# Do You Feel What I Feel?

## The Influence of Emotions on Bodily Expressions and Interpersonal Coordination – Investigating the Natural Body Sway

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## Abstract

Humans are proposed to be one of the most social species (de Gelder & Van den Stock, 2011). While spending a great amount of their time interacting with others, humans seem to be experts in recognizing and interpreting the communicative signals of their interacting partners (de Gelder & Van den Stock, 2011). Social communication has even been proposed to be a fundamental mechanism underlying the establishment and maintenance of human social bonds (Bernieri & Rosenthal, 1991). Yet, little attention is being paid to this sophisticated system of social communication in daily life.

One crucial element of social interactions is exchanging emotional information (Kret et al., 2020). Emotions allow to experience and express an inner physiological state that affects the own motor response (Frijda, 2010) and communicates it to others. For example, the expression of fear elicits a cascade of physiological responses to facilitate an appropriate response (Ax, 1953). In case of an encounter with a bear, this response is urgently needed.

Additionally, the information contained in the emotional expression can lead others to react simultaneously to the observed threat (Chartrand et al., 2005), for example, to the bear. It can also lead others to respond to the observed emotion adequately when directed at themselves (Reisenzein & Horstmann, 2018, p. 465). For instance, an angry body posture or face elicits a faster reaction than a neutral stimulus (Valk et al., 2015). Emotions can be expressed in various bodily signals, like a facial mimic, motor movements, or even more subtle forms, such as pupil dilation or skin color, and are recognized mainly by imitating the perceived movement (Kret, 2015). This imitation process is generally known as mimicry and interpersonal synchrony (Bernieri et al., 1988). Most importantly, however, many of those reactions happen unintentionally and without awareness of the interacting persons (Chartrand & Lakin, 2013).

The present thesis aims to unveil how positive and negative emotions affect a subtle bodily reaction, as the natural body sway (experiment one) and to what extend the own emotional state changes the ability to interact with others (experiment three). The experimental set-up of the third study was based on experiment two, which aimed to create an unbiased human-avatar body sway synchronization paradigm.

Previous research on emotional experience and expression found women and men to respond differently. In general, women seem to be more likely to express their emotional state through facial expressions and verbal communication, whereas men rather express their emotions through actions. Moreover, gender differences may depend on the type of emotion. Findings suggest that women more easily recognize sadness and fear in a human face, while men are better at identifying anger (Kret & De Gelder, 2012).

In line with this are the results of the present thesis: women and men responded differently to emotion inductions. Men responded more strongly to both emotional states with a greater swaying amplitude. Additionally, they were more likely to coordinate their movements with a moving avatar. On the other hand, women were more likely to rate their emotional state as more intense. During negative emotion induction, the swaying amplitude decreased, only, however, in highly empathic participants. This behavior due to unpleasant stimuli is well-known as a freezing response (Roelofs et al., 2010).

The findings of the present thesis shed some more light on the complex but sensible system of human social communication and its underlying mechanism. Even though one does not always recognize and interpret emotional signals, it is a crucial mechanism for successfully living together and works as a strong bond between all social individuals.

# General Introduction – State of Research

Recognizing and interpreting emotional signals is a crucial mechanism for successfully living together, even though most of the time, one is not aware of it (de Gelder & Van den Stock, 2011). Nevertheless, emotions can be expressed in a variety of behavioral forms (Kret, 2015). For a deeper understanding of the influence of emotions on the body, it is worth discussing the essence of emotions, which leads to one question: what is an emotion?

## Emotions

"Everyone knows what an emotion is, until asked to give a definition. Then, it seems, no one knows." (Fehr & Russell, 1984, p. 464). A sentence summarizing the efforts and troubles of so many scientists over the last centuries. The results are a vast spectrum of suggestions for a suitable definition, i.e., Kleinginna and Kleinginna (1981) identified 92 existing definitions, all of which aiming to clarify the formation, nature, and function of emotions (Reisenzein & Horstmann, 2018, p. 425).

One broadly accepted view is that emotions are natural kinds, meaning that specific incidents generate specific emotions, such as anger, fear, happiness, and sadness. Emotions then lead to an emotional sensation (feeling of happiness) and behavioral (smiling) and physiological reactions (elevated heart rate), summed up as components of emotions. Additionally, some researchers propose additional components, such as cognitive (appraisal and notions about the emotional incident), motivational (action tendencies), and neuronal impulses (e.g., Scherer, 2005). Appraisals are elicited by experience and culture, which is why people experience similar emotions differently (see Figure 1).

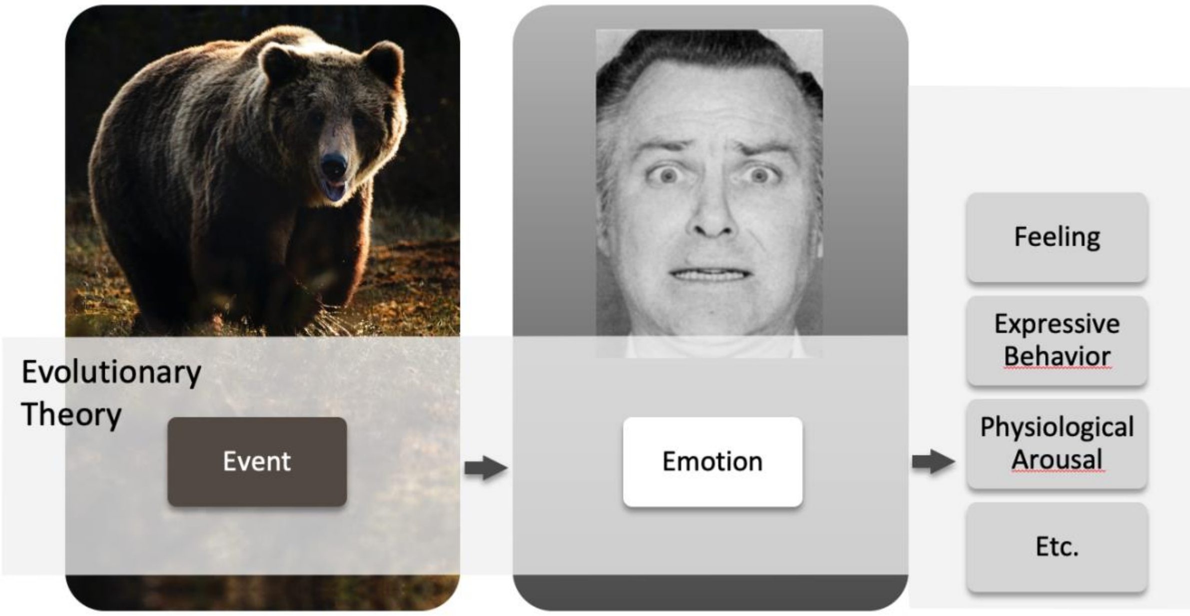


*Figure 1: Emotion as natural phenome*

On the other hand, psychologists argue that emotions are not natural kinds but constructions of people who witness specific behaviors and lack explanation. Another alternative concept to the notion of emotions as natural kinds is the conceptual act model, which considers emotional reactions as diverse and variable phenomena rather than regulated reaction patterns (Barrett, 2006) (see Figure 2).

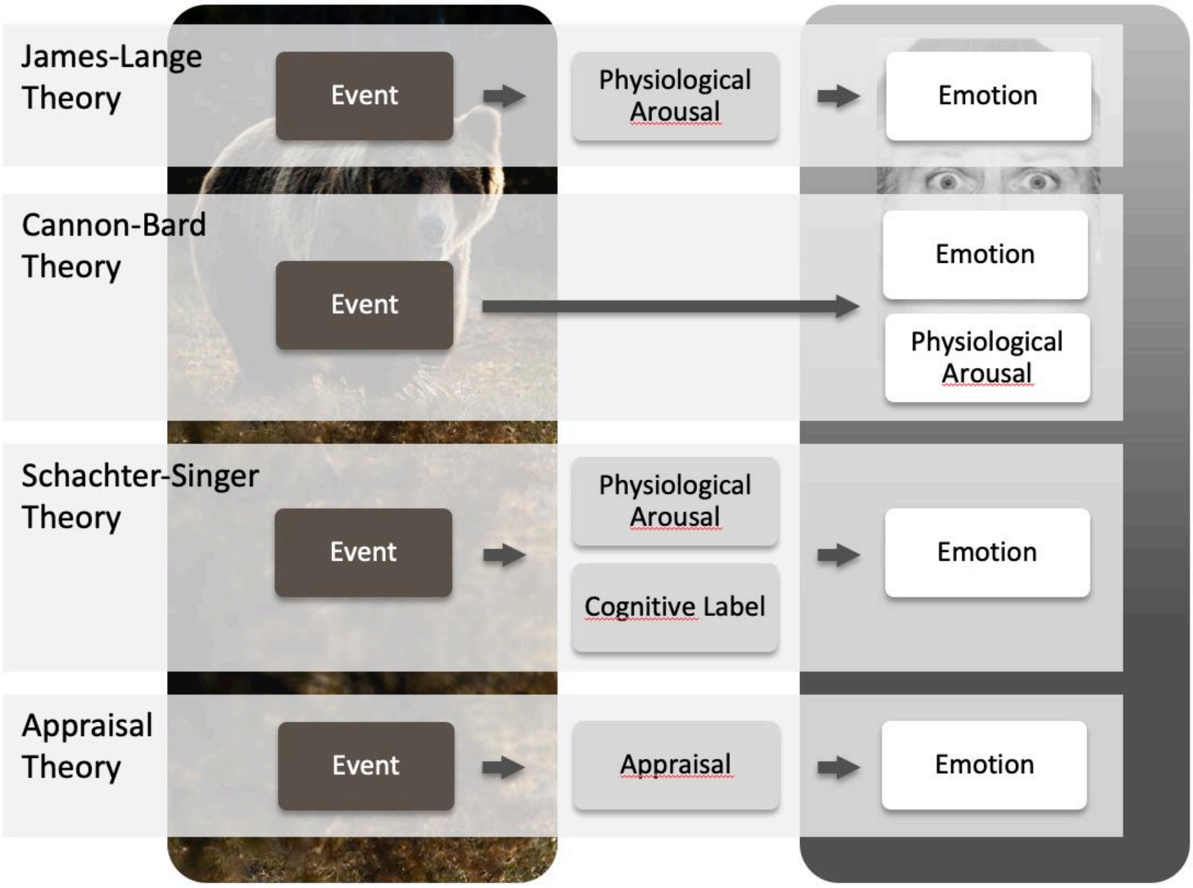


*Figure 2: Emotion as a social construct*

Most emotion theories of today build on concepts that have been developed during the so-called "golden age of emotion research." One well-established theory is the Evolutionary Theory of Emotions (or Darwinian Perspective), which is most famous for Charles Darwin's work (Darwin, 1872). He proposes that emotions evolved to sustain an individual in adapting and responding to its environment. According to evolutionary theories, emotional processes affect an individual's behavioral response at both the cognitive and the motor preparation level (M. M. Bradley et al., 1992; Hälbig et al., 2011). More recently, the effect on motor preparation was corroborated by studies showing the influence of emotions on the motor processes, such as force production (L. Schmidt et al., 2009) or speed implementations (Hälbig et al., 2011). Put together; emotions are able to change muscular reactions in situations of ecological relevance (Lelard et al., 2013). Moreover, recognizing and interpreting the emotions of others correctly also enhances the own changes of survival (Frijda, 2007).

Another basis of many modern emotion theories was independently developed by William James (1884) and Carl Lange (1885). The James-Lange Theory (or Jamesian Perspective) suggests that emotions are the consequence of the mind's perception of an own physiological process due to any stimuli or thought. For example, seeing a bear in the forest provokes the activation of the individual's sympathetic nervous system (i.e., an increase of heart- and breathing rate), leading to the emotional feeling of anxiety. Walter Cannon (1929) disagrees with James and Lange for several reasons: he, firstly, argues that an individual can experience a physiological reaction without feeling an emotion, such as an increased heart rate due to physical exercise. Secondly, an emotional response happens too quickly to rely merely on the physiological reaction. The theory he promotes states that the feeling of emotion and the physiological response happen simultaneously. Philip Bard later expanded his theory. Today it is known as the Cannon-Bard Theory.

Later on, Stanley Schachter and Jerome E. Singer (1962) revive the James-Lange Theory within their Schachter-Singer two Factory Theory of Emotions but disagree on one point: physiological feedback is not sufficient for the development of emotions. They instead speak about a cognitive interpretation and labeling of changed physiological conditions, which then leads to emotion. In accordance with the theory of Cannon and Bard, the Schachter-Singer Theory suggests that similar physiological responses can lead to different emotions. For example, an increased heart rate during the encounter with a bear in the forest will be identified as anxiety. In contrast, the same physiological reaction during the first encounter with a date will be interpreted as affection or love.

In contrast to the James-Lange Theory, Magda B. Arnold (1960) suggests the reason for emotional reactions always to be a specific external object. According to the Appraisal Theory (or Cognitive Perspective), a person needs firstly to cognitively understand that a specific external object exists (i.e., thinking there is a bear) and secondly, that this object affects the person in a good or bad way (i.e., "I am in danger"). Arnold points out three basic dimensions for her cognitive theory of emotions: evaluation, presence-absence (an incident is present vs. prospective), and coping (being able to deal with a present or future incident). Similarly, Richard Lazarus (1966) describes a primary appraisal phase and a secondary appraisal phase. While during the primary appraisal, a person evaluates the incident concerning its motives, in the secondary appraisal, a person judges its capabilities to deal with the given incident. More recently, Barrett Feldman (2009) argues that the formation of emotions is a cognitive process of a person who observes a shift by itself or another person. According to this definition, the concept of emotions is rather culture-specific because groups of people agree on how specific behavior patterns or incidents should be analyzed. One well-known researcher of the Social Constructivist Theory is Averill, who evaluates emotions as a product of socio-cultural learning (Averill, 1980).

Another question which scientists struggle to find common ground on would be: are all emotions on one level? The concept of primary, basic or intrinsic emotions suggests that the perception of ecologically significant stimuli elicit emotional processes in the evolutionarily old structures of the brain (Izard, 2009, p. 7). According to the Basic Emotion Theory (BET), joy confirms this definition. As joy happens between mothers and infants, it saves the survival of the infant. This theory essentially refers to the work of Darwin's "The Expression of the Emotions in Man and Animals" (Darwin, 1872) and consequently led to the question about the biology-culture interaction (Crivelli & Fridlund, 2019). McDougall (1923) describes basic emotions as innate instincts which foster the natural selection: pugnacity, escape, rejection of particular substances, curiosity, maternal/paternal instinct, hunger, curiosity, sex, gregariousness, self-assertion, submission, construction, acquisition, crying/appeal, laughter, comfort, rest/sleep, and migration. One significantly acknowledged theory of basic emotions is the Neurocultural Theory (Ekman, 1972), which postulates at least six basic emotions: fear, anger, disgust, happiness, sadness, surprise. Those innated affect programs release, besides the emotional feelings, physiological reactions, and emotionally characteristic facial expressions (Reisenzein & Horstmann, 2018, p. 465). Ekman puts his theory in the middle between the "relativists" (facial expressions are culture-specific) and the "Darwinism" (Crivelli & Fridlund, 2019).

Some of the most eminent researchers in the field of BET, Izard, Ekman and Cordaro, Levenson, Panksepp, and Watt, set their criteria for basic emotions but agree only partly on the other's criteria. For instance, they agree that a basic emotion (1) needs to be "primitive" in a way that it originates from subcortical brain regions, (2) it needs to be of universal characteristic signals, or (3) it needs to have the presence of neurons attributed to the emotion and to occur in non-human primates. However, they disagree, for example, in the emerging early in ontogeny (Izard) and in characteristic physiological correlates (Ekman)[1].

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[1] Ekman's characteristics for basic emotions: (1) distinctive universal signals (e.g., facial expressions); (2) universal and distinct antecedents (e.g., the sight of a snake in the grass); (3) characteristic physiological correlates; (4) are induced by an automatic processing (i.e., non-conscious or involuntary); (5) emerge early in ontogeny; (6) are present in other non-human primates; (7) have rapid onset; (8) are of short duration; (9) are not controlled voluntarily; (10) are associated with distinctive thoughts, memories, and images, as well as with (11) distinctive subjective experience (Ekman, 1999)

*Table 1[2]: Basic emotions after the authors: Izard, Ekman, and Cordaro, Levenson, Panksepp, and Watt. a: (x) only conditionally basic emotions, since higher cognitive skills are needed after language development. b: author included emotion as basic emotion; however, according to the author, final supporting evidence is not yet available. c: Panksepp and Watt use terms which are fundamental for the evolutionary survival of a species. To show their scientific importance, they choose full capitalization as a terminological convention.*

| Izard (2009, 2011) [a] | Ekman and Cordaro (2011) | Levenson (2011) | Panksepp and Watt (2011)[c] |
|---|---|---|---|
| Happiness | Happiness | Enjoyment | PLAY |
| Sadness | Sadness | Sadness | PANIC/GRIEF |
| Fear | Fear | Fear | FEAR |
| Anger | Anger | Anger | RAGE |
| Disgust | Disgust | Disgust | x |
| Interest | x | Interest[b] | SEEKING |
| Contempt[b] | Contempt | x | x |
| x | x | Love[b] | LUST |
| x | Surprise | Relief[b] | CARE |

For some scientists, the concept of basic emotions proposes a clear basis for a definition of emotions. By applying the concept of basic emotions, scientists investigate the social function of emotions (Keltner & Haidt, 1999; Van Kleef et al., 2016). The expression of emotions enables individuals to deal with social interactions that are crucial for human beings' survival. Firstly, by providing information for others, secondly, by fostering behavioral response, and thirdly, by evoking emotional and behavioral responses in the interacting partner (Van Kleef et al., 2016). According to this theory, an emotion can be expressed in a variety of ways, whereas one emotional expression tells about (1) the current feeling, (2) happenings in the present situation; (3) intentions or behavior tendencies; (4) desired reactions in an interacting partner; and (5) information of the social relationship (for review, see (Scarantino, 2017). Critics of the BET come from Crivelli and Fridlund (2019), who

[2] Table 1: adjusted table from (Tracy & Randles, 2011)

argue that BET is simplified in its exclusiveness of facial expressions and that its claim for one universal facial expression in all cultures is based on false interpretations of emotional expressions of other cultures than the European – for example, not taking into account the cultural influence on emotions (i.e., a person smiling even though she/he is sad) and biological differences on facial expressions. Instead, they offer the Behavioral Ecology View (BECV) of facial expressions based on research on animal communication and biological and cultural evolution. In contrast to basic emotions, where facial expressions have an intrinsic meaning of a specific emotion, the BECV suggests that facial expressions are tools which the individual uses to communicate a followed action (Crivelli & Fridlund, 2018).

The consequence of a concept of basic emotions is the existence of non-basic emotions. Izard, Plutchik, and McDougall propose that basic emotions are the basis for secondary emotions (Reisenzein & Horstmann, 2018, p. 464). Panksepp and Watt (2011) describe secondary and tertiary emotions, describing the latter as complex composites of emotion and cognition. Izard introduces the emotion schemas, where basic emotions merge with their related cognition to a regulatory and motivational system (Izard, 2007). According to the Neurocultural Theory, facial expressions of non-primary emotions result from ontogenesis developed through culture (Crivelli & Fridlund, 2019).

Despite the ongoing discussion, most theories agree upon one thing: emotions can be seen along two theoretically independent dimensions. In order to arrange emotions along their dimensions and to obtain self-reports of emotional experiences, scientists have developed dimensional maps. Some well-known examples are the model of Wilhelm Wundt (1903), Plutchik's Wheel of Emotions (Plutchik, 2001), Russel's Two-Dimensional Circumplex Model (Russell, 1980), or the Geneva Emotion Wheel (GEW) of Scherer (2005). While Wundt proposes three axes: valence (positive-negative), arousal (calm-excited), and tension (tense-relaxed), Plutchik's wheel consists of eight primary emotions on a positive to negative axis: joy-sadness; anger-fear; trust-disgust; and surprise-anticipation. The combination of several primary emotions can form a more complex emotional experience. For example, anger and disgust could develop into an emotional experience of contempt. The GEW and Russel's Two-Dimensional Circumplex Model suggest two axes: positive to negative and low control/arousal to high control/arousal.

Although models differ in the number of dimensions, they all have two axes in common: valence and arousal (e.g., Lang, Bradley, & Cuthbert, 1990). Here, valence is defined as "the organism's disposition to assume either an appetitive or defensive behavioral set," meaning an emotion is either perceived as positive (i.e., joy) or as negative (i.e., sadness). In contrast, arousal is defined as "the organism's disposition to react with varying degrees of energy or force" (Lang et al., 1990, p. 380). Individuals experience emotion as either arousing (i.e., exiting positively or nervous in a negative way) or as calming (i.e., relaxing or sleepy). Valence is supposed to be a predisposition for approach and avoidance behavior, whereas arousal has been theorized to let individuals react to fearful situations, for example, with freezing behavior. Freezing behavior is characterized as an involuntary stiffening of the body (Kordts-Freudinger et al., 2017), expressed by a slowing of the heart rate (bradycardia) and an increased immobility and muscle tonus (Hagenaars, Oitzl, et al., 2014). Others argue that emotional arousal is responsible for the intensity of the behavioral response (e.g., Lang, Davis, & Öhman, 2000). The concept of approach and avoidance is based on the proposed fundamental link between emotions and action tendencies, which develop from a centrally organized appetitive and defensive motivational system, which again have evolved to prepare the organism for its environment (Bradley, 2000). Thus, formulated by the Motivational Direction Hypothesis (MDH, positively poled stimuli elicit approach (appetitive motivational system), negatively poled stimuli trigger avoidance behavior (defensive motivational system) (Lang et al., 1990). The theories mentioned above go hand-in-hand with the notion that emotions convey information from the environment. The Affect-as-Information Theory states that positive emotions facilitate automatic, unconscious action tendencies, while negative emotions foster more cautious and reasoned behavior (Schwarz & Clore, 1996).

The concept of the motivational system, approach, and avoidance has been used to explain actions due to an emotional state (Dael et al., 2013; Phaf et al., 2014). Frijda even goes further by suggesting action tendencies to be the same "thing" as emotions (Frijda, 1986, p. 71). The relation between emotion and action has been acknowledged by scientists of the field, like Lazarus (1991), Tomkins (1995), and Brehm (1999). By following appraisal, which doesn't necessarily need to be consciously experienced, emotions can lead to intentional or unintentional action (Frijda, 2010). The proposed concept goes beyond perceiving and recognizing facial expressions, and as suggested by many scientists, it includes whole-body expressions (de Gelder & Van den Stock, 2011).

How complex and life-long the process of finding a suitable and broadly accepted definition is, shows the work of several psychologists who tried to collect and classify the existing definitions. For example, Kleinginna and Kleinginna (1981) found 92 existing definitions and classified them into ten categories. Another attempt ventured Izard (2010), he summed the definitions of 34 emotion scientists and evaluated them by independent judges. They came up with eleven different elements of a definition, like emotions must have a physiological, expressive, or cognitive element. However, none of these tries led to a broad agreement among the scientific community.

Although there is no consent of one meaningful definition, scientists agree that emotions elicit specific reactions, differentiated as components. Components, which are often referred to as affect programs, are emotional expressions (i.e., smiling), physiological reactions (i.e., elevated heart rate), or sensations (feeling of happiness). Recently, also action tendencies (motivational consequence) and cognition (appraisal and notions about the emotional incident) have been proposed as critical components of emotions (Componential Theories of Emotion) (Scherer, 2005).

Within this thesis, I will refer to the following working definitions, based on the definitions formulated by Schmidt-Atzert et al. (2014):

Working definition of emotion: an emotion is a qualitative, describable condition, which arises through appraisal of inter- or intrapersonal events and leads to a change of one or several of the following components: feeling, physical condition, and expression.

Working definition of feeling: a feeling is any condition which is qualitatively describable by the person itself. Through this description, others need to understand that an emotional feeling is described and not any other feeling, like the feeling of knowing someone.

Working definition of emotional expression: an emotional expression is an observable and temporarily limited behavior of a person which is (un)consciously absorbable by others.

While working definitions are a good start to work with, a differentiation to many terms like mood, feeling, or affect is still very difficult. For instance, mood is generally defined as weaker and less variable, longer-lasting, and often released without any external stimulus. Not all feelings include emotions, for example, as mentioned above, the feeling of knowing someone. Feelings are somewhat subjective representations of emotions. While affect is used synonymously with the term emotion many times, other scientists understand the experience of desire and aversion (Reisenzein & Horstmann, 2018).

