the qualitative set-up, the goal of this question is to generate a list of generalized behavioural strategies that are proven to be useful in the context of facilitating PS. Firstly, all the procedures of the experiments in the articles that were collected are analysed, and each of the procedures is clustered together on a "content-clustering" basis. Each cluster or generalized behavioural strategy is then defined and summaries of procedures from articles are reported. If available, effect sizes extracted from the methods sections of each article are used to determine whether the "general behavioural strategy" is effective overall in facilitating PS. If no data is available to determine an effect size, an analysis is performed based on the number of articles that mention the behavioural strategy and were successful in facilitating PS in contrast to those that were not successful.

"How can behavioural strategies that facilitate PS best be used?"

To answer this question each general behavioural strategy will be analysed more in depth. Each article that features a general behavioural strategy will be analysed for particular useful bits of information that would reveal intricacies of the behavioural strategy in discussion. Then the behavioural strategies will be evaluated based on how well they would perform in several different contexts.

4. Results

In the results the data gathered from the literature research and the meta-study is used to answer the questions that were raised in the introduction. First an overview of the collected articles is given. Then an analysis is made with an aim to describe the behavioural strategies that were discovered. Finally, the behavioural strategies are looked into more deeply.

4.1. General Description of data

The results of the literature search are collected below in Table 2. A total number of 53 articles were used in the analysis as a result from the search. The range of dyads featured in each article spanned from 1 to 76 dyads.

Author (year)	***Gazing***	***Conversation***	***Psychotherapy-session***	***Playing Video Games***	***Imitation task***	***Playing***	***Rhythmic Tasks***	***Miscellaneous Tasks***	***Demographic***	***Dyad Count***	***Physiological Measurement***
Baker et al. (2015)						+			*Mother / Infant*	*28*	*SC*
Chanel, Kivikangas, and Ravaja (2012))				+					*Friends*	*21*	*IBI, SC*
Chatel-Goldman, Congedo, Jutten, and Schwartz (2014)		+						+	*Couples*	*14*	*SC*
Codrons, Bernardi, Vandoni, and Bernardi (2014)							-		*Students*	*10 (triads)*	*HR*
Coleman, Greenblatt, and Solomon (1956)			+						*Therapist / Client*	*1*	*HR*
Di Mascio, Boyd, Greenblatt, and Solomon (1955)			+						*Therapist / Client*	*3*	*HR*
Elkins et al. (2009)				+				+	*Strangers*	*10*	*IBI, RSA*
Ferrer and Helm (2013)	+				+				*Couples*	*32/30*	*HR*
Field et al. (1989)						+			*Children (half w. stranger, half with friend)*	*16*	*HR*
Ghafar-Tabrizi, R. (2008)		+							*Mother-daughter*	*24*	*HR, SC*
Goldstein (1989)						+			*Children*	*20*	*HR*
Guastello et al. (2006)		+							*Students*	*37*	*SC*
Helm, J. L., Sbarra, D. A., & Ferrer, E. (2012)	+				-				*Couples*	*32*	*HR*
Helm, Sbarra, and Ferrer (2014)		+							*Couples*	*32*	*RSA*
Henning and Korbelak (2005)				+					*Students*	*32*	*IBI*
Henning, Armstead, and Ferris (2009)								+	*Mixed Students*	*4 Person team*	*HRV*
Henning, Boucsein, and Gil (2001)				+					*Strangers*	*16*	*HRV, SC*
Järvelä, Kivikangas, Kätsyri, and Ravaja (2013)				+					*Friends*	*41*	*IBI, HRV, SC*
Kaplan, Burch, Bloom, and Edelberg (1963)		+							*Students*	*18*	*SC*
Konvalinka, I., Xygalatas, D., Bulbulia, J., Schjødt, U., Jegindø, E. M., Wallot,								+	*Mixed friends and strangers*	*38 Particip ants*	*HR*
Kraus and Mendes (2014)		+							*Strangers*	*64*	*SC*
Levenson and Gottman (1983)		-							*Couples*	*30*	*IBI. HR, SC*
Liu, Zhou, Palumbo, and Wang (2016)	+								*Couples*	*16*	*SC*
Marci and Orr (2006)			+						*Experimenter - Participant*	*20*	*SC*

Marci, Ham, Moran, and Orr (2007)	+	*Therapist - Client*	*20*	*SC*
McAssey, Helm, Hsieh, Sbarra, and Ferrer (2013)	+ +	*Couples*	*4*	*HR*
Messina et al. (2013)	+	*Therapist - Client*	*39*	*SC*
Mitkidis, P., McGraw, J. J., Roepstorff, A., & Wallot, S. (2015)	+	*Students*	*37*	*HR*
Montague, Xu, and Chiou (2014)	+	*Strangers*	*24*	*HRV, IBI, SC*
Morgan, Gunes, and Bryan-Kinns (2015)s	-	*Strangers*	*5*	*HR*
Müller & Lindenberger, (2011)	+	*Singer and Conductor*	*11*	*HR*
Noy, Levit-Binun, and Golland (2015)	+	*Strangers*	*9*	*HR*
Quer, Daftari, and Rao (2016)	+	*Strangers*	*NA*	*HRV*
Reed, Randall, Post, and Butler (2013)	+	*Couples*	*44*	*IBI, SC*
Robinson, Herman, and Kaplan (1982)	+	*Therapist / Client*	*21*	*SC*
Shearn, Spellman, Straley, Meirick, and Stryker (1999)	+	*Friends and*	*24 (triads)*	*SC*
Silver and Parente (2004)	+	*Strangers*	*20*	*SC*
Strang, Funke, Russell, Dukes, and Middendorf (2014)	-	*Strangers*	*40*	*IBI*
Stratford, T., Lal, S., & Meara (2009)	+	*Therapist / Client*	*15*	*SC*
Stratford, T., Lal, S., & Meara, A. (2012)	+	*Therapist / Client*	*30*	*SC*
Thomsen and Gilbert (1998)	+	*Married Couples*	*32*	*HR, SC*
Vickhoff et al. (2013)	+	*Strangers*	*11 particip ants*	*HRV*
Walker et al. (2013)	+	*Strangers*	*34*	*RSA*
Woltering, Lishak, Elliott, Ferraro, and Granic (2015)	+	*Mother / Child*	*118*	*IBI*
Schneider (2020)	+	*Strangers*	*42*	*IBI*
Tschacher & Meier (2020)	+	*Therapist / Client*	*4*	*HR, HRV*
Reindl et al. (2018)	+	*Parent / Infant*	*31*	*46*
Gordon et al. (2020)	+	*Strangers*	*47 (triads)*	*IBI*
Fujiwara et al., (2020) Study 1	+	*Strangers*	*42*	*HR*
Fujiwara et al., (2020) Study 2	+	*Friends*	*75*	*HR*
Borelli et al. (2019)	+	*Couples*	*100*	*IBI*

Kaur et al. (2018)	+	*Children*	*24*	*HR*
Behrer et. Al. (2020)	+	*Same-sex strangers*	*76*	*HR*
Van Laar (2019)	-	*(mostly) strangers*	*70*	*IBI*

Table 2 Collection of articles after search and filtration. "+" denotes that the article features a procedure that is classified in the corresponding general behavioural strategy cluster and has been successful in facilitating PS in that article. The "-"symbol is the same as "+" except that the procedure was not successful in facilitating PS. The "X" symbol denotes that that article did not feature a procedure that was classified in the corresponding general behavioural strategy cluster. HR = Heart Rate, HRV = Heart Rate Variability, IBI = Inter-beat interval, RSA = Respiratory sinus arrhythmia, SC = Skin conductance

Table 3 features a tabulation of the clustered behavioural strategies.

Behavioural strategy	**Feature(s) in articles**	**Facilitating PS success percentage**
Conversation	14	94%
Psychotherapy-session	9	100%
Playing video games	8	88%
Imitation tasks	4	75%
Gazing	4	100%
Playing	3	100%
Rhythmic Tasks	3	66%
Miscellaneous tasks	10	NA

Table 3 Tabulation of found clusters of behavioural strategies. The first column features the name of the behavioural strategy assigned to the cluster. The second column displays the number of articles that the behavioural strategy was featured in (multiple behavioural strategies can be featured in one article). The third column contains the percentage of articles that were successful in facilitating PS using the behavioural strategy.

4.2. Behavioural Strategies

To answer the main research question, all papers procedures in the articles were categorized and clustered on the basis of the nature of the PS facilitating behavioural strategies. Each significant cluster represents a general behavioural strategy, to answer this question this report presents these general behavioural strategies and look at their effectiveness Afterwards, the very small clusters or singular mentions of behavioural strategies are discussed.

4.2.1. Gazing

This general behavioural strategy is labelled as "gazing". Most articles that used this behavioural strategy to facilitate PS referred to the behavioural strategy as "gazing" and performed it in a very similar manner in comparison to the other studies. In general, "gazing" consists of both participants facing each other, and maintaining some form of stillness. They are then instructed to look at each other directly over a prolonged period of time, ranging from 3-minutes (Ferrer & Helm, 2013) to 15-minutes (Liu et al., 2016). This behavioural strategy was performed in Ferrer & Helm (2013) where it was described as follows: "participants were asked to gaze into one another's eyes without talking or touching each other for 3 min" (p. 45). As seen in the quote the timeframe of performing the behavioural strategy was 3 minutes and heart-rate was used as a physiological metric. The behavioural strategy however wasn't very powerful in facilitating PS, as it was way less effective than the imitation task performed in this particular study and also less effective than even the baseline measurement. Only 4 out of the 53 articles used in this analysis featured gazing as a procedure with all articles being able to facilitate PS successfully.