According to these definitions, I will use the term emotion throughout my studies. However, if referring to literature, I will use the applied terms of the authors.

## Methods of Emotion Research

Besides the theoretical discussion about a suitable definition, researchers experimentally studied emotions with various methods. The next paragraph will refer to some well-established investigation methods.

### Investigating Emotions

In order to evaluate the evolutionary or socio-theoretical hypothesis, one approved method involves looking at cross-culture characteristics. If emotional principles evolved socially, then emotions differ in their nature and their amount. If, however, emotions evolved evolutionarily, then there should be similarities found on a cross-cultural level. One incident of a cross-cultural existence of emotions is the vocabulary for specific emotions, the classification of facial expressions to a named emotion, or the fact that certain situations provoke a specific emotion, i.e., typical clues for joy, sadness, or anger (Reisenzein & Horstmann, 2018, p. 469). Ekman and colleagues (1987) found their classified six basic emotions (fear, anger, disgust, happiness, sadness, surprise) in ten different countries (Ekman et al., 1987). Some of them also in a non-western culture. Numerous investigations led to the conclusion that appetitive-aversive and activated-deactivated feelings are elements of cross-cultural emotional experiences.

Apart from that, as emotional expressions have been proposed to be fundamentally linked to actions, it is reasonable to study action tendencies (Frijda, 1986). Several methods have been developed to decode the emotional expression of the face and the body. However, also the voice or other physiological reactions are investigated to study a person's emotional state (see chapter Physiological Reactions, p. 21).

### Inducing Emotions

Another possibility to investigate emotion theories demands situations that elicit an emotional state in the participant. Some of the well-controlled and commonly used methods in emotion research include presenting pictures, videos, music, or audio.

For the use of emotion induction through the presentation of pictures, Lang et al. (2008) developed a set of emotionally arousing pictures, the International Affective Picture System (IAPS). The IAPS includes categories such as mutilation, threat, erotica, and neutral pictures and can be categorized along the axis valence and arousal. It is the most frequently used picture system to induce all kinds of emotional states in a participant. The presentation of pleasant or unpleasant pictures has been found to activate emotional states of physiological changes (i.e., skin conductance, heart rate) (Greenwald et al., 1989). Especially mutilation pictures have been highly agreed to evoke disgust in both women and men (Bradley & Lang, 2007, p. 35).

It seems likely that scientists also used films to induce emotions, although no "standard" film has been established. Most films induce emotions like joy, sadness, disgust (Roberts & Levenson, 2006), and fear in phobia patients (Klorman, 1974). Less straightforward is the induction of anger (Levenson, 2003). One disadvantage of the presentation of film clips is its inaccuracy in inducing specific emotions (Schmidt-Atzert et al., 2014, p. 105). I.e., a movie about the slaughter of animals[3] provoked a broad spectrum of emotions, such as aversion, restlessness, sadness, guilt, fear, anger, and shame. Corroborating the idea of those visual techniques are findings of neuronal and psychophysiological research, which suggest that perceiving emotions activate a similar neuronal pattern as if the action would have been performed (Chartrand & van Baaren, 2009). This mechanism might be mediated through mimicry (Chartrand & van Baaren, 2009), which is the copying of actions and behavior of an interacting partner (see Interpersonal Coordination – Social Behavior, p. 35). Also, other autonomic reactions, as sweat (elevation of skin conductance), fixated attention of the eye or pupil dilation (eye-tracking), and facial heating (thermal imaging) (Kret, 2015), have been found to support this hypothesis.

[3] „Le sang des bêtes“ (Franju, 1949)

Only recently, music has found its way into experimental set-ups of emotion induction. The main advantage is the very purpose of the composer to induce emotions through the music. Music effectively induces a variety of moods (for a review see, Västfjäll, 2001).

Another acoustical method uses audio dramas or texts that the experimenter or the participant can read out and are possibly combined with a mental representation exercise. Mental representations can also be used exclusively, like mentalizing a specific incident during the past day, week, or over the whole life (autobiographic memory). Some well-known examples are the Day-Reconstruction-Method and the Diary Method, where participants reconstruct and evaluate their past days or one specific emotional incident, or the Event Sampling Methodology. Participants note their emotional states right after an incident (Schmidt-Atzert et al., 2014, p. 75). Also included in this category is the Velten-Technique; here, participants read out standardized emotional statements and put themselves into the sentiment of these emotions (imagination) (Velten, 1968). It has been proposed that all of the techniques mentioned above require the ability to simulate actions as internal models (more on this in the chapter: The Effect of Emotions on Bodily Expressions: Theoretical Assumptions, p. 51) (Zahavi, 2008).

More invasive are hypnosis methods, the use of chemical substances (e.g., nicotine, caffeine, adrenalin), and real emotional situations caused by the experimental set-up. For example, fear can be induced through a simulated malfunction of the measurement device to which the participant is connected (Ax, 1953), the notification to give a speech (Kirschbaum et al., 1993), or a following electrical shock (Katkin, 1966).

To analyze whether emotion induction actually led to a change in the participant's emotional experience, rating scales, interviews, diaries, or physiological responses are used.

### Affective Neuroscience

The development of new measurement techniques brought a great upswing for emotion science. Earlier on, scientists like MacLean (1949; 1952) investigated the formation of brains of different animal species to identify evolutionary "younger" and "older" brain structures. Their research followed the thoughts of the evolutionary perspective – an emotional reaction, stimulated by a dangerous situation, is an inherited trait – and was based on the findings of Papez (1937). The Papez'

Circuit describes the limbic-hypothalamic system to be responsible for the regulation and the experience of emotions. Today, it is common knowledge that more brain structures are evolved – we instead talk about a limbic-hypothalamic complex (Nieuwenhuis et al., 2008). Some authors (e.g., Damasio, 1986), however, still acknowledge limbic regions, like the amygdala or the anterior cingulate cortex (ACC), as an inherited emotional basis (Schmidt-Atzert et al., 2014, p. 185). With the invention of new measurement techniques, like functional magnetic resonance imaging (fMRI) or positron emission tomography (PET), the field of affective neuroscience has been pushed immensely. LeDoux (1998) developed a strong theory about fear, which strongly conflicts with cognitive theories. He presents that fear can be released through a short (30 msec.), consciously not recognizable, presentation of fear-evoking pictures (LeDoux, 1998). LeDoux explains his findings with two pathways, how emotions can be formed: a subcortical (low road: thalamus - lateral and central part of the amygdala - hypothalamus - brain stem - physiological reaction) and a cortical path (high road: thalamus - primary sensory cortex and other parts of the cortex - hypothalamus - brain stem), both starting with a visual stimulus. The subcortical path facilitates a quick and unconscious but inaccurate response to threat, while the cortical path enables a differentiated analysis of the situation, thus, takes more time for a reaction. New findings, however, found the amygdala not essential for the perception of fear, and it somewhat responsible for new motivational-relevant stimuli (A. K. Anderson & Phelps, 2002; M. Davis & Whalen, 2001). About the same time, Panksepp (1998) proposes a theory about parallel and interacting synaptic systems: seeking, rage, fear, panic/grief, lust, care, and play. Empirical evidence exists only for the first four systems. The neuro-anatomical and neurotransmitter system of seeking complies with the dopamine system, which, after activation, leads to curiosity, exploratory behavior, and the seeking of pleasant stimuli. Rage can be released after frustration or irritation and provides the body with energy and activation for the defense mechanism. The system of fear is located in the network of the amygdala. Due to avoidance of pain, animals react upon fearful stimuli with freezing, fight, or flight behavior. Essential for this mechanism are the hormones of the hypothalamic-pituitary-adrenal axis (HPA axis). The panic system is stimulated after separation or isolation; it involves the neurotransmitter of glutamate, oxytocin, and opioids (Schmidt-Atzert et al., 2014, p. 191).

The freezing response enables an individual to quickly respond to a threat with a defensive reaction, i.e., fight-and-flight behavior (Roelofs et al., 2010). Freezing behavior in humans can be found in a decrease of body sway, a natural sway around the balance point (for more on this, see chapter Body Sway, p. 30), and an increase in cortisol level (Coco et al., 2015). Experimentally tested was the freezing response in participants with stress-induced cortisol. Authors interpreted the increased reaction time in an approach-avoidance task as freezing behavior (Roelofs et al., 2005).

Gray and McNaughton (2000) categorize the emotional response mechanisms: The Reinforcement Sensitivity Theory (RST) postulates three motivational systems, 1) a behavioral approach system (BAS) is triggered by rewarding stimuli, 2) a fight-flight-freezing system (FFFS) is activated by punishing stimuli and 3) a behavioral inhibition system (BIS), which is activated by motivational stimuli (Schmidt-Atzert et al., 2014, p. 206).

### Physiological Reactions

Following the idea that emotions evolved to adapt the body to an ever-changing environment, researchers propose that, besides neuronal activation, a body reacts upon emotional incidents with several other systems like the endocrine system (e.g., the dopaminergic- and serotonergic systems) and the vegetative nervous system. Over the past years, the research found several physiological indicators after emotional events. A review about autonomies and somatic reactions after fear and anger induction validates varying reactions for both emotions (Stemmler, 2009) (see Table 2). These mechanisms occur largely without any cognitive or learning processes and were proposed to not only prepare an organism for a specific behavioral reaction but also to enable communication between individuals (e.g., body posture, facial expression, or skin color).

*Table 2: Physiological reactions after fear and anger induction compared to a control group. k = number of studies, d = effect size, * p < .05, ** p < .01* (Stemmler, 2009)

| Variable | *k* | Fear (*d*) | Anger (*d*) |
|---|---|---|---|
| blood pressure | 11 | .92** | 1.58** |
| muscular activity | 4 | .32* | 1.04** |
| heart rate | 14 | 1.32** | 1.39** |
| respiratory rate | 7 | .87** | .47** |
| skin conductance | 5 | .12 | .49** |
| face temperature | 4 | -.02 | .68** |
| finger temperature | 8 | -.68** | -.32** |

### Facial Expressions

One amply studied field of emotion expressions is the effect of emotions on the face. Scientists developed several methods to identify emotional expressions, like the observation of participants, coding systems, or measurement of muscle activation.

During observational studies, either participants or actors are asked to express a particular emotion, or individuals are induced with an emotion. Their facial expression is shown to participants to identify the emotional expression (Schmidt-Atzert et al., 2014). Wagner et al. (1986) investigated the observer's ability to recognize and evaluate valence and intensity of spontaneous facial expressions (i.e., emotions were induced and participants unknowingly videotaped) of six emotions and one neutral face. They found that participants recognized the presented emotion in 48.4% of the cases overall shown emotions. Joy was found to have the highest match (60%), while participants matched anger only at a probability of 12.7% (chance level lies at 14.3%). However, if actors consciously simulated a specific emotional expression, emotions are easily identified by observing the facial or the acoustic expression (voice). A meta-analysis found particularly the emotion joy to be easily detected by an observer, whereas emotions like anger and sadness are best recognized through voice observation (Elfenbein & Ambady, 2002). Overall, it is essential to note that emotion recognition is enormously dependent on a situation or a context, which is lacking in most experimental set-ups.

To overcome the subjective difficulties of a human observer, scientists developed several systems to standardize the analysis of emotional facial expressions. One well-known example is the Facial Actions Coding System (FACS) by Ekman and colleagues (1978), which codes an emotional expression in 44 action units. In a study where participants were exposed to a positive and a negative video sequence, the facial expressions (coded by the FACS) of the positive and negative emotions correlated with the described positive (joy) and negative emotions (disgust and fear) of the participants. However, some participants who did not show any negative facial expressions also rated subjective feelings as negative. Same inverted results were found for participants who showed negative emotional expression but did not rate any (Ekman et al., 1980). While the FACS is mainly a tool to characterize facial expression, other authors developed a register of facial expression for recognition studies, e.g., the Pictures of Facial Affect (POFA) includes 110 facial expressions of different emotions (Ekman & Friesen, 1976). In an attempt to produce a naturalistic set of facial expressions, van der Schalk et al. (2011) developed the Amsterdam Dynamic Facial Expression Set (ADFES). Short film clips of dynamical faces (neutral to emotional expression) held for about six seconds.

Another approach to objectively measure facial expressions is the use of electromyography (EMG). The EMG records a muscular contraction caused by emotional expressions in the face, which has the advantage of being more accurate and less time-consuming than the FACS. However, the electrodes can be perceived as distracting or even lead the participants' attention towards their emotional expression. Overall, the findings for all three methods show somewhat contradicting results to identify emotional expressions in the face reliably.

### Bodily Expressions

While it is commonly accepted that emotions are expressed and can be identified in a human face, research on emotional expressions through body language is still a rather rare subject, even though two well-established theoreticians, Darwin and James, already discussed emotional expressions of the whole body over a century ago. Researchers in this field argue that a fearful face signals threat; however, it does not provide any information about the reason for the threat or the actions that the individual will take to deal with the threat. On the other hand, a fearful body position signals threat and additionally provides information about the response of the individual that is threatened (De Gelder, 2006), plus it can be recognized from far away (De Gelder, 2009). Indeed, several studies found observers successfully identifying emotions only by a bodily expression or movements, e.g., pride, shame, joy, anger, fear, and disgust (Atkinson et al., 2004; Crane & Gross, 2007; de Gelder & Van den Stock, 2011), most of them being identified on a cross-cultural level (Sogon & Masutani, 1989; Tracy et al., 2013; Tracy & Robins, 2008). Some researchers even propose that bodily expressions are crucial for successful emotion recognition (Tracy & Robins, 2004). Studies presenting incongruent face-body emotions (face expressing anger, body expressing fear) found participants to answer slower and with a lower success rate than when face and body expressed the same emotion (Meeren et al., 2005). Additionally, the ratings of the facial emotion were biased by emotion expressed by the body (Meeren et al., 2005).

Non-verbal behaviors are generally divided into two categories: encoding and decoding. In encoding studies, participants or actors are being asked to express a specific emotion, or participants actually experience an emotion after emotion induction (Tracy & Matsumoto, 2008). In decoding studies, participants identify an expressed emotion (Witkower & Tracy, 2019). Researchers further distinguish between two critical processes in the expression of bodily communication: behavior types, like mere bodily expression (position of the head or the leaning direction) and behavior qualities, which is the pace and dynamics of a specific movement (i.e., fast, limp, flowing). Even though dynamic expressions show both the behavior type and the behavior quality, previous studies proved that only photographs (behavior type) (de Gelder & Van den Stock, 2011) or dynamic point-light stimuli (behavior quality) (Atkinson et al., 2004) are recognized well above chance.

While most studies investigated emotional expressions by relying on an actor's or a participant's interpretation, fewer also used emotional expressions of real-life situations or even induced emotions in a laboratory setting. In the following paragraph, selected findings of all research set-ups will be discussed for each emotion, respectively.

*Joy & happiness*

Joy and happiness seemed to be easily recognized when expressed excessively during a movement, yet there are several degrees of the expression (e.g., inside joy, laughter). Out of three emotions expressed by dancers, joy was most often identified (Shikanai et al., 2013). Contrary, there is no equivalent body pose of a smiling face. In a study where emotions were shown in a static body position, the expression of happiness was found to be the most difficult to recognize (de Gelder & Van den Stock, 2011). Bodily expressions of joy and happiness (including pride and victory) are generally rather fast and energetic (Dael et al., 2013), like upwards movements of the arms, trunk, and shoulders, an upward head tilt, closing and opening of the hands and large body movements as jumping (Coulson, 2004; de Meijer, 1989). However, laughter, another expression of joy, is accompanied by uncontrolled muscle relaxation (Kret et al., 2020).

An encoding study, presenting negative and positive, low and high arousing pictures to participants, found that experimentally induced joy (being exposed to pleasant pictures or recalling a joyful memory) increases the pace at the start of walking (measured in reaction times) (Naugle et al., 2011) and their general walking speed and smoothness of walking movements (Gross et al., 2012; Kang & Gross, 2016) relative to unpleasant pictures or a neutral recall task, respectively. An increased reaction time was also found during the process of standing up and walk initiation (Kang & Gross, 2015). It is noteworthy that bodily expressions of joy and happiness most often overlap with those of pride (Witkower & Tracy, 2019) or victory (Kret et al., 2020).

*Sadness*

"This state of mind and body is shown by their listless movements, fallen countenances, dull eyes, and changed complexion" (Darwin, 1872, p. 136). Individuals in a sad mood move slower than happy people and, if expressed generously, it was also successfully decoded by participants (Crane & Gross, 2007; Shikanai et al., 2013). Body postures of sadness include: head tilled down and cashed within the hands, arms in front of the body, slow movements, and an overall collapsed upper body and dropped shoulders (e.g., Parkinson et al., 2017).

Therefore, it not surprising that a study investigating walking movements of major depressed patients and sad students (sadness induced through music) found a reduction of walking speed, arm swing, and vertical head movements compared to a healthy control group and happy students (Michalak et al., 2009). Similarly, participants who were asked to recall a sad memory were slower to stand up and walk across the room (Kang & Gross, 2015) and showed a generally slower walking speed and a decreased walking smoothness (Gross et al., 2012; Kang & Gross, 2016). Also, head movements of pianists playing an excerpt with different emotional expressions were found to be slower when playing a sad intonation (Castellano et al., 2008).

*Anger & Dominance*

Dominance, characterized as a repeated, agonistic pattern of interactions between two individuals (Drews, 1993), causes individuals to appear as tall as physically possible (Darwin, 1872, p.128). Anger and dominance share some movement patterns with the expression of pride (i.e., head tilted back and arms akimbo) (Tracy & Robins, 2004). Studies found anger to be expressed by an expansive forward movement, stomping, and an expression of the hands or arms (closing the hands to a fist, moving arms to the front) (Witkower & Tracy, 2019).

An encoding study, investigating movement reaction times as a response to the observation of angry body positions and faces, found participants to touch the screen significantly faster when an angry body or face was shown compared to neutral stimuli. No time difference was found for fear. The authors suggest that fearful expressions might signal an environmental threat that first needs to be observed, while a threat sent from another individual needs a direct and quick response (Valk et al., 2015). Anger was also found to increase reaction times; in the experiment mentioned above, where sadness retarded the process of standing up and starting to walk, anger speeded participants up (Kang & Gross, 2015). In another study, participants also showed an increased walking speed and smoother walking movements in the vertical and anterior-posterior axes (Gross et al., 2012; Kang & Gross, 2016).

*Fear*

Fearful humans tend to make themselves smaller by a lowered head and slumped shoulders (submissive behavior) (Maclay & Knipe, 1972); however, they have also been found to freeze when being threatened (Roelofs et al., 2010). Freezing is characterized by a short phase of immobility and an increase of the heart rate. It enhances the chance to remain undetected and is mostly followed by the fight-and-flight reaction (Kret et al., 2020).

Participants who were asked to express fear shifted the balance point to the back and covered their body with the arms and the face with their hands (Witkower & Tracy, 2019). Anger and fear were successfully identified when participants observed those expressions (Coulson, 2004; Wallbott, 1998).

The findings of the encoding and decoding studies of anger and fear are supported by a study investigating muscle activation during the active expression and the passive observation of the emotions anger and fear (see below: Body Action Coding System) (Huis In‘t Veld et al., 2014).

*Disgust*

While disgust provokes a strong sensation in the body, it lags a clear description of bodily expressions. A study investigating the recognition of six basic emotions (anger, disgust, fear, happiness, sadness, surprise) by presenting specific joint rotations and weight transfers of computer-generated mannequin figures found disgust as the most difficult to be recognized. In the category disgust, mannequins were leaning backward with a tilted backward head and chest (avoidance), arms reached out in front, and the abdomen was twisted to one side (Coulson, 2004). The overall findings of the identification of disgust are low, especially when movement parameters are excluded (Kret et al., 2020). An encoding study, however, found precise behavioral results. Participants exposed to pictures of contamination and mutilation showed significantly reduced step velocity of the first steps, compared to step movements during the presentation of positive pictures. The authors suggest that pictures of contamination or mutilation evoke disgust (Naugle et al., 2011).

*Pride*

The bodily expression of pride was found to be particularly important for emotion recognition (App et al., 2011). Participants who rated intensity and valence of winning or losing tennis players failed to distinguish “winning” from “losing faces correctly”; however, they succeeded to identify winners from losers when being presented with the body combined with the face, or even only the body (Aviezer et al., 2012). Researchers identified the following behaviors expressed in combination with the emotion pride: head held upwards, swelled chest often paired with pulled-back shoulders, arms akimbo, and fists raised above the head (Tracy & Matsumoto, 2008). After winning a game, pride was found to be displayed by blind athletes who could not have copied it after visual modeling (Tracy & Matsumoto, 2008). The bodily expression of pride was also identified in remoted, highly isolated cultures (Tracy & Robins, 2008) and in 4-year-olds (Tracy et al., 2005).

*Shame & embarrassment*

Likewise, studies investigating shame and embarrassment found facial and bodily expressions equally important for communicating and recognizing the same emotion. Again, facial expressions alone were not sufficient for emotion identification since both the sender and the receiver rather relied on the bodily than on facial expression (App et al., 2011; Tracy & Matsumoto, 2008). Despite the fact that shame and embarrassment are independent emotions (Tangney et al., 1996), the bodily expressions overlap widely. Both emotions show a head tilted down and turned to the side, a collapsed upper body with dropped shoulders and arms hanging limp at sides, often hands touching over or even covering the face (Keltner & Buswell, 1997; Wallbott, 1998). Both emotions, shame, and embarrassment, seemed to be most effectively identifiable when expressions of the face could be identified (i.e., blushing, smile control) (Keltner & Buswell, 1997).

Although bodily expressions of several emotions overlap, participants accurately distinguished pride from joy (e.g., Tracy & Robins, 2008) and also sadness from shame and embarrassment (e.g., Keltner & Buswell, 1997).

Nevertheless, many of the decoding studies still rely on subjective ratings of an actor's performance, who poses an emotion after his intuitive belief and mostly exaggerated expressive behaviors or stereotypes of a certain emotion (Wallbott & Scherer, 1986). To overcome this shortcoming, several coding systems have been developed:

- The *Specific Affect Coding System (SPAFF)* (Coan & Gottman, 2007) codes several emotions expressed by the body. Although it is one of the widely cited emotion coding systems, it misses many behaviors which are generally associated with the expression of this specific emotion (Witkower & Tracy, 2019).

- The *Body Action Coding System (BACS I & II)* (Huis In‘t Veld, van Boxtel, & de Gelder, 2014a; Huis in ’t Veld, Van Boxtel, & de Gelder, 2014b) is, similar to the Facial Action Coding System by Ekman and Friesen (1978), based on the muscle activation required to express the emotion. It is focused on activation of the muscles: the trapezius, biceps, deltoid, triceps, forearm, calves, and lower back during anger and fear. The authors suggest that calf muscles are needed for the expression of fear and muscles of the upper- and forearm are activated to express anger. Muscle contractions were also observed during passively observing an actor performing an emotion, i.e., the wrist extensors responded only to the perception of fear, the calf muscles when aggression was directed towards the participant, and the muscles of the lower back were activated during the perception of an angry person.
- The *Body Action and Posture Coding System (BAP)* describes time-aligned micro-movements on three different levels: anatomical- (description of body parts), form- (direction of the movement), and functional level (communication and self-regulation) (Dael et al., 2012).
- The *Pride and Shame Nonverbal Coding System* was developed to decode several bodily and facial expressions which show pride and shame (Tracy & Robins, 2008). It was found to have good reliability and validity (Tracy & Matsumoto, 2008).

Additional to its benefits for non-verbal social communication, there is evidence that some facial and bodily expressions provide a direct advantage for the actor. For example, the enlargement of the eyes during fearful or surprising situations has visual perceptual benefits for an individual (Lee, Susskind, & Anderson, 2013). Also, the closing of the nostrils, which is practiced during the bodily expression of disgust, could prevent an individual from taking in poisonous aerosols (Chapman et al., 2009). This finding reinforces Darwin's idea that emotions facilitate actions that are beneficial for an individual to react appropriately to the environment (Darwin, 1871).

According to the studies mentioned above, emotions expressed by the face or the body have several benefits; however, if turned around, also mere motor movements seem to enhance the emotional state of a person. The *Laban Movement Analysis (LMA)* characterizes movement elements that are supposed to elicit specific emotions, namely: anger, fear, happiness, and sadness (Bradley, 2009). The idea that sensory feedback contributes to the emotional experience of an individual (Izard, 1993), is in line with the *Facial Feedback Hypothesis (FFH)* and the *Matched Motor Hypothesis (MMH)*, which propose that emotional (facial) expressions can influence the inner emotional state. Several studies demonstrated that at least feelings are affected by proprioceptive stimuli from muscle contractions of facial expressions (Buck, 1980; Carr et al., 2013; J. I. Davis et al., 2009; Strack et al., 1988), postures (Cacioppo et al., 1993; Carney et al., 2010; Riskind & Gotay, 1982), head- (Briñol & Petty, 2003) and arm movements (Cacioppo et al., 1993) (for a review see: Cuddy et al., 2018). An open, "powerful" body posture not only increased the feeling of power and the chance of taking a risk, but it also raised the level of testosterone and lowered the level of cortisol compared to a closed "weak" body posture (Carney et al., 2010). However, these results could not be replicated (Ranehill et al., 2015). Another investigation found that emotions, although to a lesser degree, were evoked in participants through mere imagination and watching others' emotional movement (Shafir et al., 2013).

The reciprocal interaction between emotion, cognition, and body, including emotional information processing, is generally understood as being part of the embodiment theories (Michalak et al., 2009). Embodiment is proposed to be an automatic process that enables an individual to simulate a particular situation by imagining a specific mental content. Lelard et al. (2019) suggest, by activating internal models and neural simulation (*Sensorimotor Simulation Theory*), this process extends to the ability to simulate another person's body posture or emotional state, which is an essential part of the research field of interpersonal coordination.

### Body Sway

Apart from facial and bodily expressions, emotions also alter the autonomic nervous system, like the state of arousal. Thus, they can be expressed through the voice, through olfaction, touch, or pupil dilation (Kret, 2015; Kret et al., 2020). This more subtle expression of an emotion can often still be recognized by an interacting partner. Additional to the suggestion of Lelard et al. (2013) that emotions are able to change muscular activity; also, the natural body sway (postural control) was found to be affected by a change of emotions. It is counted to the unconsciously communicated emotional expressions[4] and can be studied through emotion induction and by using accurate measurement technologies like a force plate, motion capture cameras, electromyography, or accelerators. They help to overcome the challenge that emotional expressions played by an actor might not represent an inner emotional state (Kret et al., 2020). The postural control interacts between perceiving the external world and reacting to it with a continuous motor response. It allows individuals to maintain a stable upright posture and, by doing so, generates a natural sway (Saripalle et al., 2014), the so-called natural body sway. Postural control has been proposed to be a requirement for many species to develop other more advanced motor abilities, like walking (Lelard et al., 2006). Movements around an individual's center of gravity, mostly micro-movements, are generally described as the natural body sway (Nishiyama et al., 2016), although, also larger body movements, during the expression of music, for instance, have been named as body sway (Chang et al. 2020).

I consider the natural body sway a strong reference for investigating the inner emotional state for two reasons: first, many (non)conscious emotional and motivational expressions are preceded by a simple upright standing, such as approach or withdrawal, which, in turn, can be followed by, for example, a caring or attacking behavior. Second, due to advanced measurement technologies, it is possible to provide an accurate movement analysis of a person's body sway in a laboratory setting. Thus, measuring the natural body sway to investigate a participant's emotional state provides a naturalistic and at the same time accurate solution.

The relationship between the natural body sway and the emotional state can be characterized through the center of pressure (COP). The COP describes the sum of all forces between a body and its supporting surface at a specific point (Murray, 1967; Słomka et al., 2013). By analyzing the trajectories of a position, amplitude, and frequency over a specific time frame, body movements and postural changes can be measured. The COP reveals several parameters on the anterior-posterior and the medio-lateral axis: the mean position of the body and the standard deviation of this position in both directions. Additionally, any movement changes due to external stimulations, like a change of the

[4] In contrast, there is a growing body of evidence that emotions can be controlled and communicated consciously. I.e., studies found that some emotions are only shown when other individuals are around (Fridlund, 1991).

swaying amplitude (measured by the root mean square (RMS)) or a change of the swaying frequency (measured by the mean power frequency (MPF)) can be assessed. The mean COP position in the anterior-posterior axis is generally used to look into approach and withdrawal behaviors (Eerland et al., 2012). While subtle forward-leaning signals an approach behavior, leaning backward instead shows an avoidance behavior (Lelard, Stins, & Mouras, 2019).

There has been plenty of investigations studying the postural response of pleasant vs. unpleasant stimuli. While some studies stick to the movement of the body sway, others use it to investigate followed movements, like step initiation or uprise movements from a chair.

One of the first emotions correlated with the natural body sway was anxiety (e.g., Balaban & Thayer, 2001; Ekdahl, 1992) and fear of falling (Adkin et al., 2002; Maki et al., 1991). Apart from that, personal traits such as risk-taking tendencies and motor processing traits (Zaback et al., 2015) have been studied. For this purpose, participants are placed on an elevated platform (40 cm - 14 m above ground) either close or with distance to the edge and are asked to perform a balance task, like rising their toes (Adkin et al., 2002), closing their eyes (J. R. Davis et al., 2009; Maki et al., 1991) or standing on one leg (Hauck et al., 2008). Other authors challenged participants' balance by exposing them to an unexpected forward push (Brown & Frank, 1997) or backward pull (Shaw et al., 2012), or by moving the platform medio-laterally (Phanthanourak et al., 2016) or rotating it (Horslen et al., 2013). Also, virtual reality set-ups have been used to manipulate the participants' emotional state of anxiety (Cleworth et al., 2012). To control whether the experimental set-up actually provokes the required fear, additionally, physiological measurements are taken. I.e., skin conductance or blood pressure rise in response to a change of the physiological state (M. G. Carpenter et al., 2006; Lelard et al., 2014; Osler et al., 2013).

This experimental set-up generally provokes a decrease of amplitude and an increase of the frequency of the center of pressure (COP) on the anterior-posterior axis. Only a study investigating a spontaneous sway behavior, quiet standing on the ground without any external perturbations, found vision-deprived participants, which were classified as higher fear subjects, to sway with greater amplitude (Maki et al., 1991). This result strengthens the hypothesis of Davis and his colleagues (2009), who grouped participants into "fearful" and "non-fearful" (of falling off a platform of 3.2 m height) and revealed two different coping strategies of threat: non-fearful participants decreased their swaying amplitude (RMS) and increased their swaying frequency (MPF) like it was seen in many experimental studies before, while fearful participants increased both their RMS and MPF of COP displacements with higher threats (J. R. Davis et al., 2009). This supports the hypothesis that participants who are less able to keep their control over balance, experience greater fear of falling (Adkin & Carpenter, 2018), even though the biomechanical preconditions are not different from those of keeping the balance on the ground (Lelard et al., 2019).

Besides those findings, participants in postural threat studies tended to lean backward, away from the platform edge (Adkin & Carpenter, 2018; Lelard et al., 2014) and stiffened their ankle (D. A. Winter et al., 1998). The reduction of the body sway and the stiffening behavior led scientists to the assumption of a freezing response as a reaction to the threat of falling (Lelard et al., 2019). Hagenaars and colleagues (2012) value movements on the anterior-posterior axis as more sensitive (trauma-related) to any fight-and-flights or approach-avoidance behaviors. Thus, initial responses will firstly reflect in this direction (Hagenaars et al., 2012). This explains why the majority of the results were found on the anterior-posterior axis. Also in support of these findings are the results of a study measuring the activity of the lower leg muscles (tibialis anterior and soleus), which indicate forward and backward swaying during exposure to fearful stimuli. Simultaneous activation of both muscles signals a stiffer stand, which is attributed to a freezing behavior (M. G. Carpenter et al., 2001).

While there has been significant effort put into the outcomes of threat on the postural response, the mechanisms causing the change are still relatively unknown. Some theories, however, have been developed. For instance, one is based on attention resources, i.e., participants under threat shift their attention towards their posture (Adkin & Carpenter, 2018) and thereby enhance their control over posture, which has been related to leaning backward (Huffman et al., 2009).

Apart from the height-induced postural threat, numerous studies investigated the emotional effect on the body sway by using visual stimulation. Some studies tried to enhance the painful effect of the pictures by asking participants to imagine the pain shown on the pictures (Lelard et al., 2013, 2017). It follows the idea that all behaviors are triggered by the motivational system through appetitive or aversive stimuli (Lang, Davis, & Öhman, 2000). Stimuli separated into highly vs. lowly arousing pictures and pleasant vs. unpleasant pictures are supposed to provoke a similar response as the observed behavior. For instance, seeing others leaning forward resembles the movements before running towards a loved one, which elicits positive feelings and approach behavior. Contrary, observing someone leaning backward might remind of the behavior elicited by something disgusting. Thus, negative feelings and avoidance behavior are likely (Kordts-Freudinger et al., 2017). Many studies found an effect of unpleasant valence on postural control; the outcomes, however, are somewhat inconsistent. In one investigation, participants were found to lean slightly forward in response to unpleasant and neutral stimuli (Stins & Beek, 2007). In another study, however, only women were withdrawing from unpleasant pictures (Hillman et al., 2004). Mostly, authors report a reduction of swaying amplitude and an increase of swaying frequency in response to negative, unpleasant, or mutilation pictures on the anterior-posterior axis and medio-lateral axis (Azevedo et al., 2005; Facchinetti et al., 2006). Other studies, however, report the same change of body sway during the observation of positive affiliative pictures on the anterior-posterior axis (Facchinetti et al., 2006). One explanation for this outcome was given by the authors of a study examining approach and avoidance behavior in response to video recordings of happy, neutral, and painful faces. Their findings that happy and painful faces induced greater amplitude of the body sway in the anterior-posterior axis compared to neutral faces and that empathic and pleasantness ratings correlated positively with the body sway elicited through painful faces led them to the conclusion that such increase of swaying is triggered by approach and cooperative behavior (Gea et al., 2014). These results are in contrast with an experimentally similar study which, however, used angry, not painful faces (Roelofs et al., 2010).

More distinct results were found by studies investigating valence and arousal separately. Similar to studies where threat was induced by an elevated platform, participants increased the MPF on their anterior-posterior axis during the high arousal condition. However, no effects of the arousal conditions were found on the RMS (Horslen & Carpenter, 2011). Another recent study further distinguished the effect of arousing pictures (and words) on a high-frequent sway (trembling) and on a rather low-frequent sway (rambling). Freezing behavior was only found in the trembling movement, which has been suggested to be less controllable than the voluntarily rambling movement. The authors further revealed avoidance behavior in response to negative stimuli, independent of their degree of arousal (Kordts-Freudinger et al., 2017).

Overall, there are two possible reactions to unpleasant stimuli: either freezing (Facchinetti et al., 2006; Roelofs et al., 2010; Stins & Beek, 2007) or withdrawal behavior (Hillman et al., 2004). The contradicting findings of previous studies led authors to conclude that postural responses of emotional visual stimuli depend on the emotional state of the participants prior to the experiment or the stimulus itself (Lelard et al., 2019). Effectively, a study investigating the effect of traumatic life events on the response of affective pictures found female participants who had experienced at least one aversive life event to show a reduced body sway to unpleasant pictures. In contrast, participants who had experienced multiple aversive life events showed a reduced body sway in response to all picture categories. No men were tested (Hagenaars et al., 2012). Another possible explanation is the inconsistently assessed time frame after the stimulus onset. Horslen and Carpenter (2011) argue that some authors used a too short sampling duration of below ten seconds (Stins & Beek, 2007) which does not allow to measure the lowest frequency components adequately.

The response in animals to aversive stimuli could be discriminated in a defensive and aggressive reaction to close and intense aversive stimuli and in a freezing reaction to distal or less intense stimuli (Blanchard et al., 1986). Thus, the type of response may lie in individual experiences and capabilities, plus on the stimulus itself (Lelard et al., 2019).

Besides affective pictures, authors also presented film scenes (Hagenaars, Roelofs, et al., 2014), arousing and affective words (Kordts-Freudinger et al., 2017), and cognitive tasks (Stins et al., 2017) to challenge the postural control. For instance, reading (Stins et al., 2017), counting and calculating digits (Andersson et al., 2002; Doumas et al., 2018; Stins et al., 2011; Vuillerme & Vincent, 2006), memory tasks (Riley et al., 2005), or attentional processes (Stins et al., 2011) were found to change the amplitude and the frequency of swaying. Overall, the results show that higher demanding cognitive tasks lead to a decrease of COP amplitude and an increase of swaying frequency along the anterior-posterior axis (Andersson et al., 2002; Riley et al., 2005; Stins et al., 2011; Vuillerme & Vincent, 2006). Those effects might interfere with emotional processes and could be a reason for previous conflicting results (Stins et al., 2011). A study investigating postural adjustment during reading sentences of high vs. low physical effort found an increase in the body sway's standard deviation on the medio-lateral axis. The authors argue that mentalizing movements of greater physical effort activates the motor program, which can affect the postural movements (Stins et al., 2017).

### Interpersonal Coordination – Social Behavior

Besides the certainty that emotions have the capability of influencing the motor process, which is an important part of emotional expressions, another crucial element of social interactions is the exchange of emotional information (Kret et al., 2020). An element of which Frijda was already aware. Yet, he also suggested that action occurs because emotions follow appraisal (Frijda, 2007). By conforming with a person's goals, emotions interfere with someone's readiness to interact with his or her social or non-social environment (e.g., Frijda, 1953). Moreover, physiological reactions elicited by emotions have been proposed to enable communication between individuals, i.e., emotional expressions of body, face, or skin color. It is, thus, crucial for any social being to recognize emotions expressed by others. Among the scientific community, it has been proposed that experiencing an emotion expressed by an interacting partner requires the activation of a simulation process (Zahavi, 2008). One mechanism that can, but does not have to, modulate the simulation process, is the convergence of movements between two or more interacting partners. Put together: interpersonal coordination enables an individual to understand another person's behavior and intention and further its emotional state (Lelard et al., 2013). Bernieri and Rosenthal (1991) even propose coordinating gestures and movements with one another to be a fundamental mechanism underlying the establishment and maintenance of human social bonds.

Interpersonal coordination is generally understood as a spontaneous overlap in time and form of facial and/or bodily movements between two or more people (Bernieri et al., 1988). The distinction between interpersonal movement synchrony and behavior mimicry, which are two basic expressions of interpersonal coordination (Bernieri & Rosenthal, 1991), is made based on behavioral timing. While interpersonal synchrony occurs at the more or less exact same time (e.g., rocking a chair or beating a drum in sync), behavior mimicry is defined as a sequential action (e.g., one person crosses his/her legs and the other follows that action). In the literature, the timing of interpersonal synchrony is not specified precisely; however, the commonly used approach is the temporal alignment within five seconds (Chartrand & Lakin, 2013). Interpersonal synchrony is proposed to be a self-organizing process and was compared to the dynamics of a cardiac pacemaker (de Bruin et al., 1983). The *Haken-Kelso-Bunz Paradigm (HKB)* describes coordinated movements from a theoretical point of view: individuals couple their movements over time and become mutually synchronous, which can be expressed either in in-phase (i.e., occurring at the same time) or in anti-phase movements (i.e., occurring in alternation) (for a review see: Ravignani, 2015). In-phase movements were revealed to be the more stable mode, although also the anti-phase was found to be reasonably stable. These coordination movement dynamics were examined both mathematically (Haken et al., 1985) and empirically (for an overview see: R. C. Schmidt & Richardson, 2008).

Mimicry is explained by the concept of the perception-behavior-link. Based on the notion of ideomotor action (W. B. Carpenter, 1875, p. 125; James, 1890, p. 522), it follows the idea that representations of perceived actions of another person lead to own actions. Furthermore, it can also be explained by the idea of schemas: a perceived action activates the semantically same schema as own actions (Chartrand & van Baaren, 2009). Scientists still argue about the causal relation between mimicry and sensorimotor simulation. While there is evidence for both, we can safely assume that an emotional expression is caused by an internal simulation of an observed emotion (Stel, 2016, p. 37).

Great support for the link between perceiving an action, and performing that action, comes from the discovery of the mirror neuron system (di Pellegrino et al., 1992). Mirror neurons seem not to differentiate between own actions or perceiving someone else performing that action. This effect has been observed in macaque monkeys (Gallese et al., 1996). In humans, watching and performing a specific hand movement activates the same cortical region and motor representation of that action (Iacoboni et al., 1999), which is considered a similar effect to the one found in macaques (Chartrand & van Baaren, 2009). Even though it is tempting to explain the whole interpersonal movement process through the miracle of mirror neurons, there is evidence that the mirror system could actually be reversed by learning (Newman-Norlund et al., 2007).

From an evolutionary perspective, interpersonal coordination has been proposed to be a more effective mechanism to promote group cohesion than other forms that enhance social bonding, like cooperation (Launay et al., 2016). Group cohesion is believed to be an important factor to enable individuals to live in large groups (Lee, Launay, & Stewart, 2020). Large groups have some significant advantages for survival, such as protecting individuals and defending a larger territory (Shultz & Finlayson, 2010). Durkheim (1912) suggests that synchronization during collective rituals enhances the feeling of excitement and the loss of individuality. Apart from humans, it can be found in several other species, for instance, in cetaceans (e.g., Cusick & Herzing, 2014), primates (Hattori et al., 2013), and cockatoos (Patel et al., 2009). However, the magnitude of this attribute concerning large groups is believed to be human-specific (Lee et al., 2020). Besides facilitating social bonds, interpersonal coordination in the form of ancient rituals, like singing and dancing, serves as a mechanism to signal group cohesion and power to outsiders. By showing outside individuals the group's capability to cooperate effectively, a group demonstrates the fitness to defend a territory. It, additionally, increases its chances to form a cooperative alliance with those other individuals (Hagen & Bryant, 2003). In line with this are the examples of military marches, where walking in step demonstrates strength and coherence (Lee et al., 2020), or the New Zealand rugby teams which perform a traditional dance, the haka[5], while facing their opponents at the beginning of each tournament (Jackson & Hokowhitu, 2002). Experimentally investigated was this approach by Fessler and Holbrook (2014): men, walking synchronously in pace, imagined the physical power (height, size, muscularity) of a fictive criminal as less imposing than did men who walked out of sync. The authors conclude that synchrony decreases the perceived relative strength of an opponent and increases one's own fighting capability (Fessler & Holbrook, 2014). A follow-up study by the same authors presented the sound of soldiers' footsteps to their participants. Soldiers marching in synchrony were perceived to be larger in size and more muscular (Fessler & Holbrook, 2016).

Another concept on how interpersonal coordination leads to an evolution-based behavioral advantage is built on the *perception-action linkage* (neural coupling of perception and action). On the one hand, adapting the own behavior to the behavior of a person who is running away from a source of danger (e.g., a predator), increases the chances of survival of both individuals (Chartrand et al., 2005).

[5] The haka is a traditional posture dance of early settlers of New Zealand. Above other rhythmic movements, it includes out-thrusts, stamping, and facial distortion, which allow the expression of a variety of emotions, such as joy, anger, and sorrow (McLintock, 1966).

Otherwise, the positive outcomes of interpersonal coordination of positive feelings between individuals may have facilitated and tightened social bonds between early humans (Vicaria & Dickens, 2016).

To sum up, interpersonal coordination has played an essential role in human evolution and is still an integral part of human social interactions. Thus, it is no surprise that interpersonal coordination already plays a significant role in early interactions between infants and their caregivers (Condon & Sander, 1974; Feldman, 2007). It is thought to help infants during their language acquisition and social development (Arbib, 2005). Already around one year of age, infants prefer synchronously moving to non-synchronously moving peers (Tuncgenc et al., 2015). Even the heart rate has been found to synchronize, called biological synchrony (also known as physiological synchrony) (Mayo & Gordon, 2020), during face-to-face interactions between mother and infant. During affect synchrony (including facial and bodily expressions, movements, and other non-verbal signals) and during vocal synchrony, heart rhythms of both the mother and the infant significantly increased when compared to moments out of synchrony. The authors suggest that physiological processes between attachment partners can be influenced by coordinating visual and affective cues (R. Feldman et al., 2011).

This critical process of social interactions intensifies throughout development and into adulthood. Both interpersonal synchrony and behavior mimicry are proposed to happen spontaneously and with negligible costs (Chartrand & Bargh, 1999). In adults, interpersonal coordination has been observed in various contexts of rhythmic activities, ranging from tapping, walking, dancing, speaking to music performance (Repp & Su, 2013). Some classic examples of interpersonal coordination studies include participants swinging side-by-side in rocking chairs with different movement periods, while visual perception towards each other was manipulated (Richardson et al., 2007). In other experimental set-ups, groups of three participants were asked to walk either at the same pace or normally, as they would do by themselves (Wiltermuth & Heath, 2009), or were seated on a virtual rowing boat either alone or in groups of six (Cohen et al., 2010). R. C. Schmidt and O'Brien (1997) observed interpersonal coordination by asking two participants to swing a pendulum while either facing each other or sitting side by side. Even though participants were reminded to keep their preferred pace, their pendulums synchronized during the facing-condition in both in- and anti-phase.

### Outcomes

Given the evolutionary theories, much experimental attention was given to the outcomes of interpersonal coordination, which are often positive. The most commonly agreed findings of interpersonal coordination are individual transformations, such as an increase of liking, compassion, and the feeling of closeness and similarity between interacting partners (Valdesolo & DeSteno, 2011). However, also personal traits transform after engaging in interpersonal coordination, like the enhancement of prosocial behavior, social cognition (see review: Mogan, Fischer, & Bulbulia, 2017; Rennung & Göritz, 2016; Vicaria & Dickens, 2016), and modulation of the sense of agency (Reddish et al., 2019).

While behavior mimicry and interpersonal synchrony have many outcomes alike, they still differ in some. Therefore, I will refer to both expressions in their respective paragraphs. Overall, there has been more research done on the outcomes of behavior mimicry. The field of interpersonal synchrony, however, is continuously growing.

*Interpersonal Synchrony*

The fact that historically, people moved, danced, and sang together, in synchrony, is often explained through cooperation. A number of studies that were looking into this phenomenon measured cooperation by conducting a public goods game (e.g., Cross, Wilson, & Golonka, 2016; Reddish, Fischer, & Bulbulia, 2013; Wiltermuth & Heath, 2009). Besides the willingness to cooperate, other personal attitudes have been found to be mediated after moving in synchrony, for instance, compassion towards each other, altruism (Valdesolo & DeSteno, 2011), and prosocial behavior (e.g., Wiltermuth & Heath, 2009). Especially social-binding traits have been amply studied, including not only movement synchrony but also vocalization synchrony (e.g., Fischer et al., 2013) and sensory stimulation synchrony (Mazzurega et al., 2011). Interestingly, the prosocial effect seems to last: participants were more willing to help the confederate in another experiment, which was not paid nor in their class hours, a day after they actually performed in a coordination task (Cross et al., 2020). Macrae and others (2008) suggest that people are more attentive to the interacting partner during synchronous activities. Their approach was confirmed by a study investigating synchronized waving with another individual. Sync-groups had a better memory of their partner's utterance and facial expression (Macrae et al., 2008). Thus, it is perhaps not surprising that interpersonal synchronization leads to a blurring of self-other boundaries (for an overview see: Smith, 2008) and, as a consequence, causes a merging of the self and the other, known as the sense of agency (Reddish et al., 2019).

Such positive social attitudes go hand in hand with the subjective feelings about the interacting partner. Thus, interpersonal synchrony has been found to increase liking (Hove & Risen, 2009), positive impressions of (M. Cheng et al., 2017), and similarity to the partner (Valdesolo & DeSteno, 2011). It also encourages trust in a partner's actions (Wiltermuth & Heath, 2009), whether they are "good" or not. Chvaja et al. (2020) revealed that highly synchronized participants rated a transgressive act of the confederate towards another student as less harmful than participants in a low-sync condition.

Contrary to this result, a study investigating prejudice towards out-group members found that participants walking in synchrony or merely imagining to walk in sync showed an explicit and implicit reduction to conform to stereotypes (Atherton et al., 2019). In a nutshell: interpersonal synchrony promotes sociality (Marsh et al., 2009).

Above outcomes concerning a dyad relationship, interpersonal synchrony has been shown to foster personal traits, such as memory. Not only a person's memory about his interaction partner (Woolhouse et al., 2016) but also the memory of other related information, which was assessed by a word memory task, was found to improve (Macrae et al., 2008; von Zimmermann & Richardson, 2016). Also, students' perception and fine motor skills in a joint task improved after rocking synchronously in a chair (Valdesolo et al., 2010). Not to forget that synchronous movement makes people feel better about themselves (Lumsden et al., 2014) and more relaxed – people watching a group of others moving in synchrony reduced their skin conductance levels compared to their controls (Kragness & Cirelli, 2021). However, the effects of synchronization were not exclusively found to improve capabilities. People also seem to reduce their ability to regulate their affective reaction (Galbusera et al., 2019).