4.2.2. *Conversation*

This general behavioural strategy is labelled as "conversation". Articles referred to this behavioural strategy as "discussing" (Ghafar-tabrizi & Ph, 2008), "Conversation" (Helm et al., 2014) or "work towards resolving an issue" (Thomsen & Gilbert, 1998), the general label of "Conversation" fits these descriptions well in a general sense. "Conversation" in general, consists of a dyad talking to each other about a topic in a limited timeframe. Often the topic was chosen beforehand by an experiment leader or one of the participants. The conversation would usually initiate by one specific participant chosen by the experiment leader (Helm et al., 2014). In Danyluck and Page-Gould (2019) a mixed design is used where conversation is combined with performing a task, in this case: "...tie knots using only one hand". The talking condition had a large effect *($t = 2.664$, $df = 63$, $d = 0.67$)* on PS when compared to the no-talking condition. In Helm et al. (2014) a similar effect was found although somewhat smaller *($d = 0.21$).* In the pilot tests, dyad also performed conversations, more specifically they aimed to discuss shared experiences they had with each other. The dyads remarked in the discussion section that these sessions were very effective in creating the "feeling" of synchronization between the two participants. Out of the 53 articles that were included in the analysis, 14 used a procedure that resembled the "conversation" behavioural strategy with around 94% of articles having success in facilitating PS.

4.2.3. Psychotherapy-session

This general behavioural strategy is labelled as "psychotherapy-session". This general behavioural strategy is on first glance too similar to the conversation behavioural strategy to be a behavioural strategy on its own. There were however a substantial number of articles focussed exclusively on the specific interaction of a psychotherapy-session, therefor it is featured as its own cluster. "psychotherapy-session" involves most of the same elements of conversation, but has some specific key details it (almost) always has. To start, "psychotherapy-session" always involves an asymmetric role dynamic, where one of the people in the dyad is the interviewer and the other is the interviewee. The subject of the conversation is also more limited than a general "conversation" task. The subject often involves around the experiences and feelings of the interviewee, while the interviewer probes the interviewee and gives their evaluations and remarks. Most articles that featured this strategy used real-life psychotherapists and their patients as subject. The "psychotherapy-session" is a relatively large area of focus for researchers focussed on PS, this is reflected in the fact that 9 out of 53 articles that were used in the analysis used some form of "psychotherapy-session" and all were successful in facilitating PS.

4.2.4. Playing video games

This general behavioural strategy is labelled as "playing video games". Articles described the procedures in detail such as "Two-person teams were asked to control the movement of an object... on a screen" (Robert Arthur Henning et al., 2001), . a "playing video games" task generally involves the dyad interacting with a digital programme. The digital programme can either be a self-made game, a popular game or a virtual task. The digital programme has a goal for both players. In the articles examined, the dyad always interacts simultaneously with the game. The total amount of times that a procedure like "playing video games was used" was used in the set of articles selected for this analysis was 8 out of 53 with 88% being successful in facilitating PS.

4.2.5. Imitation tasks

This general behavioural strategy is labelled as "Imitation tasks". In articles it is described by for example instructing the participants to *"mirror each other's physiology"* (Ferrer & Helm, 2013) and "match their partner's physiology" (McAssey et al., 2013), another way to use

imitation is "playing the mirror game" (Noy et al., 2015). A general imitation task involves the dyad being seated facing each other and being instructed to mimic each other. This is then than by either giving both participants the freedom to move and mimic, or by instructing one person to initiate a movement or gesture and instructing the other person to imitate their partner. This procedure differs distinctively from other tasks were identical movements and behaviours are coincidental, in an "imitation" task the identical nature is by design. There were 4 "imitation tasks" featured in the 53 articles used for the literature study analysis. The total amount of success rate of imitation tasks in facilitating PS based on the literature study is 75%.

4.2.6. Playing

This general behavioural strategy is labelled as "playing". The word "play" is often used by researchers describing this behavioural strategy, such as in the study of Baker et al. (2015), who describes it as "''Please play together as you typically would at home''. The general "Playing" task differs from "Playing video games" in some ways. Firstly, "playing" allows, and often involves, physical contact. "Playing video games" is mostly task-oriented, whereas "playing' can be more free-form and the goal can either be strict or fuzzy. "playing video games" is also limited to a very limited number of games that can be played, whereas "playing" can jump from one game to the other. Articles that involved a "playing" procedure often involved infants. Only three of the 53 articles used in the analysis featured "playing" as a general behavioural strategy and were successful in facilitating PS. This however does not represent the field of PS research very well, since most articles that featured some form of "playing" were filtered out of the final pool of articles used for this analysis.