*Behavior mimicry*

Mimicry is most famously known to work as social glue (Chartrand et al., 2005). And similar to how interpersonal synchrony has effects on individuals who mimic or are mimicked. It increases a person's self-esteem and fine motor skill, it boosts creative thinking and enhances liking and rapport between the interacting partners (Chartrand & van Baaren, 2009). It has been argued that, by doing so, behavior mimicry facilitates a merging of minds and thus leads to empathy and prosocial behavior. They also propose that if individuals want to connect with others, they non-consciously start mimicking them. The other way around, if an individual wants to disconnect, they automatically stop mimicking them. Mimicry is known to impact both members of the mimicry dyad, the person mimicking and the person being mimicked (Chartrand & van Baaren, 2009).

Some of the first studies on mimicry included the non-verbal communication between a therapist and the client. The assimilation of the body postures has been discovered to be positively correlated with the rapport between therapist and client (e.g., Charny, 1966; Maurer & Tindall, 1983). A great amount of research followed, including, amongst others, teacher-student interactions, interview partners, and complete strangers (Chartrand & van Baaren, 2009). However, not only being mimicked increase liking and rapport but also the mimicking person feels more affective attuned towards and bonded with the interaction partner. Thus, during interactions where mimicry occurs, empathy goes back and forth between the interacting partners and thereby serves as an essential social mechanism (Stel & Vonk, 2010). While mimicry has been revealed to be a tool to bring people together, it has also been found to converge people's experiences. This was found to be the case for experiencing a video clip (Ramanathan & McGill, 2008), to foster agreements in a negotiation context (Maddux et al., 2008), and to judge people (Van Swol, 2003) or even avatars (Bailenson & Yee, 2005) as more persuasive.

On the contrary, engaging in mimicry depletes someone's ability to differentiate the truth from a lie (Stel et al., 2009). More profoundly, however, mimicry has been revealed to be a trigger for prosocial behavior. Prosocial behavior, as a consequence of mimicry, has been measured in a variety of contexts, such as tipping amounts (van Baaren et al., 2003), picking up fallen objects (Van Baaren, Holland, et al., 2004), or donating money (Stel et al., 2008). Again, this effect was found for both the mimicker and the mimicked person. Surprisingly, those positive affiliations do not only include the mimicking partners, but also other individuals who were not directly involved in the interaction (Vicaria & Dickens, 2016). For instance, by one confederate mimicked participants rather picked up a dropped pen by a second confederate than participants who were not mimicked (Van Baaren, Holland, et al., 2004). The same was true if participants were asked to donate money. Mimicked students donated more money than non-mimicked students (Van Baaren, Holland, et al., 2004). This effect that prosociality extends to externals is also true for interpersonal synchrony. Students who moved in synchrony were more likely to share money with members of an experimentally produced out-group (Reddish et al., 2014). One theory behind this comes from Ashton-James and her colleagues (Ashton-James et al., 2007). They argue that engaging in prosocial behavior changes how people perceive themselves in response to others. For example, people who believe in a just world may be more likely to give back in the form of prosocial behavior. In line with this are the results of a study showing that men who are being mimicked rather believe in a world that is good for them (Stel et al., 2013).

At an individual level, one effect of mimicry might be its impact on a person's stress level. For example, not being mimicked was found to increase salivary cortisol concentration (Kouzakova et al., 2010). Another consequence of mimicry is the way an individual perceives its environment: being mimicked has been suggested to increase field depending processing (taking the environmental context into account) (Van Baaren, Horgan, et al., 2004) and convergent thinking ("connecting the dots") but to decrease divergent thinking ("thinking outside the box") (Ashton-James & Chartrand, 2009). Additionally, Finkel and colleagues (2006) revealed a degradation in fine motor tasks due to absent mimicry. Apart from that, other less explicit outcomes are the manipulation of preferences – someone's preference for food has been observed to be mediated while mimicking a confederate (Tanner et al., 2008), or a diminution of prejudice – participants who mimicked a black actor reaching to a water glass and drinking, did not prefer people of their in-group over black people. In comparison, participants who did not mimic the black actor or mimicked a member of their in-group preferred "Whites" over "Blacks" (Inzlicht et al., 2012).

To sum up, interacting in mimicry affects a broad array of cognitive, affective, motivational, and attitudinal traits, which all relate to and reinforce each other (Chartrand & van Baaren, 2009). Which, however, does not exclude negative outcomes. Thus, interpersonal coordination has been related to several less likable traits. Partly, because interpersonal coordination leads to more (un)conscious alertness of surrounding people, it promotes alignment to believed expectancies. It amplifies, for example, the conformity to negative stereotypes (Leander et al., 2011), the engagement in unhealthy eating behaviors (i.e., eating cookies), and procrastination (Dalton et al., 2010).

Moreover, it seems to increase the probability of complying in aggression towards members of an out-group or other species. In two unrelated tasks, a synchronous movement task and a memory task, participants were more likely to disturb the following participant by applying a noise blast during their memory task after interacting in synchrony (Wiltermuth, 2012a). Similarly, participants in the synchrony condition were rather willing to kill sow bugs based on the confederate's example (Wiltermuth, 2012b). Put together; interpersonal coordination facilitates a merging of individuals, which enhances affiliative feelings and promotes the partners' readiness to work for and with each other.

### Promoters

Most of the research on interpersonal coordination focuses on the mostly positive outcomes; it can be assumed, however, that even under optimal conditions, not all individuals are equally likely to engage in interpersonal coordination (Nessler et al., 2011). Partly because of their individual character, more likely, however, because of the characteristics of their randomly assigned interaction partner. Group membership, the level of power, or individual character traits influence the possibility of being imitated by an interacting partner.

#### *Interpersonal Synchrony*

Although synchrony seems to take part in every interaction system (e.g., fireflies, cardiac pacemaker cells, human interactions), it definitely is not inevitable (Lumsden et al., 2012). Equally to the precursors of mimicry (see below), the willingness to cooperate promotes synchronous movements significantly. Participants with a specific given strategy to build model cars showed a greater degree of synchronous hand movements (Wallot et al., 2016). In line with this are the results of a study measuring synchrony in arm movements during the removal of balls out of a basket (Allsop et al., 2016) or unconscious fingertip movements in an experimental task (Yun et al., 2012). Both showed a significant increase in synchrony after the cooperation task. Thus, having a positive goal enhances the likelihood of interpersonal synchrony.

Consequently, negative impressions may incline spontaneous synchrony – individuals who appear to be less trustworthy by arriving late, for example. The experimental set-up was designed in a way that participants were asked to arrive at the study's location with a time difference of 15 minutes. After that, "on-time" participants stepped less synchronized with a "late" partner than with another "on-time" partner (Miles et al., 2010).

Reduced interpersonal synchrony was also found between members of an out-group, i.e., unrelated spectators of a traditional ritual showed a less-synchronized heart rate pattern with the performing fire-walkers than their related spectators (Konvalinka et al., 2011). Yet, Miles et al. (2011) report that individuals rather synchronized their movements with a partner from a different group. The authors propose that, by doing so, participants (un)consciously reduced their social distance for possible benefits in later social interactions. Thus, it is noteworthy to reveal the source of the participant's behavior: if individuals wish to bond with another individual, they also happen to move in synchrony.

There is one individual character that seems to majorly impact interpersonal movement interactions: prosociality. So were, for example, pro-socially orientated individuals, whether as dispositional character or as a result of a prior manipulation, more likely to coordinate their movements with a confederate than pro-self-orientated individuals (Lumsden et al., 2012). Another trait that seemed to impact synchrony is the person's experience in engaging in interpersonal movement interactions. Sofianidis et al. (2012) found dancing experts to improve their synchronous body sway while standing side-by-side and maintaining light fingertip contact with each other. Maybe surprisingly, because in conflicts with findings of behavior mimicry, mood was not found to affect the degree of synchrony (Fujiwara & Daibo, 2018).

*Behavior Mimicry*

More research has been conducted on the positive and negative promoters of behavior mimicry. For instance, there are a number of prejudices that seem to deplete mimicry. One major reason is being in or outside of a group, such as religion (Yabar et al., 2006), family (Bernieri et al., 1988), or ethnicity (Mondillon et al., 2007). In one study, participants were either mimicked or not mimicked by either a same-race confederate or a cross-race confederate and subsequently completed a

Stroop Task. The often-discovered positive effect of being mimicked could not be replicated (Dalton et al., 2010). People's tendency to mimic another person seems to depend on their unconscious wish to affiliate with that person or group. Participants who had been excluded mimicked an interacting partner more than people who had not been excluded.

Moreover, excluded participants were more likely to mimic an in-group member than an out-group member (Lakin et al., 2008). A similar result was found in a sync paradigm (Miles et al., 2011). In both cases, participants wished to affiliate with the interacting partner, which fostered interpersonal coordination. A similar effect was found when individuals perceive similarity between themselves and the partner, such as a similar opinion (Van Swol & Drury-Grogan, 2017) or viewpoint (Castelli et al., 2009). Also, individuals with seemingly more power were found to be mimicked more than those with seemingly less power (C. M. Cheng & Chartrand, 2003). As implied above, if people do not want to affiliate with someone, they happen to mimic less. Observing a person eating ice cream discouraged participants from engaging in mimicry if that person had a social stigma, i.e., was obese (Johnston, 2002). Also, partners of a romantic relationship mimicked an attractive person of the opposite sex less than people who were not in a romantic relationship (Karremans & Verwijmeren, 2008). A disliked person (McIntosh, 2006), or partners with whom participants felt they could not compete (Lanzetta & Englis, 1989), have been found not to be mimicked at all, or mimicry was less likely to occur. And last but not least, even the name seems to be a sign of affiliation. Individuals who are named the same were found to be more likely to coordinate their behavior (Guéguen & Martin, 2009).

Assuming there is no prior sympathy for an interaction partner, another mechanism impacts interpersonal coordination: sharing a goal or intentionality with a possible interacting partner. Both consciously primed (being explicitly told to cooperate with the interacting partner) and unconsciously primed (being presented with affiliation words) participants mimicked a confederate over a longer period than participants in the no-goal condition (Lakin & Chartrand, 2003).

The results mentioned above picture mimicry as a tool to get engaged with apparently important in-groups. A mechanism that can be used, at least unconsciously (Chartrand & van Baaren, 2009).

Apart from the characteristics of the interacting partner, individual traits play a part in the manner of interaction. Prior to the experiment, pro-socially primed participants were significantly more likely to mimic an opened or closed hand (Leighton et al., 2009). High-socially anxious individuals mimicked a virtual avatar to a lesser degree than low-socially anxious individuals (Vrijsen et al., 2010). Also, social information processing (the ability to comprehend what others need, which is part of a social intelligence questionnaire) was significantly correlated with participation in mimicry (Genschow et al., 2018). Besides pro-socially oriented individuals, several studies found highly empathic participants (emotional empathy) to be more likely to mimic emotional faces (Dimberg & Thunberg, 2012; Rymarczyk et al., 2016; Sonnby-Borgström, 2002; Sonnby-Borgström et al., 2003). However, Chartrand and Bargh (1999) found no effect of emotional empathy on mimicking behavior but rather of cognitive empathy (perspective-taking).

One last important promoter of mimicry is the personal emotional state. It has been hypothesized that people in a positive mood engage more in automatic actions, while people in a negative mood rather rely on processes of which they are fully consciously aware (Chartrand & van Baaren, 2009). In line with this were the results of previous experiments where participants mimicked either an emotional face or the pen playing behavior of an experimenter after they have been induced with a positive mood. Compared to participants in a negative mood, who neither mimicked the artificially generated emotional faces nor the experimenter (Likowski et al., 2011; Van Baaren et al., 2006). Comparing three discussion tasks with different affective goals (cooperation, competition, fun) revealed positive affect to be positively associated, and negative affect to be negatively associated with mimicry (Tschacher et al., 2014). Contradicting this result are the findings of a study investigating the convergence of movements between two participants while arguing over a specific topic. Mood and behavior mimicry were not correlated (Paxton & Dale, 2013).

The findings as mentioned above demonstrate a variety of social contexts which potentially influence someone's preposition to engage in interpersonal coordination and thereby stress the importance of an experimental design that allows minimizing unconscious biases resulting from pre-existing differences in rapport.

## Gender Differences in Emotion Processing

The above-mentioned paragraphs pointed out a diversity of influencing personal traits; there is, however, one fundamental element that affects every social interaction: gender. It can be assumed that besides the above-mentioned personal characters, gender plays a role in how emotions are expressed and to what extent this affects interpersonal coordination.

Women and men differ according to their biology and their socialization (Lehane, 2015). However, is it also the case when it comes to emotions? While there has been a great effort to answer this question, it seems beneficial to distinguish between experiencing/perceiving emotions and emotional expression through the body.

*Emotional experience and body perception*

Research corroborating the idea of women and men being different include studies where women report higher affective intensity, such as anxiety, sadness, hostility, and positive emotions as happiness and joy (Feldman Barrett et al., 1998); or love, joy, sadness, and fear (Grossman & Wood, 1993). In line with this are the findings that women rate unpleasant pictures (e.g., M. M. Bradley et al., 2001) or the description of affective scenes as more intense (Tobin et al., 2000). On the other hand, men are known to experience anger (e.g., A. H. Fischer et al., 2004) and erotic emotions (Karama et al., 2002) more strongly. Apart from subjective ratings, there is some evidence that women and men perceive emotions differently in their bodies and thus respond physiologically in an unequal manner. For example, women's skin conductance and heart rate react more sensitive to sadness (induced through movies) than the physiological parameters of men. Skin conductance was also elevated after watching a movie that induces sadness, while heart rate increased due to sad and disgusting movies (Fernández et al., 2012). Some authors argue that physiological differences in perceiving and expressing emotions might be caused by different hormones, chromosomes, and neuronal activation patterns (Kret & De Gelder, 2012). Specifically, testosterone (Kret & De Gelder, 2012), but also oxytocin and vasopressin (Bos et al., 2012) are known to influence emotion regulation and affective states. Indices for chromosomal gender differences on emotion perception come from mouse models, i.e., gender differences are found at a developmentally early stage, before hormonal sex differences can be distinguished (A. P. Arnold & Chen, 2009; Ngun et al., 2011). Some studies on hemispheric lateralization suggest that cerebral activation pattern caused by processing emotions are gender-dependent (Kesler-West et al., 2001; Killgore & Yurgelun-Todd, 2001; Williams et al., 2005).

Contrary, there is evidence that women and men react to emotions in a physiologically equal manner. A study showed no different parameters for heart rate, skin conductance, respiratory rate, and muscle activity of the corrugator during the presentation of affective film clips. They, however, found differences between men and women in their self-reports: in line with previous studies, women rated unpleasant movies as less pleasant and more arousing than men (Codispoti et al., 2008). On the other hand, Feldman Barrett et al. (1998), who report gender differences in the global emotional disposition, did not find any differences in instantaneous emotional experiences during social interactions.

*Emotional expression*

Similar to emotional experience, there has been no distinct consent whether women and men express emotions to a different degree. Women have been found to show more pronounced emotional expressions in the face than men (Kring & Gordon, 1998; LaFrance et al., 2003; Sonnby-Borgström et al., 2008). Moreover, women were found five times more likely to show their tears than men (Walter, 2006) and to smile. However, a meta-analysis revealed that smiling mainly occurred in situations where they were expected to do so (LaFrance et al., 2003).

More recently, however, different emotional expressions have been assigned to the type of emotion and to the cultural predisposition; men rather accept to show strong and powerful emotions, while for women, less powerful emotions are more acceptable (Safdar et al., 2009). Kret and De Gelder (2012) suggest that while women rather communicate their emotion through facial expressions or interpersonal communication, men express their emotion in action. Furthermore, previous findings lead to the assumption that different types of emotions are perceived and expressed differently in both genders (Kret & De Gelder, 2012). In line with this assumption are the findings of a study investigating emotional expressions and experiences in different emotions. Interestingly, they found women to rate specific emotions as more intense on the dimensions valence, motivation, and arousal (i.e., *valence* and *motivation*: disgust and horror; *arousal*: disgust, horror, anger, sadness, amusement, and pleasure). But men perceived emotions such as anger, pleasure, and amusement as stronger, which could be measured in their heart rate (Deng et al., 2016).

Taken together, there are indications for different bodily reactions and emotional perceptions in response to different emotions. Whether they arise from biological differences, like hormones, chromosomes, and brain structures, or whether they originate culturally, because it is more excepted for women, for example, to show tears; cannot yet be distinguished completely.

### Approach - Avoidance Tendencies

Following the results of the studies mentioned above, less research has been done on behavioral gender differences. In the context of approach and avoidance tendencies, Hillman et al. (2004) found postural reactivity in response to unpleasant pictures. Images of attack and mutilation provoked an anterior movement in men, proposing an approach tendency, while women were found to express a posterior movement which equals a defense tendency. Moreover, an investigation of the viewing distance of affective pictures, measured by eye-tracking, revealed a gender difference during the first ten seconds. Women watched pleasant pictures at the beginning at a significantly shorter distance than pleasant pictures in later time frames, while men watched the same pictures at the beginning at their longest distance compared to later time frames. The authors conclude that women pay more attention to details in the beginning and withdraw afterward to have a general overview, while men act the other way round (Laukkal & Haapala, 2013). Looking at the ability to keep postural control without any specific emotions induced, men seem to sway more than women (Ekdahl, 1992).

### Interpersonal Coordination

Although interpersonal coordination has been investigated in a broad array of contexts, the literature has not yet considered gender differences to a large extent. Previous investigations on gender differences in behavior mimicry found very mixed results, indicating no direct effect (for review see Lehane, 2015). Overall, women might respond stronger to the exposure of emotional faces (Sonnby-Borgström et al., 2008), especially when presented with happy, sad, or fearful stimuli (Soussignan et al., 2013). Women also mimicked positive and negative voices on the phone to a significantly higher degree than men (Rueff-Lopes et al., 2015). Gender differences were also found to impact the outcomes of mimicry: engaging in mimicry significantly increased the belief in a just world in men but not in women (Stel et al., 2013). Moreover, men were more likely to mimic their female interacting partner when perceived as highly attractive; women, however, rather engaged in mimicry when they believed to interact with a male partner of socially higher status (Van Straaten et al., 2008). Studies of gender effects on interpersonal synchrony are rare. One study reports that female pairs march more synchronously than male pairs (M. Cheng et al., 2017). As for behavior mimicry, the outcomes of interpersonal synchrony differ between women and men: male dyads were found to be more creative after a joint-action condition than female dyads or mixed dyads (Gaggioli et al., 2019). The lack of revealed gender differences could be explained through methodological differences, i.e., stimulus exposure length, social context, or the type of mimicry investigated (Lehane, 2015).

Despite the ambiguous findings, Lehane (2015) proposes two main reasons why women and men differ in behavior mimicry: biological differences and socialization influences. From an anatomical point of view, men are known to exhibit larger facial movements when expressing surprise, happiness, sadness, and disgust, which could explain a more profound feeling of the aforementioned emotions, so the author (Lehane, 2015). In contrast, women are known to show more activation of brain areas containing mirror neurons; thus, women and men may use different processing strategies of emotion recognition (L. C. Anderson et al., 2013). Finally, an increased level of testosterone led women to mimic a confederate to a significantly lower degree than women with no manipulation of the testosterone level (Hermans et al., 2006). In conclusion, men should mimic to a lesser extent because of their generally higher level of testosterone (Lehane, 2015). In addition, due to the existence of strong stereotypes of both genders in many cultures, this fact should not be left out of the discussion of gender differences concerning interpersonal coordination. It can be argued that gender differences in facial mimicry descend from the kind of emotion that is being expressed (Lehane, 2015).

Another point is made by the fact that women outperform men in most social factors, like empathy and social communication (Baron-Cohen et al., 2003; M. Cheng et al., 2017; Jolliffe & Farrington, 2006). For instance, women were found to be more responsive to facial affect (Sonnby-Borgström et al., 2008). As interpersonal coordination is largely mediated by social factors (see Promoters, p. 44), it leads to the prediction that women start with better prerequisites to engage in coordinated movements (M. Cheng et al., 2017).

## The Effect of Emotions on Bodily Expressions: Theoretical Assumptions

To complete the understanding of the effect of emotions on motor movements and on social interactions, it is crucial to illuminate the models and theories on which research of those processes is based on.

The idea that the observed emotional expressions induce that same emotion dates back to Lipps (1907). He suggested that mimicry enables an individuum to recognize and understand the feelings of their interaction partner. Even earlier on, W. B. Carpenter (1875, p. 125) and James (1890, p. 522) propose a theory behind this observation: the notion of ideomotor action. Merely thinking of a behavior elicits the probability of the same action. Corroborated by neurophysiological research, the idea spread that simulating an emotional expression enhances the emotional feeling and simultaneously leads to the imitation of this emotional expression. Another evidence for a shared representation comes from the *perception-action link*, also known as the *Common-Coding Hypothesis*. It proposes a shared system of representation for perception and action (Prinz, 1990).

Those ideas have been embraced within the concept of embodiment. Put together, the embodiment of emotions proposes a reciprocal relationship between emotional expression and information processing (Michalak et al., 2009). For instance, the *Matched Motor Hypothesis (MMH*) states that merely perceiving an emotional expression of another person elicits a similar own emotional expression (Hess & Fischer, 2013). Similarly, the *Facial Feedback Hypothesis (FFH)* proposes that own facial expressions can influence the inner emotional state through a feedback process (Strack et al., 1988). However, evidence for this concept is contradicting (Buck, 1980). Laird (1974) investigated the connection between facial movements and the emotional experience by asking participants to activate either frown- or smile-corresponding muscles. In support of the FFH, smiling participants judged their mood as happier than frowning participants. In probably the most well-known study by Strack et al. (1988), participants were asked to hold a pen in their mouth, either across the mouth or lengthwise, to enable or inhibit a smile while rating cartoons. Participants with a forced smile perceived the cartoons as more humorous than did participants with a closed mouth. On the other hand, participants who were prevented from mimicking an emotion by biting on a pencil or chewing chewing gum were impaired in recognizing the presented emotions (Oberman et al., 2007).

Related to the concept of ideomotor, a more recent model on non-verbal communication is the *Sensorimotor Simulation Theory*. Like other models, it suggests that emotion recognition leads to the activation of that same emotion and thereby to a congruent emotional expression but implies the activation of a simulation process. Put together, this theory states that understanding the emotion of an interacting partner involves a neural simulation process of the motor movements caused by an emotional state. The simulation process replays an individual's past experience to enhance the emotional information (Dokic & Proust, 2002, p. 8). For instance, the technique of inducing an emotion by simply presenting a picture requires a mental representation of an actual or potential emotional event, like tissue damage (Lelard et al., 2013). This imagination of another person's behavior activates internal models and simulation processes (Zahavi, 2008) and thereby enhances the own affective state of pain (Lelard et al., 2013). This process can happen with or without behavior mimicry but definitely involves representing our own embodied emotional experiences (Niedenthal et al., 2005). In literature, this process is known as emotion contagion (Cacioppo et al., 2000; Hatfield et al., 1993). The concept of sensorimotor simulation refers back and reframes the *James-Lange Theory*: the own physiological state but also the interpretation of someone's emotional expression is the origin of an emotional experience (Ross & Atkinson, 2020). Scientists argue about the causal relation between mimicry and sensorimotor simulation. But while there is evidence for both, i.e., an emotional expression is caused by internal simulation of an observed emotion (Hawk et al., 2012) or the mimicked expression generates the same emotion which leads to an internal simulation (e.g., Strack et al., 1988), it is most likely that both, the simulation process and the own emotional expression are involved in understanding an observed emotional expression (Ross & Atkinson, 2020).

With the aim to shed light on the *Sensorimotor Simulation Theory*, one line of research focuses on emotional expressions of non-observed body parts. The authors challenge the idea by arguing that also other body parts than the observed ones should respond. To address this question, angry and fearful faces were presented while the muscular activity of the participant's face and forearm were investigated. The results show: muscle patterns are activated in the face, more importantly, however, also in the forearm, respective to the observed emotion (Moody et al., 2018).

These results provide a promising avenue to understand the processing of perceived emotional expressions by simulation.

Pursuing on the evidence for the *Sensorimotor Simulation Theory*, the aim of the first experiment is to deepen the understanding of this hypothesis by answering the following questions:

1. Does emotion recognition extend to a behavioral response measured in the body sway?
2. To what extent is the motor response affected by different emotional stimuli?
3. Is there a difference in emotion recognition and the behavioral response between women and men?

The second experiment serves as a pilot study for the experimental set-up of the third experiment. By building a well-controlled experimental paradigm, it should answer two critical questions:

1. Does the body sway of an avatar projection lead to interpersonal coordination?
2. Is there a difference in interpersonal coordination between women and men?

As emotion recognition through facial or bodily expression is essential for social interaction, one can assume that emotions interfere with one's readiness to engage in interpersonal coordination. Frijda (1953, 2007) considers emotions to not only lead to intentional or unintentional actions which follow "appraisal," as I mentioned above. He also states that in concordance with an individual's goal, emotions enhance or decrease the probability to interact with its (non-)social environment. Two concepts have narrowed down his thought: the A*ttention-Focus Theory* (Wood et al., 1990) and the *Affect-as-Information Theory* (Schwarz & Clore, 1996). According to the *Attention-Focus-Theory*, sadness directs the attention of a sad person towards its inner emotional state in order to learn about the sadness's source and meaning. Conversely, an inner happy state directs the attention to a person's environment (Wood et al., 1990).

The *Affect-as-Information Theory* is based on the assumption that mood conveys information from the environment. Therefore, a person in a positive mood sees no threat in its environment, which facilitates automatic, unconscious action tendencies, while a person in a negative mood assumes its environment to be more dangerous, which fosters more cautious and reasoned behavior (Schwarz & Clore, 1996).

Both theories lead to the same conclusion that there is an influence of emotions on interpersonal coordination.

Based on the results of the second experiment and referring to the aforementioned hypothesis, the third experiment was conducted to answer the following questions:

1. Does the own emotional state influence the ability to engage in interpersonal coordination with others? Are there different reactions due to positive or negative emotions?
2. Does this process differ between women and men?

# Measurement Techniques for Movement

There are a number of well-established measurement techniques (see Methods of Emotion Research, p. 17); for the following three experiments, the techniques of motion capture (experiment one) and a force plate (experiment two and three) were chosen to investigate emotional expressions.

## Motion Capture

An optical motion capture (MoCap) allows to record and analyze the movement of objects and people precisely. It is based on infrared-sensitive cameras that capture the two-dimensional coordinates of the motion. By recording the motion with several cameras, a three-dimensional picture can be calculated. As a prerequisite, body parts need to be marked with retroreflective markers. This allows following the movement of exactly the marked spots from several camera views rather than the movement of the whole body. Those lightweight markers are covered with retroreflective tape. The infrared strobe of the cameras is reflected and used for calculations of the coordinates. The applied Vicon Nexus 2.7.1 software (Vicon ©, Vicon Motion System Ltd., UK) can be used in a variety of applications, e.g., medical, sports, animation, or the industrial field.

The following steps need to be prepared before data collection:

- *Aiming of the cameras*: aiming the cameras at the region which needs to be recorded (i.e., the middle of the room where the participant will be situated)
- *Masking*: to avoid any other reflecting spots in the room or on the participants to be traced, all reflecting parts of clothing should be covered and further can be masked through Vicon Nexus by improving calibration robustness and reconstruction quality
- *Calibration*: all cameras need to be calibrated to enable the production of accurate 3D data
- *Setting the volume origin*: the origin of the volume needs to be set to fixate the center of the recorded space and the directions of the axis x (medio-lateral), y (anterior-posterior), and z (vertical)

- *Calibrate floor plane*: by using markers in the volume, the position of the floor plane can be set. This ensures an accurately aligned coordinate system with the floor of the captured volume, which might be uneven

Further preparation steps after the participant has arrived:

- *Subject-specific measurements*: to directly calculate the kinematics (e.g. angles, kinetics forces, movement, powers), the exact dimensions of a participant need to be measured and put into a template of Vicon Nexus (see Table 3). This enables to calculate the kinematics and kinetics from the x, y, and z position of each marker
- *Marking the participant*: markers of 14 mm dimension will be attached according to the *full body Plug-in Gait* model, a specific model of placing the markers onto the participant
- *Calibration trial*: capturing the marked participant in a simple static pose (e.g., a T-pose or motorbike pose, see Figure 3)
- *Labeling skeleton template*: automatically or manually labeling all markers of the calibration trial in the Vicon recording software. The template can later be used to automatically label all the experimental trials

*Table 3: Dimensions of the Participant*

| **Name** | **Description** |
|---|---|
| body mass | [in kg] |
| height | [in cm] |
| shoulder offset | distance between the acromion and the shoulder joint center [in mm] |
| elbow width | distance between the medial and lateral epicondyles of the humerus [in mm] |
| wrist width | distance between the anterior and posterior part of the wrist [in mm] |
| hand thickness | distance between the dorsum and palmar surface of the hand [in mm] |
| leg length | distance from the iliac crest to the malleolus [in mm] |
| knee width | medio-lateral width along the knee axis [in mm] |
| ankle width | medio-lateral width of the malleoli [in mm] |

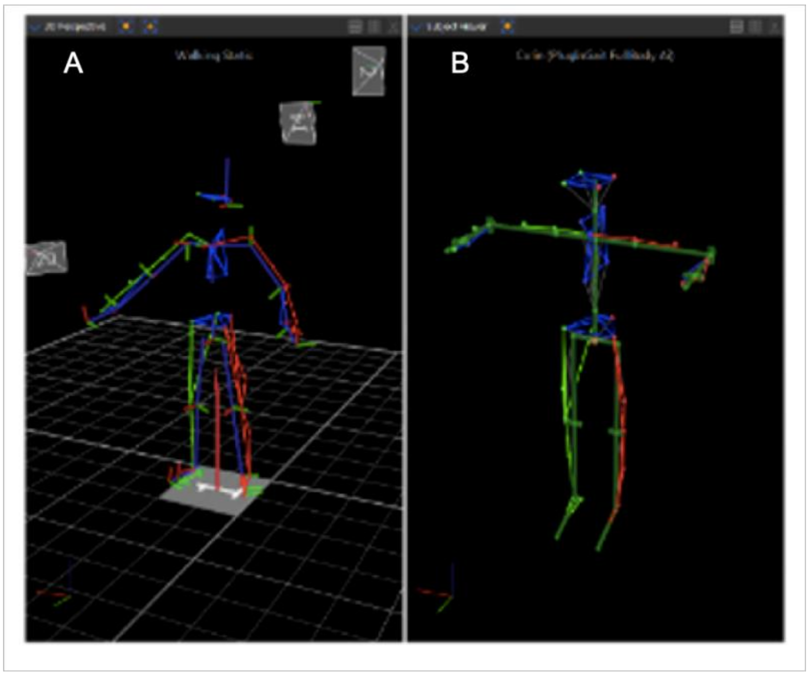


*Figure 3: Static Pose (motion capture): A: motorbike pose, B: T-pose (Vicon Motion Systems Ltd., 2017, p. 105)*

There are different models to mark and label a participant. For experiment one, the *full body modeling with Plug-in Gait* (see Figure 4) was used. It is based on the Newington-Helen Hayes gait model (R. Davis et al., 1991) and tracks the full body kinematics. A *Plug-in Gait* uses the subject-specific measurements and the recorded marker trajectories (x, y, and z marker position) to calculate the joint kinematics (the relative movement between two segments of a body) and the kinematics (the motion of a segment) for a person. The *Plug-in Gait* model uses three or more points to display one segment (e.g., for the lower leg: knee, tibia, ankle) and calculates the participant's joint center position from the XYZ position of each marker for each frame. It has been validated by R. B. Davis and colleagues (1991).

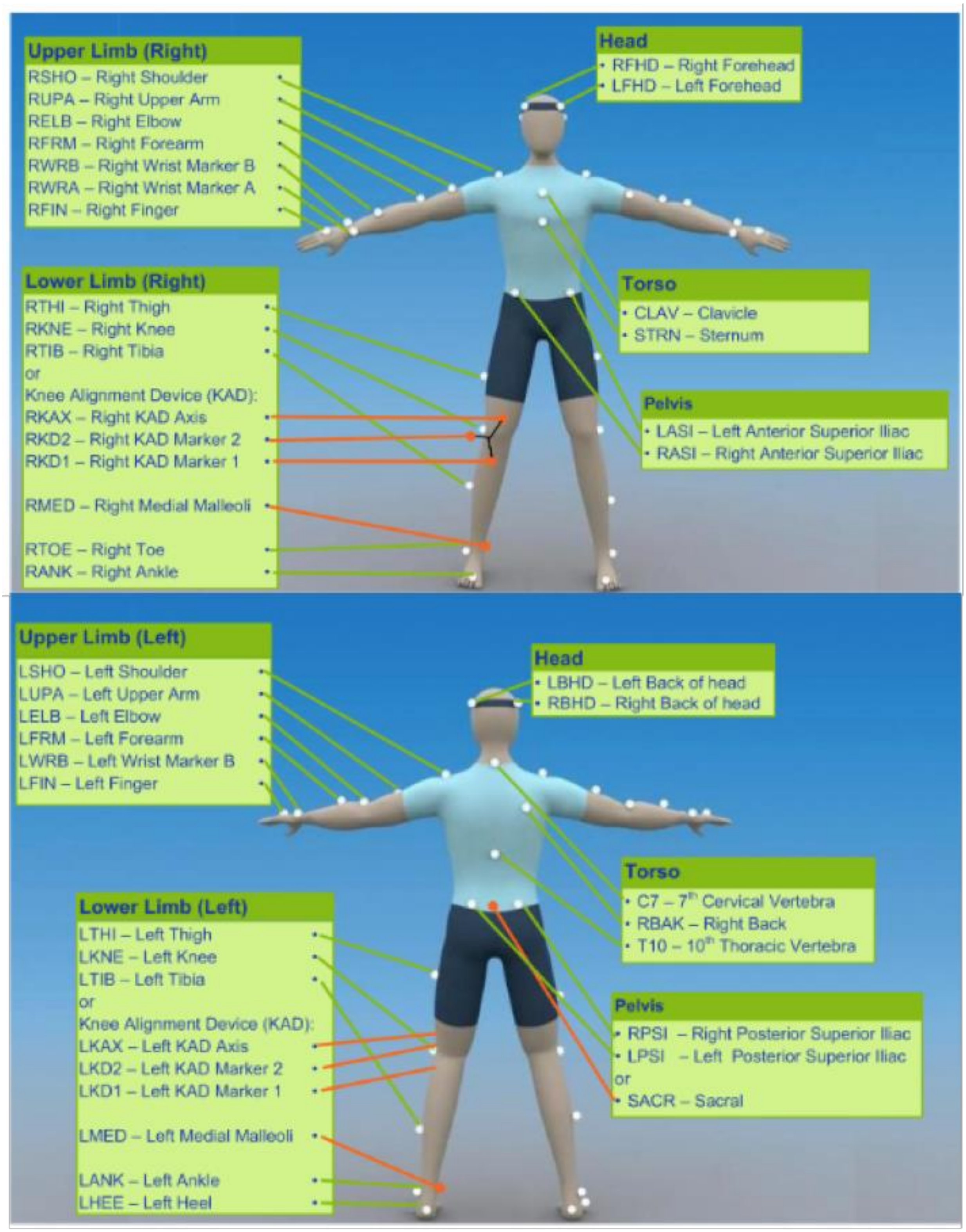


*Figure 4: Full body modeling with Plug-in Gait* (Vicon Motion Systems Ltd., 2018, p. 28)

After all the preparation steps are finished, and data acquisition has been completed, the recorded data will again be labeled (automatically) after a pre-defined template and reconstructed to create a 3D model. Any gaps within the experimental trial of a marker need to be filled. Gaps develop when a marker cannot be captured by the cameras (i.e., it is lost during the trial or covered by the clothing texture). A pipeline, which is an automatic data processing operation run by the *Plug-in Gait* model, finalizes the data processing, including filtering and producing the output file.

### Force Plate

The force platform precisely analyzes the ground reaction forces by measuring the three orthogonal forces (Fx, Fy, Fz), the moments (Mx, My, Mz) and the center of pressure (Cx, Cy, Cz) of the x (medio-lateral axis), y (anterior-posterior axis) and z (vertical axis) coordinate system as the subject stands on its top surface. Moments are rotations around axes; clockwise rotations express positive moments (see Figure 5). Sensors are based on either the strain gauge or piezoelectric principle. The strain gauge principle, which is applied in the AMTI force plate and used in the experiment two and three works with a spring body underneath the surface. The spring body deforms when a force is applied to the platform’s surface; this causes compressions and extensions of the attached strain gauges, which changes their electrical resistance. It has the great advantage of featuring low natural frequencies with high accuracy, optimal for analyzing the natural body sway. It is also stable for long-term measurements and can compensate for temperature changes. One disadvantage might be overstraining and material fatigue due to deformation. The other principle of piezoelectric is based on piezoelectric crystals, which react to force application with a charge shift at their molecular level and their lattice structure. This charge shift can be converted into a voltage signal. It enables measuring high and fast natural frequencies but makes long-term and small forces difficult to capture.

By altering the forces on top of the platform, the direction, amount, and moment of the applied force can be obtained. Figure 5 shows the three forces and the three recorded movements, as the subject is in contact with the platform. Forces apply along the axes (x, y, and z), the arrows point in the direction of a positive force recording.

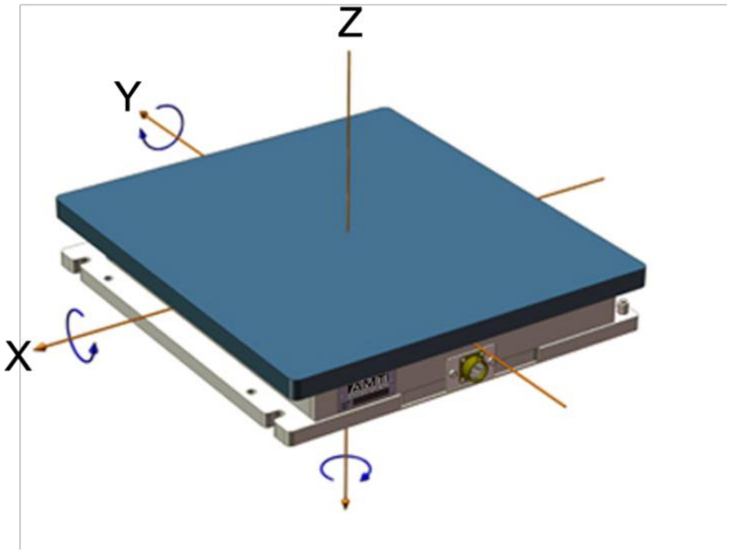


*Figure 5: Force platform with the three orthogonal x, y and z coordinate system* (Lamkin-Kennard & Popovic, 2009)

Force plates are commonly used in the fields of sports and medicine to analyze gait patterns, balance capabilities, and other biomechanical parameters.

At the beginning of each experimental session, the scale of the force plate needs to be tarred (zero level) to set any existing forces on the plate data to zero.

Physiological measurement techniques, like motion capture and force platforms, provide an accurate indicator of subtle emotional states expressed through the body, such as body sway and freezing behavior (Kret et al., 2020)

# Experiment One – Emotions Expressed through the Body Sway

The focus of experiment one lies on the effect of emotions on the natural body sway by investigating different emotional stimuli.

## Summary of State of Research on Emotional Bodily Expressions

A large body of research points to the importance of bodily expressions of emotions. De Gelder (2009) suggests bodily expressions are equally valid for emotion recognition as facial expressions, while other authors assigned it to provide even more information than facial expressions on long distances (De Gelder, 2009). While a fearful face might elicit empathy, a fearful body may trigger a flight response (De Gelder, 2009). This behavioral activation in response to emotional stimuli has been investigated on the basis of approach and avoidance action tendencies, which have been proposed to be interrelated with emotions for a long time (Frijda, 1986, p. 71). According to this idea, emotions are categorized into motivational systems to prepare an individual to respond to positive or negative stimuli with approach and avoidance behavior, respectively (Lang et al., 1990). In line with this are the results of a study showing that participants were faster in pulling cards with positive words and to push cards away with negative words (Solarz, 1960).

Additionally, and as mentioned above, the emotions' ability to affect muscular activity also influences the natural body sway. The natural body sway is a product of an individual's perception of and reaction to the external world, thereby allowing him to maintain a stable upright stand (Saripalle et al., 2014). In support of the motivational system, one would expect pleasant visual stimuli to provoke an approach behavior and unpleasant stimuli to elicit an avoidance behavior. Current research results, however, seem rather contradicting. For instance, in one study, participants were found to lean slightly forward in response to unpleasant and neutral stimuli (Stins & Beek, 2007). In another study, however, only women were withdrawing from unpleasant pictures (Hillman et al., 2004). Besides approach and avoidance reactions, many authors report a reduction of swaying amplitude and an increase of swaying frequency in response to negative, unpleasant, or mutilation pictures on the anterior-posterior axis and on the medio-lateral axis, which has been interpreted as freezing behavior. Freezing behavior is a possible response to aversive stimuli, mostly however, in response to highly arousing stimuli, rather than to unpleasant stimuli (negative valence). Participants presented with unpleasant stimuli were found to increase the MPF on their anterior-posterior axis (Horslen & Carpenter, 2011).

Put together, participants react upon unpleasant stimuli with either freezing (e.g., Roelofs et al., 2010) or with withdrawal behavior (Hillman et al., 2004). The above mentioned contradicting findings have been explained by the participants' emotional experience prior to the experiment, the stimulus itself (Lelard et al., 2019), or methodological differences between the experimental set-ups, i.e., assessed time frames after stimulus onset were proposed to be another possible explanation (Horslen & Carpenter, 2011).

However, another possible explanation for these inconsistencies could be an uncontrolled gender effect. Women and men differ in their biology and socialization, and, as previous research revealed, this affects emotional experience and expression. To the best of my knowledge, only one study investigated approach and avoidance tendencies in women and men separately so far. The authors found that men rather approach aversive stimuli while women tend to avoid them (Hillman et al., 2004).

Despite gender, being able to recognize an emotional expression requires the activation of a sensorimotor simulation process, which has been proposed to cause similar motor movements (Hawk et al., 2012) and affects the own emotional state. In support of this concept, Moody et al. (2018) found that besides the observed fragment of a body, the face, also other body parts, the forearm, were activated in response to emotional stimuli. These results are a promising first step to understand the processing of perceived emotional expressions by simulation.

### Aim of Experiment One

Proceeding on these results and to test the sensorimotor hypothesis (*Sensorimotor Simulation Theory)*, the first aim of the present study was to investigate behavioral reactions in response to positive and negative emotional stimuli. Referring to the assumption that emotions convey information from the environment (*Affect-as-Information Theory*) (Schwarz & Clore, 1996), for positive emotional stimuli, more generous, unconscious action tendencies were expected, expressed in an increased swaying amplitude (RMS), along with a decreased frequency (MPF). Whereas for negative stimuli, a more cautious and reasoned behavior was expected, shown in a decreased swaying amplitude (RMS) and an increased swaying frequency (MPF).

For a deeper understanding of the simulation process, different emotion induction methods were used: a) visual stimuli (affective pictures) to control perceived images, b) acoustical stimuli (emotional music), as music is known to initiate and intensify emotional, cognitive processes (i.e., emotional memory) (Västfjäll, 2001), and c) a combination of visual and acoustical stimuli to elicit a more profound emotional experience. The strongest evidence for a simulation process was expected for the combined condition of pictures and music.

The second aim of this study was to investigate behavioral gender differences (approach and avoidance tendencies) in response to positive and negative emotional stimuli, as gender has been proposed to be a major factor that influences postural control (Ekdahl, 1992). According to the above-mentioned study of Deng et al. (2016), women were expected to rate their emotional experience higher than men, but men to respond stronger in their approach and avoidance tendencies than women.

## Methods

Data collection of the first experiment consisted of questionnaire ratings by the participants and physiological data recordings – measurement of body swaying behavior by using motion capture cameras. Raw data were manually pre-processed, and swaying parameters were calculated using R. All data were statistically analyzed in IBM SPSS.

### Participants

45 young adults (24 female, 21 male) participated in the study (female age, *M*: 20.11, *SD:* 3.02; male age, *M*: 22.44, *SD*: 3.10), four had to be excluded due to failure of the technical equipment or performance mistakes[6]. Muscular and psychological disorders were controlled for. The experimental procedure was conducted according to the ethical guidelines of Helsinki.

[6] All four participants lost markers for the *Plug-in Gait* model during the experiment, without the experimenter taking notice. These participants were excluded from the data analysis.

## Procedure

Prior to arrival, participants gave written informed consent to participate in the experiment and were asked to fill out the following questionnaires: Body Perception (BQP-SF) (Porges, Stephen, 1993), Brief COPE (Carver S. Charles, 1997), MDBF (Steyer et al., 1994) and SAM (M. Bradley & Lang, 1994). Participants' body proportions were taken according to the *Plug-in Gait Reference Guide* by Vicon (Fellinger et al., 2010). Reflection points were attached according to the *full body Plug-in Gait* model. For the main part of the experiment, participants were standing 250 cm across from a TV screen (106.7 cm screen diagonal), with their feet hip-width apart, in the pre-defined center of the recorded volume (volume origin). They were asked to stand quietly on both feet with their arms hanging at their sides and to pay attention to the pictures on the TV screen. Each participant was inducted with a positive and a negative emotion. There were three *conditions* for each emotion respectively (pictures, music, and pictures combined with music). Before and after all emotion inductions, a baseline (*pre-* and *post-baseline*) was recorded. Each condition was presented for three minutes, each baseline lasted one minute. During the neutral baseline, no pictures or music was played. Both *emotion induction phases* were presented in counterbalanced order. The presented pictures were either pre-selected positive or pre-selected negative pictures of the International Affective Picture System (IAPS) (Lang et al., 2008). The music was rated by students of the same sample prior to the experiment and validated to effectively elicit positive and negative emotions: (positive music: "summer of 69", by Bryan Adams; negative music: "Amoi seg' ma uns wieder", by Andreas Gabalier). At the beginning of the experiment, and after each condition, participants rated their subjective emotional state in the SAM questionnaire (Lang, 1980).

## Measures

The influence of positive and negative emotions on the natural body sway was assessed by using motion capture cameras. The individual variability of emotions on the swaying behavior was evaluated by three specific questionnaires. An additional mood ratings questionnaire after each emotion condition controlled for the effect of emotion induction.

### Motion Capture

Optical motion capture data were recorded by eleven infrared cameras (Vicon ©, Vicon Motion System Ltd., UK) and a set of 53 retroreflective markers, put onto specific anatomical landmarks of the participants' body according to the *full body Plug-in Gait* model. Data were recorded at a sample rate of 200 Hz.

### *Questionnaires*

Prior to the experiment, three questionnaires (Body Perception Questionnaire (Kolacz et al., 1993), COPE (Carver S. Charles, 1997) and MDBF (Steyer et al., 1994)) evaluated individual abilities to perceive and cope with arousing situations and to assess the mood state. The SAM questionnaire (M. Bradley & Lang, 1994) evaluated whether emotion inductions were subjectively perceived as a change in emotion.

#### *SAM*

The paper-and-pencil version of the Self-Assessment Manikin (SAM) (Bradley & Lang, 1994) measures the state of *pleasure*, *arousal* and *dominance* of a person by using three types of pictograms (see Figure 6) on a five-point Likert-scale. Its test-retest reliability ranges from $r$ = .96 to .98 and correlations of two samples with two years apart were found to be $r$ = .90 (Kanske & Kotz, 2010).

The internal consistency of *arousal* was found to be .89 and *valence* between .63 to .82 (Cronbach's α) (Backs et al., 2005). The dimension *dominance* has a weak independent effect (cf. Bradley & Lang, 1994).