4.2.7. Rhythmic Tasks

This general behavioural strategy is labelled as "Rhythmic tasks". Some articles describe rhythmic tasks as follows: "drumming with one another" (Morgan et al., 2015), "subjects sing Fairest Lord Jesus" (Khoff et al., 2013) and to perform a movement while "while listening to a metronome rhythm" (Codrons et al., 2014). Singing is also included in this task, specifically when it requires dyads to sing synchronous is a similar rhythm. The general "rhythmic tasks" procedures are very similar to the general "imitation" procedures, they differ in that "imitation" is more general and demands similar movements and gestures, while "rhythmic tasks" are more about making dyads perform a procedure in a rhythmic fashion. A total amount of 6 "rhythmic tasks" are found in the pool of 53 articles used for this analysis with around 66% being successful in facilitating PS.

4.2.8. Miscellaneous tasks

This general behavioural strategy is labelled as "Miscellaneous tasks". This term excludes any procedures that are described by other general behavioural strategies terms and the "resting" procedure. The general term used to describe the procedures that are too distinctive from the other tasks to be included in any of the clusters. Below are some examples of studies that included procedures that were too distinctive to be included with the generated clusters:

Attending research team meetings (Henning et al., 2009)

Designing a car with "Lego" (Mitkidis et al., 2015)

Performing in a real-life military simulation (Elkins et al., 2009)

Programming a robot (Schneider et al., 2020)

A behavioural strategy that was used a lot in the trial sessions of study 1, but was not found in the literature review, was the searching and viewing of video or audio material. Sometimes dyads were instructed to watch videos but this was mostly after the actual PS facilitating procedure.

A total amount of 10 out of 53 articles features tasks that could not be associated with any of the abovementioned general behavioural strategies and where therefore labelled as a "miscellaneous task".

4.3. Effective use of behavioural strategies

In the following section, each behavioural strategy that was described previously will now be looked into more in depth. Findings are used to formulate a form of the behavioural strategy that would be most effective and the behavioural strategy will be weighted on how it performs in different situations and among different groups of people.

4.3.1. Conversation

A conversation procedure will mostly be two participants simply talking about a topic, the most relevant thing to discuss in this case is the topic of the conversation, although the position of the participants might be relevant (such as facing each other), most articles do not specify these things or experiment and compare results with the positions the participants take. Some articles claimed that positive conversations about past experiences within the dyad were most effective. The claim that conversation has to be positive is disputed in other articles (Ghafar-tabrizi & Ph, 2008, Woltering et al., 2015) and the effect of negative conversation topics is highlighted in articles such as (Thomsen & Gilbert, 1998). Another finding to consider was that high conflict conversations were more successful in facilitating PS than low conflict conversations.(Ghafar-tabrizi & Ph, 2008). The conversation procedure has the added benefit of being able to be combined with other tasks, like in Danyluck & Page-Gould (2019), although in this article it did not have any special interaction with the other task that was being performed. In the pilot tests, the participants also affirmed that talking about shared past experiences was very effective in perpetuating the feeling of synchronization. A significant number of studies that used the conversation procedure also used dyads that were very familiar with each other, often romantic couples and people that were married to each other (Helm et al., 2014, Levenson & Gottman, 1983, Thomsen & Gilbert, 1998). This makes sense since talking about shared experiences is much easier to do with your spouse or romantic interest than with strangers, although studies exist where strangers talking facilitated significant PS (Silver & Parente, 2004).

Conclusion: The "conversation" procedure can best be performed by asking the dyad to talk about a shared past experience, preferably one which featured a high level of conflict. The conversation topic does not have to be positive or negative per se. This is an effective procedure to use with people that are very familiar with each other (Couples, Friends, Family etc.).

4.3.2. Psychotherapy-session

One important factor for Psychotherapy-sessions to be effective seems to be therapeutic alliance, which boils down to a caring respectful and trusting relationship between therapist and client (Stratford et al., 2012). In Marci & Orr (2006), the role of the interviewer is always filled by the same person, the role of the interviewee was reserved for each of the participants. The "psychotherapy-session" can thus be used if only one participant per experiment session is needed or required. The participant could than take the role of the interviewee and the experiment leader or assistant could take the role of the interviewer. Articles that featured the

"psychotherapy-session" procedure also were distinct in that they were often used in an experimental context that was more long-term and "within" compared to other studies, the number of dyads that were used was therefore also significantly lower.

Conclusion: Psychotherapy-sessions works best for dyads that have high therapeutic alliance.