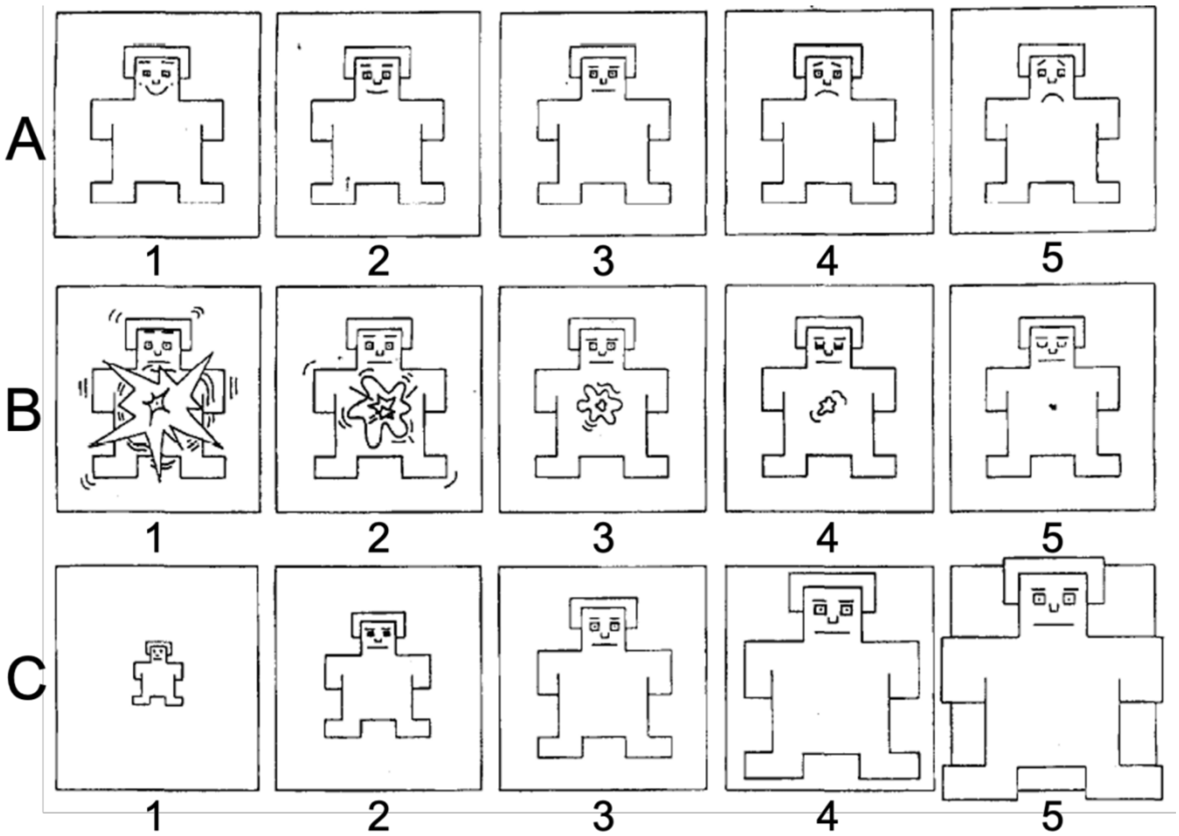


*Figure 6: SAM (Self-Assessment Manikin). Row A: pleasure, row B: arousal, row C: dominance. 5-point Likert scale from 1 to 5; feeling very happy to very sad (row A), very aroused to very calm (row B), very small to very strong (row C)*

### *Body Perception*

The Body Perception Questionnaire (BQP) measures subjective body awareness and its autonomic reactivity by investigating the autonomic nervous system (ANS). The ANS carries information of functions of the organs and tissues (Kolacz et al., 1993). It was originally developed to assess individual consciousness of the condition of specific organs which are controlled by the autonomic nervous system (Porges, 1993). The Body Perception Questionnaire's *very short form* (BPQ-VSF) is reduced to one domain: body awareness and twelve items. The body awareness focuses on the perception of physiological processes (Kolacz et al., 1993). The BPQ-VSF was found to have a test-retest reliability of $r = .99$ (one week later) and an internal consistency between .83 and .91 (Cronbach's α) of three different samples (Cabrera et al., 2018).

#### COPE

The Brief COPE is a shortened version of the COPE inventory by (Carver S. Charles, 1997). It evaluates possible strategies how people cope with stress. It contains 14 scales with two items each: distraction, denial, emotional support, behavioral withdrawal, positive reinterpretation, humor, active coping, alcohol and drugs, instrumental support, living the emotions, planning, acceptance, self-incrimination, and religion. Out of the 14 scales, three main scales can be calculated: *active functional coping*, *active cognitive coping,* and *dysfunctional coping* (Carver S. Charles, 1997). The brief COPE was found to have a test-retest reliability between r = .05 and r = 1.00 (after 7 to 8 weeks) (Yusoff et al., 2010) with an internal consistency of Cronbach's α = .43 and .97 (Snell et al., 2011). Cronbach's α found by Carver (1997) itself lies between .45 and .92.

#### MDBF

The short version of the multidimensional mood questionnaire (Mehrdimensionaler Befindlichkeitsfragebogen - MDBF) (Steyer et al., 1994) consists of three bipolar scales: *good* and *bad* mood, *vigilant* and *fatigue*, *rest* and *restlessness* with four items each, resulting in twelve items in total. The test-retest reliability of the MDBF was found to be between r = .69 and r = .86 (Kohlmann et al., 2021) and an internal consistency of .92 (Cronbach's α) (Hinz et al., 2012).

### Analysis

After pre-processing of the raw data, body sway and questionnaire data were analyzed statistically. For all data which violated the assumption of sphericity, the calculations of the Greenhouse-Geisser correction were used. Any alpha error accumulations were corrected according to Bonferroni ($p = \frac{\alpha}{n}$).

#### Motion Capture Vicon

In order to detect any gaps in the marker trajectories and to scan the data for any irregularities, raw data were manually inspected. Gaps were automatically filled, and a Woltring filter was applied by using automatic pipelines of the Vicon Nexus 2.7.1 software (Vicon ©, Vicon Motion System Ltd., UK). The Woltring filter is based on a fifth-order spline interpolating function (Woltring, 1986). This ensures smooth trajectories for further calculations. The first three and the last three seconds of every condition or baseline were removed.

The root mean square (RMS), over a period of 180 seconds (condition) and 60 seconds (baseline), and the mean power frequency (MPF) were calculated in R. The RMS is defined as the square root of the mean square power over a defined time interval (Merletti, 1999), with higher RMS values indicating greater movement. The MPF calculates the average frequency within a power spectrum (Winter & Patla, 1997), each frequency component is weighted by its power.

For statistical analysis, the delta-test baselines of the body sway were calculated. The delta-test baseline is calculated as the difference between each *condition* (pictures, music, and pictures combined with music) and the mean of *pre-* and *post-baseline*. Thus, positive values indicate an increased swaying amplitude, or frequency, due to emotion induction, and negative values indicate a decreased swaying amplitude, or frequency, compared to the baseline. To analyze the influence of the three *positive conditions* (pictures, music, and pictures combined with music) and the three *negative conditions* (pictures, music, and pictures combined with music) on the body sway, an ANOVA with repeated measurements was performed. Setting the delta values *condition* (pictures, music, and pictures combined with music) and *emotion* (positive and negative) (3*2) as within subject factor, and *gender* as between subject factor, for both axes separately.

To analyze whether the participants' mood at the beginning of the experiment had an influence on their body sway during emotion induction, an ANOVA with repeated measurements was conducted, with the delta values *condition* (pictures, music, and pictures combined with music) and *emotion* (positive and negative) (3*2) as within subject, and *scale* (good-bad mood, vigilant-fatigue, and rest-restlessness) as covariate.

### SAM

To control whether emotion inductions were subjectively perceived as a change in emotion, participants were asked to fill out a SAM questionnaire (Bradley & Lang, 1994) after each condition, including the baseline conditions. An ANOVA with repeated measurements with *category* (pleasure, arousal, dominance) as within subject factor, and *order of condition* (ratings after emotion conduction: baseline, positive pictures, positive music, and positive pictures combined with music and negative pictures, negative music, and negative pictures combined with music) and *gender* as between subject factor, was conducted.

### Questionnaires

Questionnaires were evaluated according to corresponding manuals and analyzed statistically.

*Body Perception*

The Body Perception T-score of the BPQ manual (Porges, 1993) was assessed for the following analysis. To investigate whether women and men experienced their body perception differently an ANOVA with repeated measurements was used to investigate gender differences in the ratings of the questionnaires: *T-score* as withing subject factor and *gender* as between subject factor.

*COPE*

Of the 14 scales of the COPE inventory (Carver S. Charles, 1997) the mean of three main scales: *active functional coping*, *active cognitive coping*, and *dysfunctional coping* were be calculated and further used. An ANOVA with repeated measurements, *scale* as within subject and *gender* as between subject factor, was used to investigate gender differences in the COPE ratings.

*MDBF*

For the MDBF questionnaire (Steyer et al., 1994), the negative items were recoded and the sum of each scale (good-bad mood, vigilant-fatigue, rest-restlessness) was used for further calculations. To investigate gender differences of the mood state prior to experiment an ANOVA with repeated measurements was used to investigate gender differences in the ratings of the questionnaires (within subject: *scale,* between subject factor: *gender)*.

*Correlations*

To analyze whether the awareness of the own body, the ability to cope with stress, or the general mood, had an influence on the body sway, scores of each questionnaire were correlated with the delta values of the body sway data of the six conditions using a Pearson's correlation. The alpha error accumulation for the three questionnaires was corrected according to Bonferroni and the adjusted alpha levels were set to $p$ = .017, ($p = \frac{\alpha}{n}$ ).

## Results

The results show effects of emotions on the body sway and interactions between the questionnaire ratings and the swaying behavior. Additionally, correlations between the emotion conditions and the questionnaires were found. Gender effects were found for the body sway data, the SAM- and the MDBF questionnaire.

### Motion Capture Vicon

To evaluate whether the participants' swaying amplitude (RMS) was affected laterally (x-axis), an ANOVA with repeated measurements, with *condition* (pictures, music, and pictures combined with music) and *emotion* (positive and negative) as within subject (3*2) and *gender* as between subject, found one significant interaction between *emotion* and *gender*: $F(2.000,36.000) = 4.898$, $p = .033$, partial $\eta^2 = .120$. Men increased their body sway during both emotion inductions, positive ($M = .62$, $SD = 1.26$) and negative ($M = 1.22$, $SD = 1.90$) and showed a greater swaying amplitude than women. While women increased their body sway after positive conditions, they decreased their sway during the negative conditions. (positive: $M = .22$, $SD = 1.69$, negative: $M = -.16$, $SD = 2.10$). A conducted t-test revealed a significant difference of the swaying amplitude between women and men during the negative emotion induction $t(36) = .090$, $p = .004$ (see Figure 7).

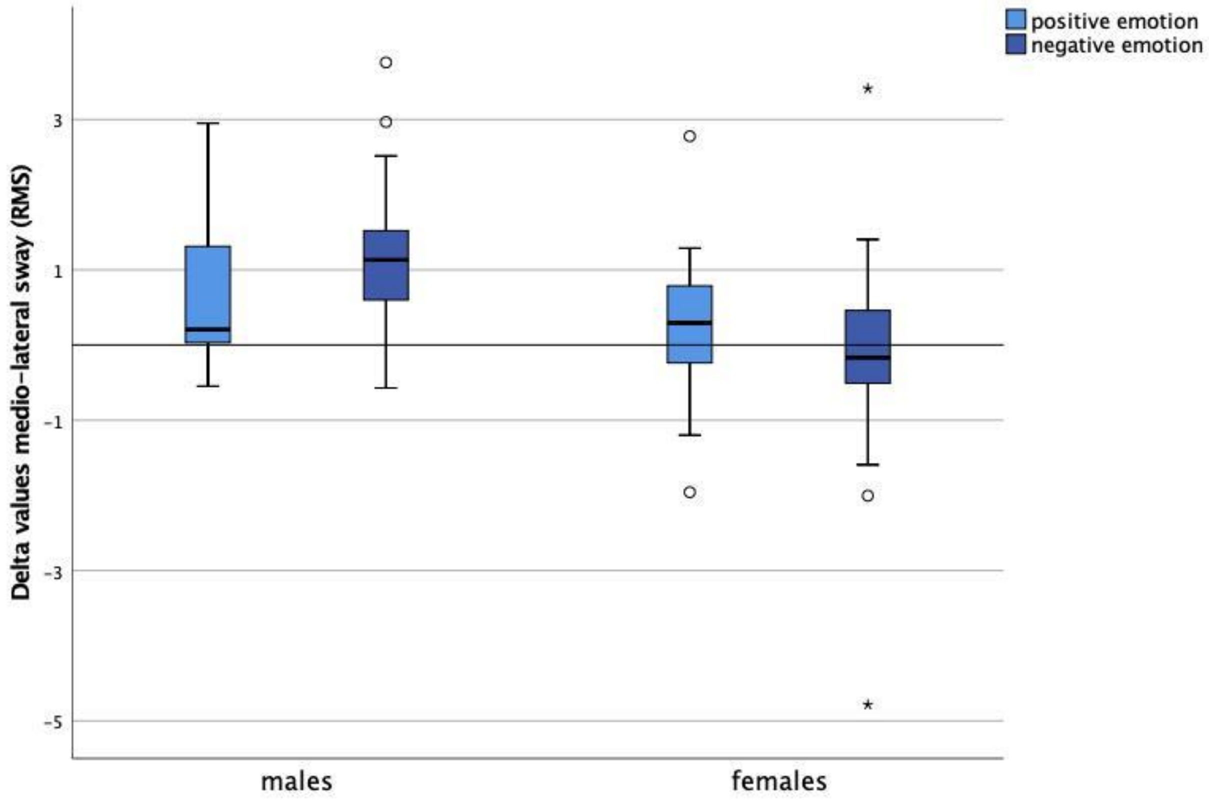


*Figure 7: Swaying amplitude (RMS) during positive and negative emotion induction of women and men respectively.*

An ANOVA with repeated measurements on the y-axis (anterior-posterior sway) revealed no significant result for gender differences. No effects were found for the swaying frequency values (MPF). Mood ratings (MDBF) at the beginning of the experiment had no influence on the swaying parameters ($p > .05$).

### SAM

To control emotion inductions, an ANOVA with repeated measurements was conducted for the subjective emotional state ratings. There was a significant main effect of the *category*: $F(1.477,444.499) = 276.867$, $p < .001$, partial $\eta^2 = .479$. The highest values were found for *pleasure*: $M = 3.57$, $SD = 1.04$, followed by *dominance*: $M = 3.06$, $SD = .79$, and *arousal*: $M = 2.10$, $SD = .94$. A Bonferroni post hoc test revealed all three variables, *pleasure, arousal, dominance*, to be significantly different from each other ($p < .01$) (see Table 4).

*Table 4: Means (SD) and Mean Differences (SEM) between the SAM variables 1) pleasure, 2) arousal, 3) dominance*

| SAM variables | *M* | *SD* | *Mean Difference (SEM)* | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. pleasure | 3.57 | 1.04 | - | | |
| 2. arousal | 2.10 | .94 | -1.48 (.07)** | - | |
| 3. dominance | 3.06 | .79 | -.51 (.04)** | .97 (.07)** | - |

A significant interaction between *category* (pleasure, arousal, dominance) and *order of condition* (ratings after emotion conduction) was revealed $F(8.860,44.499) = 10.193$, $p < .001$, partial $\eta^2 = .169$. Detailed values are shown in Table 5.

*Table 5: SAM ratings after positive and negative condition: pictures, music, and pictures combined with music*

| | Order of Condition | *M (SD)* | *95% CI* | |
|---|---|---|---|---|
| | | | *Lower bound* | *Upper bound* |
| pleasure | neutral | 4.06 (.61) | 3.87 | 4.24 |
| | pos. picture | 3.84 (.88) | 3.58 | 4.11 |
| | pos. music | 4.22 (.74) | 4.00 | 4.44 |
| | pos. picture music | 4.40 (.75) | 4.17 | 4.63 |
| | neg. picture | 2.93 (.65) | 2.74 | 3.13 |
| | neg. music | 2.98 (1.01) | 2.67 | 3.28 |
| | neg. picture music | 2.56 (.84) | 2.30 | 2.81 |
| arousal | neutral | 1.99 (71) | 1.78 | 2.20 |
| | pos. picture | 2.00 (.93) | 1.72 | 2.28 |
| | pos. music | 2.16 (.98) | 1.86 | 2.45 |
| | pos. picture music | 2.18 (1.07) | 1.86 | 2.50 |
| | neg. picture | 2.18 (.91) | 1.90 | 2.45 |
| | neg. music | 2.00 (1.00) | 1.70 | 2.30 |
| | neg. picture music | 2.22 (.97) | 1.93 | 2.51 |
| dominance | neutral | 3.21 (57) | 3.04 | 3.38 |
| | pos. picture | 3.20 (.69) | 2.99 | 3.41 |
| | pos. music | 3.38 (.72) | 3.16 | 3.59 |
| | pos. picture music | 3.53 (.66) | 3.33 | 3.73 |
| | neg. picture | 2.64 (.71) | 2.43 | 2.86 |
| | neg. music | 2.78 (.88) | 2.51 | 3.04 |
| | neg. picture music | 2.69 (.79) | 2.45 | 2.93 |

The second significant interaction was found between *gender* and *variable* (pleasure, arousal, dominance): $F(1.477,44.499) = 4.504$, $p = .020$, partial $\eta^2 = .015$. Men had higher ratings in the category *pleasure* (*M* = 3.60, *SD* = 1.02) and *dominance* (*M* = 3.10, *SD* = .72) than women: *pleasure* (*M* = 3.54, *SD* = 1.06) and *dominance* (*M* = 3.03, *SD* = .84). Women had higher ratings of *arousal* (*M* = 2.23, *SD* =.92) than men (*arousal M* = 1.96, *SD* = .95). A conducted t-test revealed a significant difference between women and men in the category *arousal*: $t(305.005) = -2.559$, $p = .011$ (see Figure 8).

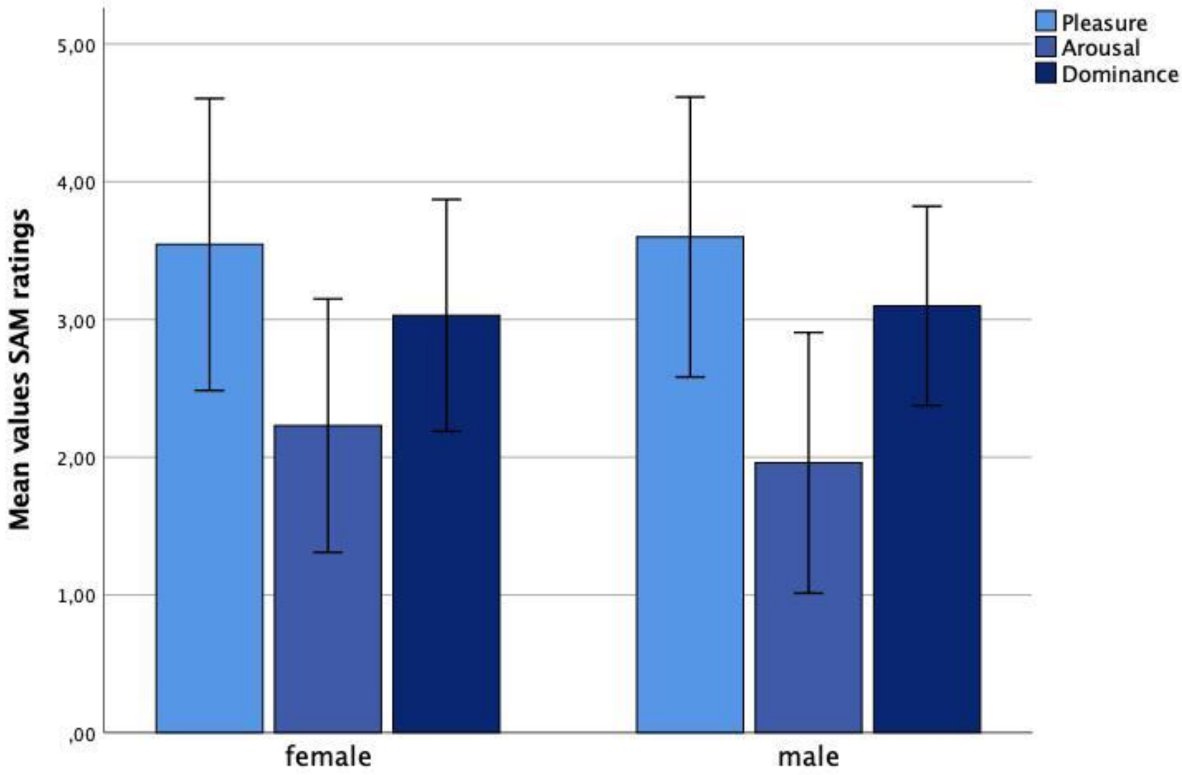


*Figure 8: Means (SD) of emotional states ratings (SAM) for men and women respectively.*

## Questionnaires

### *Body Perception & COPE*

No different ratings of gender (no main effect or interaction) were found for the Body Perception or COPE questionnaires ($p > .05$).

### *MDBF*

A repeated measurement ANOVA with the *scale* (three scales of the MDBF questionnaire) as withing subject factor and *gender* as between subject factor found a significant main effect for *scale*: $F(1.780,34.000) = 19.511$, $p < .001$, partial $\eta^2 = .358$. A Bonferroni post hoc analysis revealed the scale *vigilant-fatigue* ($M$ = 12.97, $SD$ = 2.85) to differ significantly from both other scales: *good-bad* mood ($M$ = 15.43, $SD$ = 3.10) and *rest-restlessness* ($M$ = 14.92, $SD$ = 2.95) ($p < .01$) (see Table 6)

*Table 6: Means (SD) and Mean Difference (SEM) between the MDBF scales 1) good-bad, 2) vigilant-fatigue, 3) rest-restless. ** p < .01*

| MDBF scale | *M* | *SD* | *Mean Difference (SEM)* | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. good-bad | 15.43 | 3.10 | - | | |
| 2. vigilant-fatigue | 12.97 | 2.85 | -2.56 (.44)** | - | |
| 3. rest-restlessness | 14.92 | 2.95 | -.26 (.37) | 2.31 (.41)** | - |

A significant interaction was found between *scale* and *gender*: $F(1.780,34.000) = 4.101$, $p = .025$, partial $\eta^2 = .105$; male ratings indicated higher resting values and women rated to be more vigilant (see Table 7).

*Table 7: MDBF ratings on the scales good-bad, vigilant-fatigue and rest-restlessness of both genders*

| MDBF scale | Gender | *M (SD)* | *95% CI* | |
|---|---|---|---|---|
| | | | *Lower bound* | *Upper bound* |
| good-bad | women | 15.43 (3.20) | 13.95 | 16.53 |
| | men | 15.44 (3.50) | 14.03 | 17.08 |
| vigilant-fatigue | women | 13.14 (2.92) | 11.88 | 14.13 |
| | men | 12.75 (2.84) | 11.34 | 13.99 |
| rest-restlessness | women | 14.10 (3.10) | 13.19 | 15.37 |
| | men | 16.00 (2.42) | 14.72 | 17.28 |

*Correlations*

One correlation reached significance: *cognitive functional coping* correlated positively with the delta value of *positive pictures combined with music*: $r = 479$, $p = .013$, $n = 26$.

## Discussion

Experiment one aims to examine the *Sensorimotor Simulation Theory* by investigating motor movements in response to different emotional stimuli. If the notion of this concept is true, then other body parts than the observed ones should respond with an emotional movement expression. Accordingly, behavioral responses were measured, i.e., alteration in the body sway, elicited by positive and negative emotions, respectively. However, the current experimental set-up revealed no impact of either emotion or condition on the body sway. This absent main effect might be explained by the fact that women and men responded quite strongly in the opposite direction. While men increased their medio-lateral swaying amplitude as a reaction to both emotions, women decreased their body sway in response to the negative emotion compared to the baseline. To the best of my knowledge, so far, one previous study found a similar result: while men responded with approach behavior towards unpleasant pictures, women expressed a posterior movement (Hillman et al., 2004). The authors suggest that unpleasant stimuli release the defense mechanism in women more strongly compared to men. The decreased body sway during the exposure to negative stimuli in this experiment can be interpreted as a freezing reaction, which is also known to be a defensive response (Roelofs et al., 2010). Apart from that, men generally seem to sway more than women. A study investigating the impact of several physiological and psychological parameters on postural control in patients with rheumatoid arthritis found gender to be one of the two most important factors (including gender and age) (Ekdahl, 1992).

Moreover, the men's greater reaction to the positive emotion corroborates the finding that men react upon pleasant stimuli significantly stronger than women, which was previously measured in a decline in heart rate (Deng et al., 2016). The same study found a gender difference in sadness which equals the negative emotion from this study. The presumption of Kret and De Gelder (2012) that women are more willing to report about their emotion was partly confirmed by the results of subjective emotion ratings. Women reported higher arousal due to the emotion induction, whereas men scored higher in the category pleasure and dominance. The fact that women indicated a stronger arousal state corroborates the interpretation that negative emotions led to a freezing behavior.

Moreover, it goes in line with the above-mentioned study, which reports that women respond stronger to sadness with arousal than men (Deng et al., 2016), while dominance as an expression of strong and powerful emotions is culturally rather accepted to be expressed by men (Safdar et al., 2009). Overall, the SAM ratings revealed pleasure to be most affected through emotional stimulation, followed by arousal and dominance. Besides the emotional state ratings after emotion induction, women rated to be more vigilant and restless before the experiment started, while men indicated to be more fatigued and rested. In sum, both genders were found to be in a mostly positive mood and to be more rested than vigilant at the start of the experiment. This result is partly in line with the results of a large-scale study investigating the mood state of 2443 women and men at different age groups. Likely to the current observation, men indicated being more rested and women more restless; however, women were found to be more fatigued than men (Hinz et al., 2012). In contrast to the investigation of Hinz et al. (2012), who observed the mood state within no specific context and in the participant's home, students of the current study rated the mood state prior to an unknown experimental set-up which could have diminished feelings of fatigue; especially in women who are known to react more sensibly to situations with increased arousal (Deng et al., 2016) and rated their own mood state as more restless at the beginning of this study.

Contrary to the expectation, no alteration of the swaying frequency was found. Possibly, negative emotion induction rather increased unpleasant feelings than a higher status of arousal, as shown by the emotional state ratings after each condition. An effect of an increased state of arousal caused by an elevated level of stress on the postural response was previously found by Doumas et al. (2018). The authors suggest that this interaction of postural control and stress is a well-known fact. While this argument does not hold for the current study, it does call for initiating future research. As pointed out by Horslen and Carpenter (2011), many inconsistencies of similar experimental set-ups arise from methodological limitations. It is, thus, inevitable for further understanding of emotional influences on the postural control to disentangle positive-negative- and high-low arousing stimuli on different time frames after stimulus onset. For example, Bouman and Stins (2018) found an alteration in sway path length in response to high-arousing pictures 200 milliseconds after stimulus offset. No effect, however, was found for the time window 200 milliseconds after stimulus onset.

Finally, a better cognitive coping strategy correlated positively with an increased swaying amplitude during the presentation of positive pictures combined with positive music. An unexpected but not surprising fact since it fits the findings of previous research which has shown that positive emotions increase coping skills and additionally enlarge a person's attention and cognition (Fredrickson & Joiner, 2002).

By investigating the *Sensorimotor Simulation Theory*, experiment one could not provide a main effect of positive or negative emotions on the body sway. It, however, shows that women and men respond differently, independently of the stimulus and despite diverse personal traits, such as the ability to cope with stress, body awareness, or the general mood state prior to the experiment.

### Limitations

One major limitation of the current study are the presented stimuli. One can assume that individuals respond to specific images not equally strong; for instance, women might respond differently than men. Besides that, music is a very personal topic. Another possibility to induce emotions could be to assign a personal positive or negative music piece to every participant. Thus, it would be beneficial to carefully control emotion-inducing stimuli according to gender differences in a follow-up study. Possibly, emotions in women are rather triggered through joyful or fearful social stimuli, such as positive and negative images of children. In contrast, men might react stronger to threatening cues, especially when they come from other men (Kret & De Gelder, 2012). This also implies the influence of different qualities of negative and positive emotions. Future studies should investigate several qualities of emotions. For example, fear might rather trigger women, whereas anger could provoke a stronger behavioral response in men. It is also possible to use other more personalized emotion induction techniques. For example, recalling an emotional memory or a specifically assigned music might trigger a similar emotional response in both genders.

Furthermore, the study is limited by small sample size.

The first experiment revealed an effect of perceived emotions on subtle motor movements, like the natural body sway. Those findings shed some light on emotional body expressions. It, however, does not yet explain how expressed emotions enable or prevent social communication between individuals. This element of social communication will be investigated in the following two experiments.

# Experiment Two – an Interpersonal Coordination Paradigm[7]

The second experiment serves as a pilot study to develop an experimental set-up. It aims to produce a methodological basis that allows to reduce biases originating from the pre-existing rapport between the participants.

## Summary of State of Research on Interpersonal Coordination

Bodily expressions for social communication are based on one fundamental tool: synchronized gestures and movements (Bernieri & Rosenthal, 1991). Interpersonal coordination is generally known as spontaneous overlap in time and form of facial or body movements between two or more people (Bernieri, Reznick, & Rosenthal, 1988). Mimicry and interpersonal synchrony are differentiated through their behavioral timing. As a fundamental part of human social interaction, it routes back to traditional ceremonies of ancient cultures (Hagen & Bryant, 2003) and already plays an important role in early exchanges between infants and their caregivers (Condon & Sander, 1974; Termine & Izard, 1988). Many studies focus on the outcomes of interpersonal coordination, which are, to a large extent, positive. However, people have individual prerequisites which influence their ability to coordinate movements. Personal traits, as empathy (Dimberg & Thunberg, 2012; Rymarczyk et al., 2016; Sonnby-Borgström et al., 2003), group membership (Bourgeois & Hess, 2007; Likowski et al., 2011; Yabar et al., 2006), mood (Chartrand & van Baaren, 2009; Van Baaren et al., 2006), or even the first impression of the interaction partner (Miles et al., 2010) leads to varying degrees of coordinated behavior and has not been controlled for in many studies.

Another factor that has been proposed to influence interpersonal synchrony is gender. Especially women who generally outperform men in many social skills (i.e., empathy, social communication) are thought to be more responsive to bodily expressions than men (M. Cheng et al., 2017). On the other hand, men have been suggested to be more skillful when it comes to motor-coordination abilities (M. Cheng et al., 2017), which could favor men in coordination tasks as the one

[7] The results presented in this chapter were published previously in: Scheer, C., Horn, L., & Jansen, P. (2021). Moving in synchrony with an avatar – presenting a novel and unbiased body sway synchronization paradigm. *Current Psychology*.

applied in the current study. The fact that not all individuals are equally likely to coordinate movements also questions findings of previous studies (Hale & Hamilton, 2016).

### Aim of Experiment Two

Therefore, in an attempt to eliminate any pre-existing effects, the main goal of this study was to create a simplified experimental set-up: a human-avatar synchronization paradigm. In this set-up, participants' body sway was measured while being exposed to a medio-lateral moving and non-moving avatar, as well as to medio-lateral moving and non-moving object. The avatar's silhouette was shaped like a human, while the object's silhouette was a rectangular column. Previous work on coordinated body sway found that conversations lead to subtle coordination of the bodies. While cooperating on a visual search task, participants facing each other and those looking in the opposite direction coordinated their swaying behavior (Shockley et al., 2003). More recently, Shockley et al. (2007) specified their previous results by showing that specific elements of the conversation, such as speaking rate and accentuation of words, enhance acoustical mediation and thereby lead to more synchronous body sway. Also, being interested in a romantic relationship seems to be expressed by a non-verbal body sway. Thereafter, a person's movements which are mirrored by a partner, correlate with the interest in a long-term relationship (Chang et al. 2020). These findings indicate the natural body sway to be a promising parameter for investigating interpersonal coordination.

A recent human-avatar synchronization study found the human-avatar interaction as a comparable set-up to a human-human interaction (Sacheli et al., 2014). But contrary to this, and other previous human-avatar synchronization studies (Meerhoff et al., 2017; Sacheli et al., 2014, 2015) where participants were told to follow the avatar's movements actively, the present study investigated an unconscious synchronization behavior between the participant's and the avatar's movements. Unconscious synchronization was provoked by misleading the participant to pay attention to a secondary task since social synchronization is believed to happen unconsciously, unintentionally, and effortlessly (Chartrand & Lakin, 2013). One recent study tested interpersonal closeness after participants engage in more (0.25-0.58 seconds delay) or less (1.67-4.33 seconds delay) coordinated movements with a group of avatars and found greater perceived closeness after the coordinated movement condition (Tarr et al., 2018). Other studies using avatars as mimicking partners used white female avatars, which could not exclude pre-existing bias, such as experiencing being part of an in- or an out-group (Forbes et al., 2016; Likowski et al., 2008). In the study of experiment two, however, mimicry was manipulated by the avatar itself. It is crucial for a bias-free experimental set-up to know whether participants are likely to engage in coordinated movements with a moving avatar. Therefore, a neutral-looking avatar was chosen since a recent study found the gender but also the avatar's emotions to influence whether participants coordinated their movements (Zhao et al., 2019). Moreover, one major advantage of using an avatar over an actual human is to avoid a possible experimenter effect. There is preliminary evidence that positive effects of interpersonal coordination diffuse if controlled for (Atwood et al., 2020).

Participants were, firstly, expected to express a greater swaying amplitude while being exposed to the moving avatar than while being presented with the non-moving avatar. It was also hypothesized that this difference would not be found when comparing the moving column to the non-moving column.

Secondly, women were expected to engage in coordinated movements to a greater extent than men since women are known to be more skilled in social interactions.

Thirdly, participants who scored higher in empathic- and more positive in mood questionnaires were expected to coordinate their movements to a greater extent than participants who scored lower.

## Methods

Like in the first experiment, data collection consisted of questionnaire ratings and physiological data recordings. Compared to experiment one, the measurement technique was changed, and the body sway was recorded by a force plate. Using a force plate is specifically for small swaying parameters more suitable and generally more conventional. Again, raw data were manually pre-processed, and swaying parameters were calculated using MATLAB. All data were statistically analyzed in IBM SPSS.

### Participants

49 healthy students (35 female and 14 male) participated in the study (female age, *M*: 20.40, *SD*: 2.61; male age *M*: 23.36, *SD*: 3.23). Six participants had to be excluded due to performance

mistakes[8]. Participants were informed about the following procedure and gave written informed consent to participate. The experimental procedure was approved by the ethical committee of the University of Regensburg (protocol number: 18-1202-101) and conducted according to the ethical guidelines of Helsinki.

### Procedure

At arrival, participants signed a written informed consent and were asked to fill out two questionnaires: the Questionnaire of Cognitive and Affective Empathy (QCAE) (Reniers et al., 2011) and a mood state questionnaire (Mehrdimensionaler Befindlichkeits-Fragebogen - MDBF) (Steyer et al., 1994). During the recording of the swaying parameters, participants were asked to stand barefoot on the force plate (AMTI OR6-7-2000 Series Model Force Platform, Watertown, MA 02472, USA) with their feet hip-width apart and 250 cm across from two screens: a large projected screen (180 x 120 cm) and a small TV screen (106.7 cm screen diagonal). The small TV screen was situated on a table in front of the large screen. Participants were asked to stand still and equally balanced on both feet and to pay attention to the pictures of the TV screen. To ensure attention being held on the TV screen, they were told that after the experiment was finished, they would have to answer questions about these pictures. Pictures presented on the TV screen were prior to the experiment selected neutral pictures of the IAPS (International Affective Picture System) (Lang et al., 2008). At the same time, on the large screen either the avatar (*social condition*) (see Figure 9) or the column (*non-social control condition*), in the same height and width as the avatar figure, were presented, starting in counterbalanced order (see Figure 10). Both the avatar and the column were presented in a *non-moving phase* (pre-baseline), quietly standing, for thirty seconds, followed by a *moving phase*, swaying back and forth, from the left to the right side, for one minute, and again followed by a *non-moving phase* (post-baseline) for thirty seconds. The swaying frequency resembled the natural body sway frequency (i.e., below 1Hz; (Funato et al., 2016). During a break of 15 seconds between the social condition and the non-social control condition, participants were allowed to move freely.

[8] In four cases, the force plate was not tarred to the zero line, as instructed by the official guidelines of Vicon Motion Systems Ltd UK. One subject asked to withdraw from the experiment (the trial was terminated) and during one trial, no data was collected for unknown technical reasons.

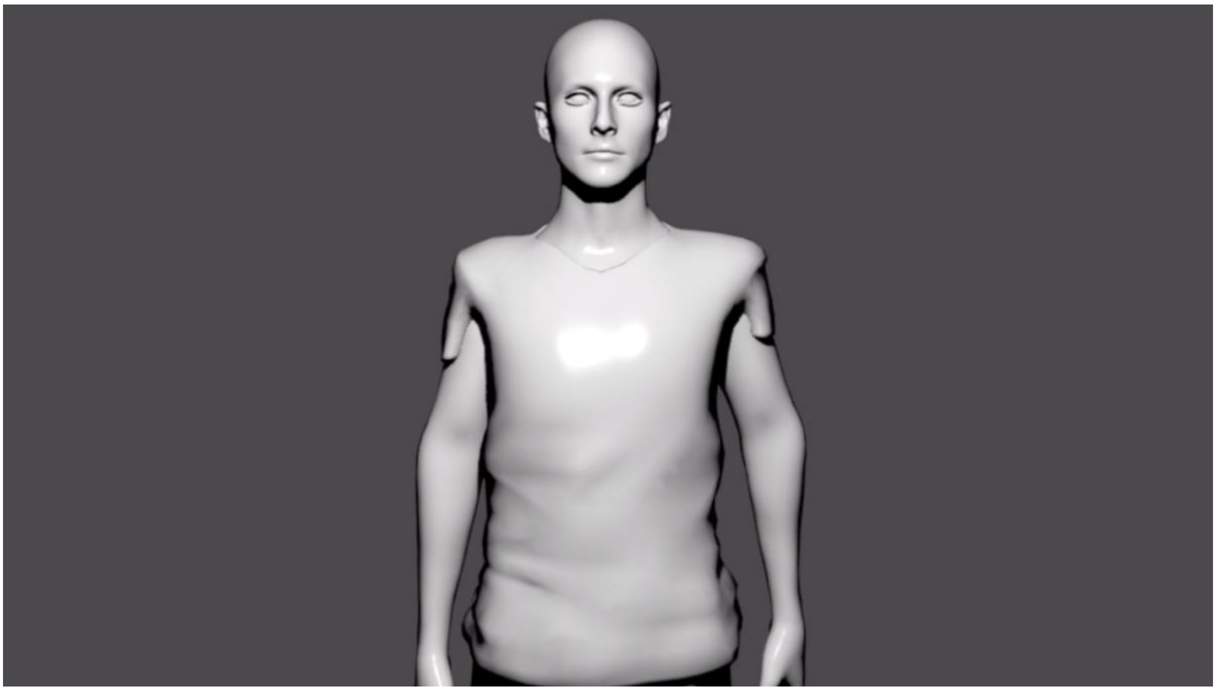

*Figure 9: Life-sized Avatar (social condition) presented on the large screen*

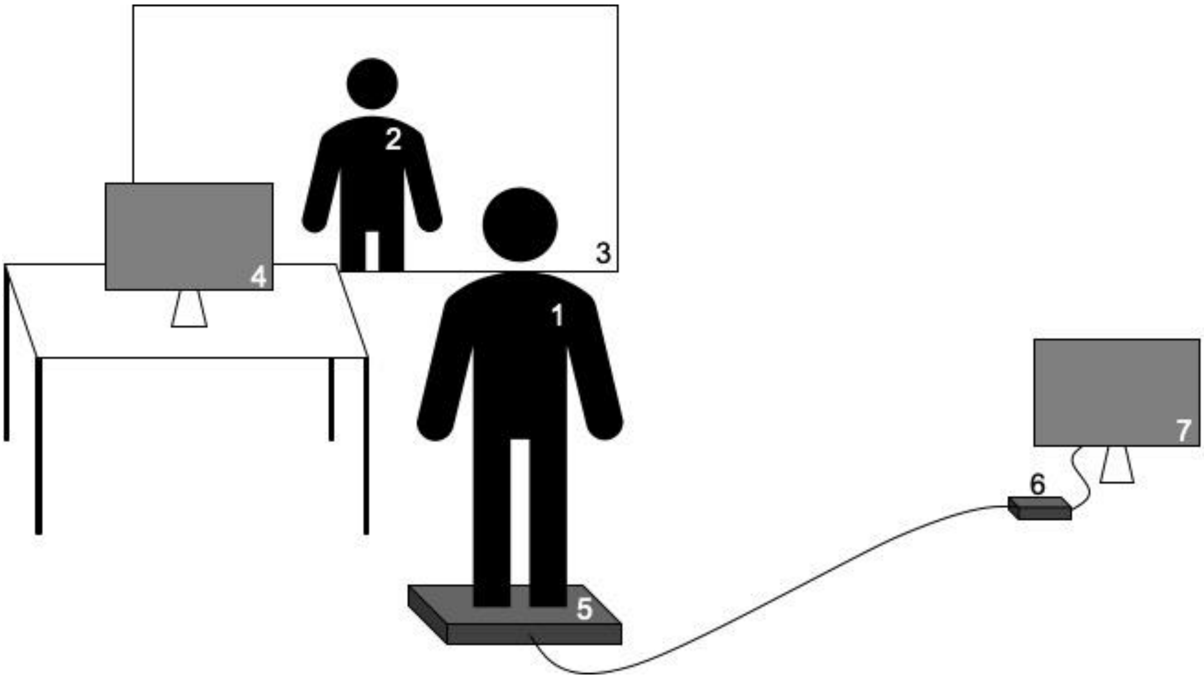


*Figure 10: Experimental set-up experiment two and three: 1: participant, 2: avatar (during social condition), column (during non-social control condition), 3: large screen, 4: TV screen, 5: force plate, 6: amplifier, 7: Vicon Nexus recorder*[9]

[9] Figure 10 was published in advance in Scheer et al. (Scheer et al., 2021)

### Measures

In experiment two, the effect of positive and negative emotions on the natural body sway was assessed by using a force plate. The individual mood state prior to the experiment and the ability to empathize with others was evaluated by two questionnaires.

#### Force Plate

Medio-lateral movements were recorded at 960 Hz using a forceplate (AMTI OR6-7-2000 Series Model Force Platforme, Watertown, MA 02472, USA); no offline filters were applied.

Prior to testing the questionnaires, Questionnaire of Cognitive and Affective Empathy (QCAE) (Reniers et al., 2011), and Mehrdimensionaler Befindlichkeits-Fragebogen (MDBF) (Steyer et al., 1994) were filled-out, using an online survey available at: www.soscisurvey.de (Leiner, 2019).

#### Questionnaires

The questionnaires, QCAE (Reniers et al., 2011) and MDBF (Steyer et al., 1994) were assessed at the beginning of the experiment to evaluated individual abilities to empathize with others and to assess the mood state. The Affect Grid questionnaire evaluated whether emotion inductions were subjectively perceived as a change in emotion.

##### *QCAE*

The Questionnaire of Cognitive and Affective Empathy (QCAE) (Reniers et al., 2011) measures a person's ability to emphasize with others. It assesses cognitive and affective empathy and consists of five principal factors (*cognitive empathy*: perspective-taking and online simulation, *affective empathy*: emotion contagion, proximate responsivity, and peripheral responsivity) and 31 items. The five factors of the QCAE achieved an internal consistency of .65 to .85 (Cronbach's α) (Reniers et al., 2011).

##### *MDBF*

The multidimensional mood questionnaire (Mehrdimensionaler Befindlichkeitsfragebogen - MDBF) (Steyer et al., 1994) consists of three scales with four items each, as described in experiment one (see MDBF, p. 67).

## Analysis

Likewise, to experiment one, data were pre-processed and analyzed statistically. In case of a violation of the assumption of sphericity, the calculations of the Greenhouse-Geisser correction were used. Any alpha error accumulations were corrected according to Bonferroni ($p = \frac{\alpha}{n}$).

### Force Plate

Raw data were controlled for artifacts manually, the first three and the last three seconds of every condition or baseline were deleted. A low-pass filter (Butterworth 2$^{nd}$ order) was applied offline, using Vicon Nexus 2.7.1 (Vicon Motion Systems Ltd UK).

The root mean square (RMS) and the mean power frequency (MPF) of the x-axis over a period of sixty seconds were calculated in MATLAB. Because the avatar was swaying laterally, only swaying parameters on the x-axis were investigated. To statistically analyze the influence of the swaying avatar on the body sway, an ANOVA with repeated measurements was performed, putting *social/non-social control condition* (avatar and column) and *moving/baseline phase* (2*2) as within subject, and *gender* as between-subject. As *baseline phase*, the mean of the pre- and post-baseline was calculated of each condition (avatar and column), respectively. Additionally, a t-test was performed comparing the *baseline phases* of each condition to the corresponding *moving phases* (avatar and column), respectively.

The alpha error accumulation was corrected according to Bonferroni and the adjusted alpha levels were set to $p$ = .0125, ($p = \frac{\alpha}{n}$).

### Questionnaire

According to the corresponding manuals, the questionnaires were evaluated and subsequently analyzed statistically.

*QCAE*

The ability to empathize with others was measured by the QCAE: Questionnaire of Cognitive and Affective Empathy (Reniers et al., 2011). For further calculations, its five main factors (*cognitive empathy*: perspective-taking and online simulation, *affective empathy*: emotion contagion, proximate responsivity, and peripheral responsivity) are summed to the scales of *cognitive empathy* (CE) and the sum of *affective empathy* (AE). A t-test was conducted to investigate gender differences in the ability to empathize with others, for each scale (CE and AE) respectively. To investigate whether women and men experienced their ability to emphasize with others differently, an ANOVA with repeated measurements was used to investigate gender differences in the ability to empathize with others (*scale* as within subject and *gender* as between subject factor).

*MDBF*

For the MDBF questionnaire, the sum of each scale (good-bad mood, vigilant-fatigue, rest-restlessness) is used for further calculations. To investigate gender differences of the participants' mood state prior to the experiment, an ANOVA with repeated measurements was conducted with *scale* (the three scales of the questionnaire) as within subject, and *gender* as between subject factor.

*Correlations*

To investigate whether the ability to empathize with others, or the current mood state had an influence on the degree of synchronization, the scores of both questionnaires were correlated with the swaying parameters using the Pearson's correlation. The alpha error accumulation for both questionnaires were corrected according to Bonferroni, and the *p*-value was set to $p = .025$ ($p = \frac{\alpha}{n}$) to reach significance.

## Results

The results show an effect of the swaying figure on the participants' body sway. Additionally, gender effects were found for the body sway data and QCAE questionnaire.

### Force plate

An ANOVA with repeated measurements (2*2) revealed a significant interaction between the *social/non-social control condition* (avatar and column) and the *moving/baseline phase*: $F(1.000,41.000) = 4.865$, $p = .033$, $\eta^2 = .106$. An additionally conducted t-test of the root mean square between the *moving phases* (avatar and column) and the mean of their *baseline phases* revealed a significantly greater swaying amplitude while participants were exposed to the moving avatar, compared to being exposed to a non-moving avatar: $t(42) = 2.925$, $p = .006$. Participants showed a greater body sway movement while being exposed to the moving avatar ($M = 2.24$, $SD = 3.33$)

compared to the non-moving avatar (*M* = 2.17, *SD* = 3.29). No such difference was found while being exposed to the moving column (*M* = 2.17, *SD* = 3.26) compared to the non-moving column (*M* = 2.16, *SD* = 3.35) ($p > .0125$) (see Figure 11).