4.3.3. Playing video games

When choosing to use a videogame in an experiment revolving around generating PS in dyads, the first choice that should be considered is whether a competitive or cooperative videogame should be used. Through analysis it was confirmed that cooperative games are generally more effective in facilitating PS and in some articles cooperative games could facilitate PS where competitive games did not (Reindl et al., 2018) In Järvelä et al. (2014) there was PS generated using a "worms-like" game. Several conditions were tested and it was found that the cooperative condition and the competitive condition facilitated the same magnitude of PS, in contrast to other articles. Most interesting however, the condition that was both competitive and didn't feature any enemy AI agents has the highest magnitude of measured PS, the researchers argued" AI agents in this type of game disturb the players from focusing solely on each other's actions". Interacting with computers to perform virtual tasks or playing video games requires a certain number of technical skills, this means that certain groups of populations will have trouble performing these kinds of tasks, such as the elderly. Some games are also too difficult to control for some demographics, such as very young children or the disabled, the experiment leader must therefor be critical for choosing the right game or virtual task for the chosen demographic.

Conclusion: the way a video game procedure should be applied should most likely be in a cooperative context, where the focus is on the players themselves and less on the environment presented in the game. This can be achieved by choosing a game that does not feature any AI agents in the game and has minimal interaction with other variables.

4.3.4. Playing

To make the most out of "playing" procedures it is important to give participants freedom and the ability to play how they feel most comfortable. This is seen in the article of Baker et al. (2015), where the participants were asked to play like they would normally play. Participants in the trial sessions of Study 1 also used the "playing" behavioural strategy like this and indicated this was effective. Another aspect of "playing" that can be exploited is that physical touch is often encouraged, it is argued in other articles that touch itself may be enough to facilitate PS (Chatel-Goldman et al., 2014). This was also seen in the fourth trial session, where the dyad came up with several different kinds of playing in a free-form, some where the participants touched each other in some way. The dyad gave as feedback that these sessions of "playing" was when they felt most in-sync. They also said the collaborative effort of deciding and thinking up what to play was effective. Due to the freeform nature of the "playing" procedure, it is suitable for demographics that are not suited to partake in more complex procedures, such as very small infants. Many articles that were excluded from this study utilized procedures that resembled "playing" the most because only the "mother-infant" demographic would be able to perform them.

Conclusion: "playing" can be structured but is most effective when a free-form approach is taken. Touch as a component is also encouraged. This procedure is especially useful when dealing with young participants

4.3.5. Imitation tasks

The literature featuring imitation tasks did not go much in depth regarding the procedures so it is hard to go into the specifics. Most of the articles featured couples, but only two out of three

articles were successful in facilitating PS. In Helm et al. (2012) both an imitation procedure and a conversation procedure were used. In this article only the conversation procedure was effective in facilitating PS. Imitation tasks were not completely free form in the articles that used an imitation procedure. An initiator needs was assigned that initiated an action, thereafter the other member of the dyad will imitate the action.

Conclusion: Imitation tasks need some form of structure. An initiator needs to be assigned, who will initiate the action. The technique was mostly used with couples.

4.3.6. Rhythmic Tasks

In Morgan et al. (2015) drumming is used as a rhythmic task, but in this article they were not successful in facilitating PS between the dyads. Singing can be used to design a rhythmic task, making the dyad sing together, at the same time and in the same rhythm are great starting points. Some studies used specifically a choir setting to facilitate synchrony and performing in rhythm (Müller & Lindenberger, (2011), Vickhoff et al., (2013)). Kaur et al. (2018) used three different types of rhythmic tasks (clapping, marching and drumming) in the same study, all three had the same success in facilitating PS. This implies that the act of doing something in rhythm is enough for PS to be facilitated. In the trial sessions each dyad was instructed to try a breathing exercise and follow the rhythm of the other participant. The feedback programme often showed high PS levels during this task, although the participants themselves never mentioned the breathing exercise as a significant moment of synchronization. For infants it might be hard to keep a consistent rhythm and to stay in synch with other participants.

Conclusion: there are many ways for rhythmic tasks to be applied but singing and breathing in rhythm seem to be good applications of the behavioural strategy.

5. Discussion

When two individuals share an experience such that their respective affective states become similar, their physiology might synchronize in the same way, this phenomenon is psychophysiological synchronization (PS). Apart from PS being an interesting phenomonon in of off itself that is worth studying, there are various positive effects associated with PS, such as increases in empathy (Weber & Quiring, 2019) or team performance (Elkins et al., 2009) between dyads. Published studies use different methods when trying to facilitate PS in their experiment. This report looked if it is possible to facilitate PS using different kinds of behavioural strategies. There was also an examination of whether feedback had any influence on the dyad's ability to facilitate PS. In the following sections the two studies and its implications are discussed in more detail.

5.1.1 Qualitative study

A qualitative study was performed featuring five trials. In the trials, dyads would be free to come up with procedures which they though would be effective in facilitating PS, whereafter they would perform those techniques while physiological signals were being measured. The aim of the study was discovering what behavioural strategies dyads would come up with and how successful these strategies were for facilitating PS between the dyads. Furthermore, by performing a post-discussion with the participants about how they experienced the trials, insight could be gained about what specific elements of the behavioural strategies were most effective. Bio-feedback was also used in these trials and dyads were constantly made aware of

the PS levels between themselves. Bio-feedback was included in the study because participants might be able to use the information gathered from feedback to more effectively

The dyads most frequently performed breathing exercises, played competitive or cooperative video games on the computer or phone and looked up videos on YouTube. There wasn't a great variety of methods that were tried out, and participants might have felt somewhat limited in what procedures they could come up with. That limitation was not only a lack of equipment but also a lack off creativity. Participants often mentioned two specific factors that they felt were most influential in building PS: Performing the same actions or working towards completing a task. This implies that the task itself might not be as relevant as long as these factors are included. Just the simple act of looking up a video to watch was more effective sometimes than actually watching the video, because the former required interaction and working together.

The use of feedback was not very successful. The use of Bio-feedback led to several issues in the trial sessions. Dyads were often confused about what they saw, the numbers and what the numbers represented. Most of the times, the feedback did not line up with how they were experiencing the synchronization. The numbers themselves would often fluctuate from value to value with no understandable pattern. No empirical calculations were done using data, but some participants did notice some slight improvements in their PS score with certain behaviours they performed. The very short time-frame that was used to calculate PS scores and the speed at which the dyad had to synchronize with each other might be the most important reason why the PS scores seemed off. It could be that PS is more useful as a tool to be used in analysis after a procedure is performed and where physiological metrics are measured over a longer period of time and over many different dyads, rather than as direct feedback measured in a very narrow time-frame for only one dyad. Nevertheless, if real-time feedback is going to be used, the application developer must be aware of how to present the feedback; using terms such as "covariance" might confuse potential users. In other words, the application developer must look into how they can give the feedback in a user-friendly manner. One such method is to utilize algorithms in the application to calculate a PS score that's easy to interpret and use that score as feedback. When participants receive such feedback, they can react accordingly and may change their behaviour patterns, this in turn creates new data to collect and process.

5.1.2. Literature review study

A literature study was also performed. A literature search was executed and the articles that were found were filtered resulting in 53 articles being included in the literature study. This literature study was performed to examine what is happening in the current scientific context of PS, what behavioural strategies were being used and how effective these strategies were. Using the insights from various articles, generalized behavioural strategies were generated.

The most often featured behavioural strategies were "Conversation", "Playing Video Games" and "Psychotherapy-Session" with the latter being always successful in facilitating PS. "Gazing" and "Playing" were always successful in facilitating PS, but both only were used three times and there is therefor less evidence if these procedures are truly that effective. The effectiveness of the "conversation" and "Psychotherapy-session" behavioural strategy could be explained due to the emotional element present in these procedures, as it's shown that conversations procedures with a high level of conflict are especially effective in facilitating PS (Ghafar-tabrizi & Ph, 2008). This is further evidenced since articles that featured both strangers and non-strangers showed that non-strangers more easily facilitated PS. The "Playing Video Games" procedure is likely effective due to the interactive element between dyads in the

procedure. This becomes especially clear that when AI are introduced (and there is thus less direct dyad interaction) PS facilitation is hampered (Järvelä et al., 2014). These findings imply that procedures that are highly interactive and emotionally involved are effective and that these factors are likely the motors in facilitating PS.

It seems that PS can thus be somewhat facilitated and spurred on using behavioural strategies, as testified by the high number of articles that were successful in facilitating PS, more over it seems that whether PS occurs frequently or occurs at all may be more related to various different factors. Most studies discussed concluded that relationship closeness is often the key deciding factor in groups that do feature high levels of PS against groups with no or low levels of PS. Other contributing factors such as autism symptoms (Baker et al., 2015), therapeutic alliance (Stratford et al., 2012) or relationship satisfaction (Helm et al., 2014) seem to have a more significant role in facilitating PS than different behavioural strategies do. With these conclusions in mind, the question "Can PS be artificially facilitated using behavioural strategies?" is hard to definitely answer.

Even if there are PS facilitating techniques, it's still hard to determine their effectiveness due to a gap in the literature. The literature has a serious gap in empirically determining how effective these techniques, that are used in all the PS literature, actually are. Despite these limitations, this paper still tries to give some recommendations in regards to what techniques to use and when. The implications of these findings are that researchers or application developers should not only consider the behavioural strategy when they seek to facilitate PS but also the beforementioned factors that could also influence the generation of PS between dyads.

5.1.3. Recommendations for behavioural strategies facilitating PS

Creating procedures to facilitate PS is not easy as it's not self-evident that PS will actually occur between dyads. In the following section some advices are written down such that researchers can create procedure with more assurance that PS facilitation will actually be successful.

When designing a procedure for an experiment on PS, there are some aspects one should consider before choosing a general behavioural strategy to use. At the very start, the experiment designer should consider what the objectives and independent variables of the study are. Any general behavioural strategies that conflict directly with this objective should be ruled out immediately, a study that requires silence rules out procedures that model after "conversation", "psychotherapy-session" and maybe "rhythmic tasks" behavioural strategies. Thereafter, the designer should look at what kind of participants the study is aiming to employ. Table 3 shows an overview of some of the findings of the analysis that are recorded in the "results" section. If there is no specific demographic that needs to be considered this step could be ignored.

	Preferred	*Undesirable*
Parent-Infant	Playing	Rhythmic tasks, Playing video games, Conversation, Psychotherapy-session
Children	Playing	
Elderly		Playing video games
Therapist-client	Psychotherapy-sessions	
Couples	Conversation	

Friends	Conversation

Table 4 Preferrable behavioural strategies per demographic

When goals, independent variables and demographic have been addressed, other factors could be considered. Using the results section as reference, the general behavioural strategies that have the most evidence of being effective are “conversation”, “psychotherapy-session” and “playing video games”. “Gazing” was shown to be the least effective and is therefore not recommended. If the study is designed to be a long-term within-subjects design, with few participants “psychotherapy-session” may be the final best choice to base your procedure on. This also applies if the researcher is required to be one half of a dyad or if the research requires one participant to be dominant in the interaction over another participant. For other experimental designs, “conversation” and “playing video games” are likely to be most effective. “Playing video games” may require more resources, expertise and time to set up, so if these factors are restricted one might consider using “conversation” instead. Familiarity between the participants is however important for “conversation” to be most effective, if the participants are total strangers a better alternative might be “rhythmic tasks”. Of course, one could also choose to create a procedure with elements of more than one general behavioural strategy.

5.2. Limitations

5.2.1. Limitations regarding the qualitative research set-up

Due to the nature of this report, the limitations of the qualitative set-up can only be described in the context of the experiment only being performed a couple of times in a pilot run scenario. Limitations regarding the qualitative set-up are therefore also hard to discuss since the actual study was not performed in its completed form.

Based on the trial sessions some limitations can be discussed. For the experiment to create novel behavioural strategies, the participants need to be able to have as much freedom as possible, so that they are not restricted in performing procedures they come up with. However, due to the nature of the experimental set-up the participants have to remain relatively still sitting in a chair, since they are hooked up to several measuring devices. A procedure such as running a lap around the building is impossible to perform. The range of procedures that can therefor actually be performed is therefore limited. The set-up itself may also be creatively limiting, since the experiment can only provide a limited set of tools beforehand (computer and mobile phones being the most prominent) participants will naturally try to come up with methods using these specific tools. A participant can’t come up with the procedure to play guitar if a guitar isn’t provided beforehand, for example. This thus also limits the range of ideas that are brought forward in the first place.

There are also limitations in regards to the latter discussion parts of the experiment. The reflection on the procedures is an important element in the study, however to be able to effectively reflect on the experiment, the participants need to be able to grasp the concepts of PS and the PS score. In the trial sessions, it seems participants still found it hard to completely understand the concept of PS; one participant even thought the concept of PS was just a lie and the experiment was actually about something else. Giving a complete introduction to PS therefor is important, but it may be impossible for members of the general public to get it in such a short period of time.

5.2.2. Limitations regarding differences between literature study and Qualitative set-up

When deciding to do a literature review rather than the qualitative set-up several ways of answering the research question were lost, in this section these limitations are discussed. When answering the research questions, the data was used. One thing that must be acknowledged is that PS can partly be a reflection of synchronization of on the cognitive level as well as on the physiological level. in the qualitative study both the cognitive (post-discussion) as well as the physiological (PS score) levels are examined. Therefor it is a big detriment that information of the cognitive state of participants performing the behavioural strategies could not be collected in the literature study. In the qualitative set-up this information would be collected during the post experiment discussion with the participants, where they could give feedback on their mental states during the performance of the different behavioural strategies. This makes it harder to make conclusions about how the behavioural strategies work on the cognitive levels when only looking at the literature review.

The prospective demographic group that the qualitative set-up was meant to study were dyads of students, which are expected to be able to come up with, perform, and reflect on PS facilitating techniques independently with little interference from the experiment leader. This caused some limitations however when gathering and analysing the several research papers found in the literature search, since a relatively large part of the research area concerning PS seems to revolve around demographics that are not in line with the original intended demographic of this report. Specifically a lot of papers (e.g. Gates et al. (2015) seemed to focus on small infants and their guardians interacting, often times playing in a manner that two mature participants wouldn't ever do in a normal social setting. This decision to filter these articles did limit the number of studies suitable for analysis to a significant margin.

5.2.3. Limitations regarding Literature study

Analysis of the articles gathered in the literature review was not as straightforward as was expected initially. The main goal of the literature review was to find what behavioural strategies were used to facilitate PS and how big the effect of the behavioural strategy actually was. With this information an effect size comparison could be performed after which a semi-quantitative conclusion could be made about which behavioural strategy had the strongest effect. However, the aim of the papers used in the literature study always had a different approach from what the goal was of this thesis. In general, most were not concerned about the behavioural strategies that they were using but rather other independent variables such as relationship status. Therefore, most of the analysis of the data was not interested in looking at the effect of the behavioural strategy but rather at the effect of another independent variable. Gathering an estimation of the effect the behavioural strategy had was therefore difficult, and was therefore not really present in the results. Overall researchers very rarely did a baseline and experimental tests and than gave a comparison of the level of PS between them. The comparison was mostly done between groups, such as relationship status, and not within. This made it impossible to determine whether a PS facilitating behavioural strategy was little or very effective. Researchers also often didn't include an analysis on whether there was PS but just assumed it would appear when performing a PS facilitating behavioural strategy. In these cases they would often make a participants do a behavioural strategy and then sort the participants ,in hindsight, into a low PS group and a high PS group, like in Danyluck & Page-Gould (2019). The problem with this procedure is interpreting the results: was PS facilitated in any of the low and high PS groups, and should only high PS groups be counted as having a presence of PS? The case might

also be that there was no PS present at all and the difference between the high and low PS groups was just noise.

The alternative to using effect sizes as empirical evidence to indicate which behavioural strategy was the most effective in facilitating PS was to analyse how many articles reported PS being present when using a certain behavioural strategy. When looking for articles it became clear that, there were very few articles where no PS was generated between dyads at all. It can be presumed that the high number of articles that could facilitate PS are a result of publication bias. Many articles that can not facilitate PS to begin with are useless for researchers when they are concerned about the effects that PS does have on certain variables. Furthermore, some of these articles might in earlier stages run into trouble with facilitating PS with a certain behavioural strategy, but might then have changed their procedure accordingly. If this was the case this would have been great information to have for analysis, however in the current environment there is no such information.

5.3. Implications and future research

This thesis can be used by other researches as a stepping stone for when they are designing their procedure for their study which features elements of PS.

For future research there are several key issues that could be further extrapolated with research. Most importantly is that the qualitative set-up written down in the methods section of this report was only able to be performed in limited sessions, due to the restrictions associated with Covid-19. The results of such an experiment would still hold value, even following the contributions of the literature review from this report. Giving participants the chance to come up with procedures would add new ideas to the already established ones in the current PS research field. The participant feedback on their ideas and the implementation of "bio-feedback" would bring much value as evidence that these behavioural strategies and the "bio-feedback" would be effective (or not).

Secondly, with this report a number of general behavioural strategies and its applications are put forward. However, the exact effectiveness of each of these behavioural strategies is still somewhat in question. The literature review has revealed that many articles the PS literature pool are not concerned by the effectiveness of the various PS facilitating techniques, and this is a significant gap in the literature. A research that would take the advices of this report and tested them in a real-life setting would be valuable to affirm some of the findings of this report. A study design could split participants into groups of dyads. These groups could the each receive a different procedure like playing a video game or performing an imitation task. Finally, a comparison could be made between the magnitude of PS measured in each group. Using the comparison, a conclusion can be reached what behavioural strategy is most effective in a general setting.

5.4. Conclusion

In this report there was a search and examination of various behavioural strategies. To do this, two studies were designed and performed: a qualitative set-up and a literature study. Using clustering, several general behavioural strategies were found, including: gazing, conversation, psychotherapy-session, playing video games, imitation task, playing, rhythmic tasks and miscellaneous tasks. Most evidence for effectiveness in facilitating PS was found for conversation, psychotherapy-session and playing video games. The study found that each behavioural strategy had unique applications and contexts in which they would be most useful. Finally, the study found that dyads had a hard time interpreting bio-feedback and using it to facilitate PS between themselves.

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Appendix A: Participant Questionnaire

Dyad Nr:_____ Participant Nr:_____

Please encircle after each 2-minute activity you perform.

How well did the synchronization score, shown on the computer, reflect how in-sync you felt with your partner during the activity.

	Not at all	A little bit	Somewhat	Fairly well	A great deal	Almost perfectly
1.	O	O	O	O	O	O
2.	O	O	O	O	O	O
3.	O	O	O	O	O	O
4.	O	O	O	O	O	O
5.	O	O	O	O	O	O
6.	O	O	O	O	O	O
7.	O	O	O	O	O	O
8.	O	O	O	O	O	O
9.	O	O	O	O	O	O
10.	O	O	O	O	O	O
11.	O	O	O	O	O	O
12.	O	O	O	O	O	O