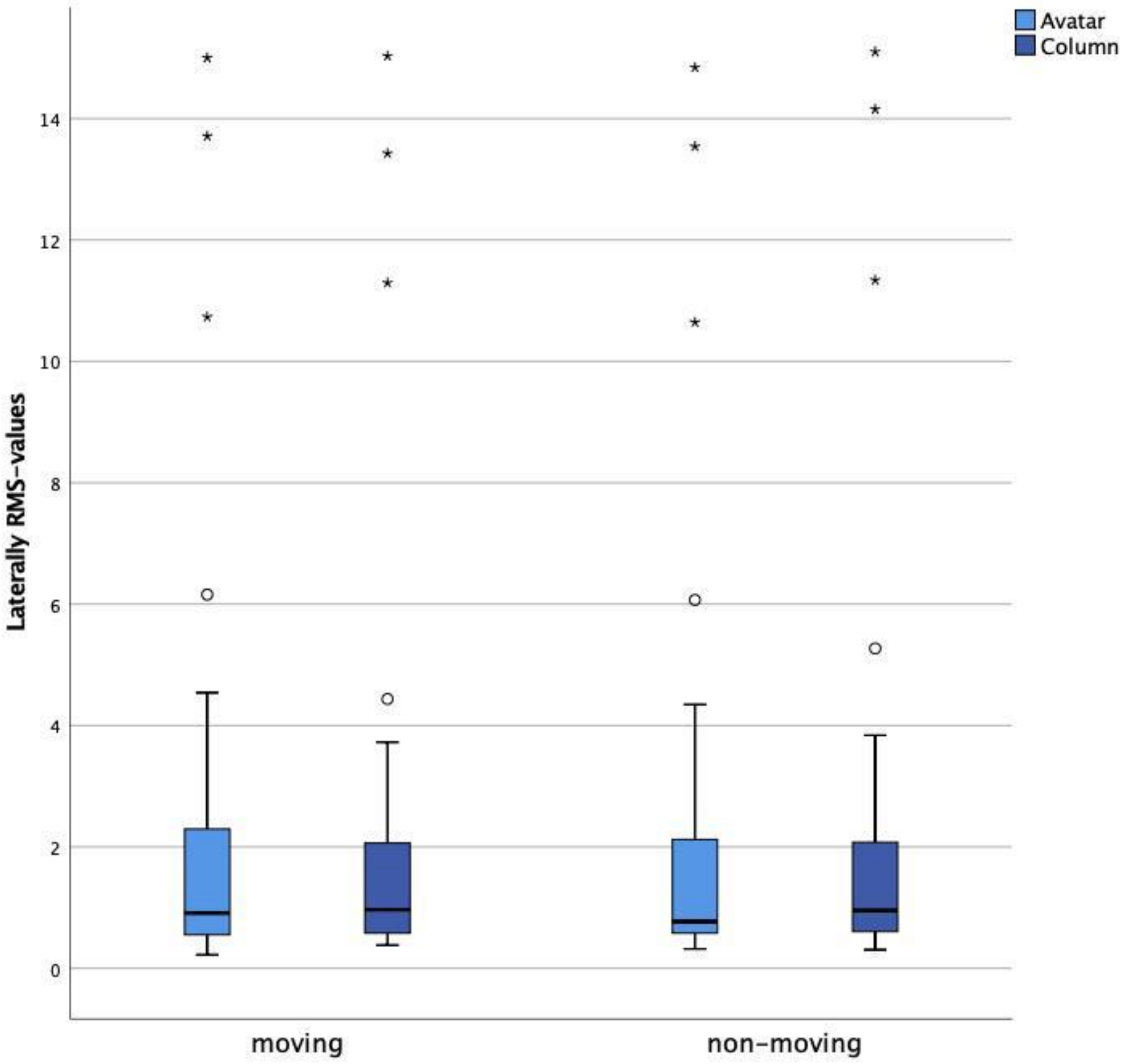


*Figure 11: Swaying amplitude (RMS) during presentation of a moving and non-moving avatar and column.*

Another significant interaction was found between the *social/non-social control condition* (avatar and column), *moving/baseline phase* and *gender*: $F(1.000, 41.000) = 4.235$, $p = .046$, $\eta^2 = .094$. Mean values indicated a greater difference between the moving and non-moving avatar and the moving and non-moving column for the male participants (see Table 8).

*Table 8: Mean (SD) and 95% Confidence Interval of the moving and non-moving column and avatar for women and men respectively*

| Gender | Social Condition | Phase | *M (SD)* | *95% CI* | |
|---|---|---|---|---|---|
| | | | | *Lower bound* | *Upper bound* |
| men | column | moving | 1.77 (1.35) | -.23 | 3.78 |
| | column | non-moving | 1.90 (1.53) | -.17 | 3.96 |
| | avatar | moving | 2.04 (1.85) | -.01 | 4.09 |
| | avatar | non-moving | 1.93 (1.81) | -.10 | 3.95 |
| women | column | moving | 2.30 (1.71) | 1.72 | 3.48 |
| | column | non-moving | 2.25 (3.80) | 1.04 | 3.46 |
| | avatar | moving | 2.31 (3.73) | 1.11 | 3.51 |
| | avatar | non-moving | 2.25 (3.68) | 1.06 | 3.44 |

Mood ratings (MDBF) prior to the experiment had no influence on the swaying parameters.

## Questionnaire

*QCAE*

A t-test revealed a significant difference between the genders for the scale *affective empathy*: $t(47) = 2.019$, $p = .049$. Women rated higher ($M = 27.63$, $SD = 2.89$) than men ($M = 25.86$, $SD = .65$). Ratings of the scale *cognitive empathy* showed no gender differences (see Table 9).

*Table 9: Differences in affective empathy (AE) ratings between women and men*

| | Women | | Men | | | |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *t*-test | *p* |
| Affective Empathy | 27.63 | 2.89 | 25.86 | .65 | 2.019 | .049 |

*MDBF*

A repeated measurements ANOVA revealed a significant main effect of *scale* $F(1.999,40.000) = 6.591$, $p = .002$, $\eta^2 = .138$. A Bonferroni post hoc signified the scale *good-bad* ($M = 15.81$, $SD = 3.18$) and *vigilant-fatigue* ($M = 12.84$, $SD = 3.68$) to differ significantly from each other ($p < .01$) (see Table 10). There were no significant interactions between the ratings of the MDBF questionnaire and the two genders ($p > .05$).

*Table 10: Means (SD) and Mean Difference (SEM) between the MDBF scales 1) good-bad, 2) vigilant-fatigue, 3) rest-restless.*

*** p < .01*

| MDBF scale | *M* | *SD* | *Mean Difference (SEM)* | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. good-bad | 15.81 | 3.18 | - | | |
| 2. vigilant-fatigue | 12.84 | 3.68 | -2.66 (.75)** | - | |
| 3. rest-restlessness | 14.56 | 4.07 | -1.59 (.73) | 1.07 (.74) | - |

*Correlations*

There were no significant correlations between the ability to empathize with others or the mood state and either of the conditions and phases: moving and non-moving avatar and moving and non-moving column ($p > .05$).

## Discussion

The aim of experiment two is to develop a human-avatar body sway synchronization paradigm as a reliable set-up for well-controlled synchrony studies. Participants were found to coordinate their movements with the medio-lateral swinging avatar, while there was no such effect when presented with a moving neutral object (i.e., a same-sized column). Apart from that, participants did not move beyond their natural body sway when both objects stood still. This allows two presumptions: the participants' swaying amplitude was, firstly, not simply caused by the presentation of a moving object, and secondly, it provides a first indication of a human-avatar body sway synchronization paradigm. These results are in line with findings of a study investigating the participant's body sway in response to point-light displays of a balancing gymnast. Participants responded with an increase of body sway only to the presentation of an upright gymnast. No effect was found when the gymnast was displayed upside down. The authors conclude that perceiving moving point lights is not sufficient to elicit a change of the postural sway; only the lights in the shape of a human figure increased the body sway (Tia et al., 2011).

Another main result of this study was the different synchronization behavior between women and men. Contrary to predicted, men were more likely to coordinate their movements with the swaying avatar than women. This finding corroborates the notion of Cheng et al. (2017), who speculates that men benefit from advanced motor-coordination abilities. According to the authors, men outperform women in a variety of motor performances, starting in early childhood. Moreover, previous research mostly investigated mimicry of emotional stimuli, which may come more easily to women as they are more likely to recognize emotional expressions in the face (Hess & Bourgeois, 2010), and were found to show more brain activity in areas linked to social perception (L. C. Anderson et al., 2013). Yet, the rather virtual-looking avatar of this study might not have elicited the same social response as a real human would have done.

Concerning the participants' swaying frequency, the paradigm revealed no differences between a moving and a non-moving avatar or a moving and a non-moving column. The analysis of the MPF showed no significant changes due to the swaying avatar or column. The absence of this effect could be explained by the fact that the avatar's swaying frequency resembled the natural body sway, which has been proposed to be below one Hz (Funato et al., 2016). For future studies, it would be interesting to test whether different swaying frequencies of the avatar provoke a change in the participant's natural sway.

Another interesting finding, which partly contrasts previous results, is the lack of correlation between positive mood and the degree of coordination. There have been findings in both directions, e.g., mood to correlate positively with interpersonal coordination (Van Baaren et al., 2006), and the absence of a correlation (Miles et al., 2010; Rehberger, 2014); however, the result could also be explained by a methodological implication. Mood assessed by self-reports represents an explicit mood state which may not mentally be connected to the follow-up task (Miles et al., 2010) and therefore would not correlate with a nonconscious process, such as coordinated movements (Chartrand & van Baaren, 2009). Overall, participants rated their mood state to be generally positive but less vigilant at the beginning of the experiment, a result that endorses the findings of the first experiment.

The other missing correlation was found between the ability to empathize with others and the body sway amplitude caused by the swaying avatar. Yet, previous findings are not entirely consistent: while several studies demonstrated emotional empathy to increase mimicry (Dimberg & Thunberg, 2012; Rymarczyk et al., 2016; Sonnby-Borgström, 2002; Sonnby-Borgström et al., 2003), Chartrand and Bargh (1999) found perspective-taking but not emotional empathy to be interrelated with coordinated movements. It is noteworthy to say that most findings are based on studies on mimicry of emotional faces, which overall found both cognitive and emotional empathy to be positively correlated to facial mimicry (Holland et al., 2020). Compared to the one study which evaluated perspective-taking in relation to mimicry of face rubbing and foot shaking, participants in the current experiment filled out the empathy questionnaire prior to the experiment. Thus, the positive findings of Chartrand and Bargh (1999) could be explained by the fact that participants were already socially primed after engaging in mimicking behavior since mimicry is known to foster social behavior and attitudes.

While empathy did not correlate with the body sway's amplitude, women and men scored differently in both empathy categories. Women rated higher in the category affective empathy, which is a well-established fact (e.g., Jolliffe & Farrington, 2006; Reniers et al., 2011). No difference, however, was found between the ratings of women and men in the category cognitive empathy.

Both non-existing correlations could be explained by the rather neutral-looking avatar. Especially empathic abilities, which are enhanced by the feeling of similarity (Valdesolo & DeSteno, 2011), may trigger coordination behavior with an actual person more likely than with a virtual avatar. Besides, previous research has measured empathy right after the coordination task, which might be just the amply studied outcome of mimicry, rather than the participant's general empathic qualities.

Overall, the results showed that an avatar's body sway elicits an increased swaying frequency in the participant, irrespective of any prior mood states or empathy ratings. Moreover, it allowed some exploratory insight into different coordination behavior between women and men. The current study does not yet explain the complex mechanism of human social interaction; however, it serves as a profound experimental paradigm for future synchronization studies to investigate possible causations on interpersonal synchronization.

### Limitations

The main limitation of the human-avatar synchronization paradigm is the uncontrolled swaying parameters of the avatar. To measure an exact synchronization process, the amplitude and frequency of the avatar and the participant need to be coupled. This would allow to precisely distinguish behavior mimicry from interpersonal synchrony and to conclude whether synchrony happened in the in- or out-phase.

Additionally, a larger sample size of women and especially of men would give more insight into gender effects.

Experiment two provides a promising experimental set-up for controlled experimental investigations to study possible promotors on interpersonal coordination. One of which could be the emotional state of the participants which will be investigated in experiment three.

## Experiment Three – the Effect Emotions on Interpersonal Coordination

Based on the findings of experiment two, experiment three investigates the influence of emotions on the ability to coordinate movements with an interacting partner.

### Summary of State of Research - Promoters of Interpersonal Coordination

Being among the most social species (de Gelder & Van den Stock, 2011), emotion recognition through facial or bodily expression is essential for successful interpersonal interactions in humans. Frijda (1953, 2007, 2010) already considered emotions to lead to intentional or unintentional actions which follow "appraisal", and in concordance with an individual's goal, enhances or decreases the probability to interact with its (non-)social environment. It is, thus, tempting to conclude that emotions interfere with an individual's readiness to engage in coordinated movements.

Two concepts have narrowed down this thought: the A*ttention-Focus Theory* (Wood et al., 1990) and the *Affect-as-Information Theory* (Schwarz & Clore, 1996). Based on the assumption that emotions convey information from the environment (Affect-as-Information Theory), Van Baaren et al. (2006) state that positive mood facilitates automatic, unconscious action tendencies, while negative mood fosters more cautious and reasoned behavior. In two experiments, they found evidence for this consideration; in one study, participants' mood was rated prior to the mimicry task. In a follow-up, happy and sad mood states were induced through movie scenes. Both studies confirmed: positive mood leads to more, negative mood to less mimicry.

The other notion suggests that sadness enhances self-focused attention (A*ttention-Focus Theory*), diminishing one's capability to engage in social interactions (e.g., Wood et al., 1990). A study investigating facial mimicry in response to happy, sad, or angry faces found participants in a happy mood (induced through video clips) to mimic both happy and sad faces. In contrast, participants in a sad mood did not mimic at all. Moreover, they rated sad faces as more intense than happy participants. No significant effect is reported for angry faces, suggesting that facial mimicry of angry faces is more context-depending (Likowski et al., 2011). This presumption is in line with the results of a previous study; here, facial mimicry in response to angry, fearful, and neutral faces was investigated. Participants were induced with fear or no specific emotional state through the presentation of video clips. In fact, induced fear led to more fearful facial expressions while watching fearful but also angry faces. The authors argue that emotions foster, at least partly, behavior mimicry since no effect was found for neutral faces (Moody et al., 2007).

One could conclude that both of the above-mentioned theories consider positive emotions to enhance interpersonal coordination behavior, while the opposite occurs for negative emotions. Contrary to these findings, however, participants' mood manipulated by an argument had no impact on mimicry between the interacting partners. The authors argue that measurement techniques might not have been accurate enough (Paxton & Dale, 2013). Another factor for this result could be the fact that mimicry of neutral body postures, compared to emotional faces or bodies, was measured. Since an emotional face or body signals a positive interaction and thus, elicits affiliative behavior, other related body movements might not affect the own emotional state in an equally strong manner. It is, therefore, essential to disentangle findings of facial mimicry from other behaviors.

## Aim of Experiment Three

Pursuing on the results of experiment two, which provide a reliable basis for well-controlled synchrony studies, the study in experiment three investigated whether emotions impact an individual’s readiness to coordinate movements with a neutral avatar. Because a negative emotional situation leads to either a protective (Lelard et al., 2013) or a freezing response (Roelofs et al., 2010), participants in a rather positive emotion were predicted to be more likely to coordinate their body sway with the swaying avatar than participants in negative emotion.

Further, it was expected to find a stronger influence of emotion (positive and negative) in women than in men. Firstly, because women are known to score higher in other social interactions, and secondly, because previous studies found women to respond stronger to the emotions of pleasure and sadness (Deng et al., 2016).

## Methods

The methods of experiment three followed the same procedure as experiment two. Data collection consisted out of questionnaires and the body sway. Physiological data were manually pre-processed, and swaying parameters were calculated using MATLAB. All data were statistically analyzed in IBM SPSS.

### Participants

50 healthy young adults (36 female and 14 male) volunteered in the study (mean ± SD: female age 20.66 ± 2.5; male age 23.2 ± 32.86). Five participants had to be excluded due to performance mistakes[10]. Participants were informed about the following procedure and gave written informed consent to participate. The experimental procedure was approved by the ethical committee of the University of Regensburg (protocol number: 18-1202-101) and conducted according to the ethical guidelines of Helsinki.

### Procedure

At arrival, participants were asked to give written informed consent and to fill out two questionnaires: the Questionnaire of Cognitive and Affective Empathy (QCAE) (Reniers et al., 2011) and a mood state questionnaire (Mehrdimensionaler Befindlichkeits-Fragebogen - MDBF) (Steyer et al., 1994). During the main experimental data acquisition, the same procedure of the set-up established in experiment two was used (see Figure 10). Only, during the present experiment, pictures presented on the TV screen were either a series of selected positive pictures (*positive emotion condition*) or a series of negative pictures (*negative emotion condition*) of the IAPS (International Affective Picture System) (Lang et al., 2008). At the same time, on the large screen, an avatar was presented in a *non-moving phase* (pre-baseline), quietly standing, for thirty seconds, followed by a *moving phase*, swaying back and forth from the left to the right side, for one minute and again followed by a *non-moving phase* (post-baseline) for thirty seconds.

Each participant was exposed to both the *positive* and the *negative emotion condition* in counterbalanced order with one minute break in between. At the beginning of the experiment, and after positive and after negative emotion induction, participants were asked to rate their subjective

[10] One participant had already participated in the previous experiment (experiment two) due to a failure in the registration, the other four participants had to be excluded due to failure in the experimental set-up.

emotional state in an Affect Grid questionnaire (Russell et al., 1989) which was designed to assess the personal affect along the two scales: *positive* to *negative* and *arousal* to *sleepiness* (see Figure 10).

For emotion induction selected positive and negative pictures of the International Affective Picture System (IAPS) were combined with music and presented in a slideshow on the TV screen. Music for the *positive emotion condition*: "summer of 69", Bryan Adams and for *negative emotion condition*: "heal", Tom Odell. The music has been pre-selected and rated to elicit a positive/negative emotional state by students before the beginning of the experiment.

### Measures

Like in experiment two, the effect of positive and negative emotions on the natural body sway was assessed by using a force plate. The individual mood state prior to the experiment and the ability to empathize with others was evaluated by two questionnaires. An additional mood rating questionnaire after each emotion condition controlled for the effect of emotion induction.

#### Force Plate

Medio-lateral movements were recorded at 960 Hz using a force plate (AMTI OR6-7-2000 Series Model Force Platforme, Watertown, MA 02472, USA); no offline filters were applied.

#### Questionnaires

Both questionnaires, the Questionnaire of Cognitive and Affective Empathy (QCAE) (Reniers et al., 2011) and the Mehrdimensionale Befindlichkeits-Fragebogen (MDBF) (Steyer et al., 1994) were answered before the experiment started using an online survey, available at: www.soscisurvey.de (Leiner, 2019).

The affect grid, by Russell et al. (1989), was developed to quickly assess the emotional state along the axis of *pleasure-unpleasure* and *arousal-sleepiness* in a 9x9 grid (see Figure 12). The authors report a reliability of .98 for pleasure and .97 for arousal.

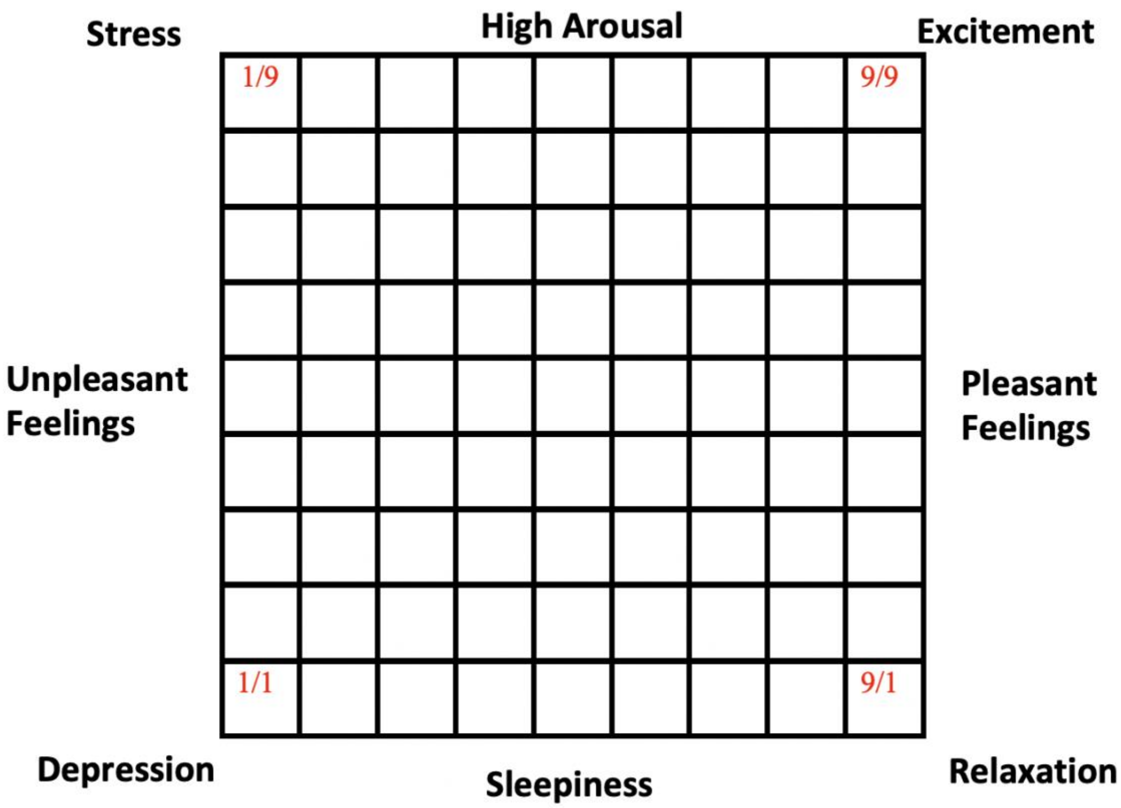


*Figure 12: Affect Grid[11] - emotional state rating along the dimensions valence (unpleasant to pleasant feelings) and arousal (sleepiness to high arousal).*

### Analysis

The analysis of experiment three followed the same procedure as experiment one and two. For all data which violated the assumption of sphericity, the calculations of the Greenhouse-Geisser correction were used. Any alpha error accumulations were corrected according to Bonferroni ($p = \frac{\alpha}{n}$).

### Force Plate

Raw data were controlled for artifacts manually. The first three and the last three seconds of every condition or baseline were removed. A low-pass filter (Butterworth 2nd order) was applied offline using Vicon Nexus 2.7.1 (Vicon Motion Systems Ltd UK). The root mean square (RMS) and the mean power frequency (MPF) over a period of sixty seconds of the x-axis were calculated in MATLAB.

[11] Affect grid by Russell et al. (1989) with minor adaptations.

For further calculations the mean of the pre- and post-baseline (*baseline phase*) for each *emotion* (positive and negative) was calculated respectively. To statistically analyze the influence of both emotion inductions (positive and negative) on the body sway, an ANOVA with repeated measurements was performed setting *emotion* (positive and negative) and *moving/baseline phase* (2*2) as within subject and *gender* as between-subject.

To analyze whether the participant's mood at the beginning of the experiment had an influence on their body sway during emotion induction, an ANOVA with repeated measurements with *emotion* (positive and negative) and *moving/baseline phase* (2*2) as within subject and *scale* (good-bad, vigilant-fatigue and rest-restlessness) as covariate.

### Affect Grid

To control whether emotion induction was subjectively perceived as a change of the personal emotional state, participants were asked to fill out an Affect Grid questionnaire (Russell et al., 1989). It is designed as a 9x9 grid with both categories, *pleasant* to *unpleasant* and *arousal* to *sleepiness* along the axes x and y. The affect grid was evaluated by assigning ascending numbers from 1 to 9 to each box of the grid, starting with 1 in the lower left corner which is equivalent to the most negative and sleepy emotional state (see Figure 12).

An ANOVA with repeated measurements with *category* (pleasure and arousal) were set as within subject factor and *order of condition* (ratings after emotion induction: baseline, positive, negative) and *gender* as between subject factors.

### Questionnaire

According to corresponding manuals questionnaires were evaluated and analyzed statistically.

*QCAE*

Of the QCAE, the five main factors (*cognitive empathy*: perspective-taking and online simulation, *affective empathy*: emotion contagion, proximate responsivity, and peripheral responsivity) are combined to the sum of *cognitive empathy* (CE) and the sum of *affective empathy* (AE) and used for statistical analysis. A t-test was conducted to investigate gender differences in the ability to empathize with others, for each category (CE and AE), respectively. An ANOVA with repeated measurements was used to investigate gender differences in the ability to empathize with others (withing subject: *scale*, between subject: *gender*).

*MDBF*

For the MDBF questionnaire, the sum of each scale (good and bad mood, vigilant and fatigue, rest and restlessness) is used for further calculations.

An ANOVA with repeated measurements was used to investigate gender differences of the mood state prior to the experiment.

*Correlations*

To investigate whether the ability to empathize with others or the current mood state had an influence on the degree of synchronization, the scores of both questionnaires were correlated with the swaying parameters using the Pearson's correlation. The alpha error accumulation for both questionnaires were corrected according to Bonferroni, and the *p*-value was set to $p$ = .025 ($p = \frac{\alpha}{n}$) to reach significance.

## Results

The results show again an effect of the swaying figure on the participants' body sway, independent of the induced emotion. A gender effect was found for the Affect Grid questionnaire. Additionally, a correlation between the ability to empathize with others and the swaying behavior during the negative emotion induction was found.

### Force Plate

An ANOVA with repeated measurements revealed a significant main effect for the *moving/ baseline phase*: $F(1.000,43.000) = 4.301$, $p = .044$, $\eta^2 = .091$. Participants showed a greater body swaying amplitude when being exposed to the moving avatar ($M = 1.40$, $SD = .99$) than being exposed to the non-moving avatar ($M = 1.32$, $SD = .86$). This effect was independent of emotion or gender (see Figure 13).

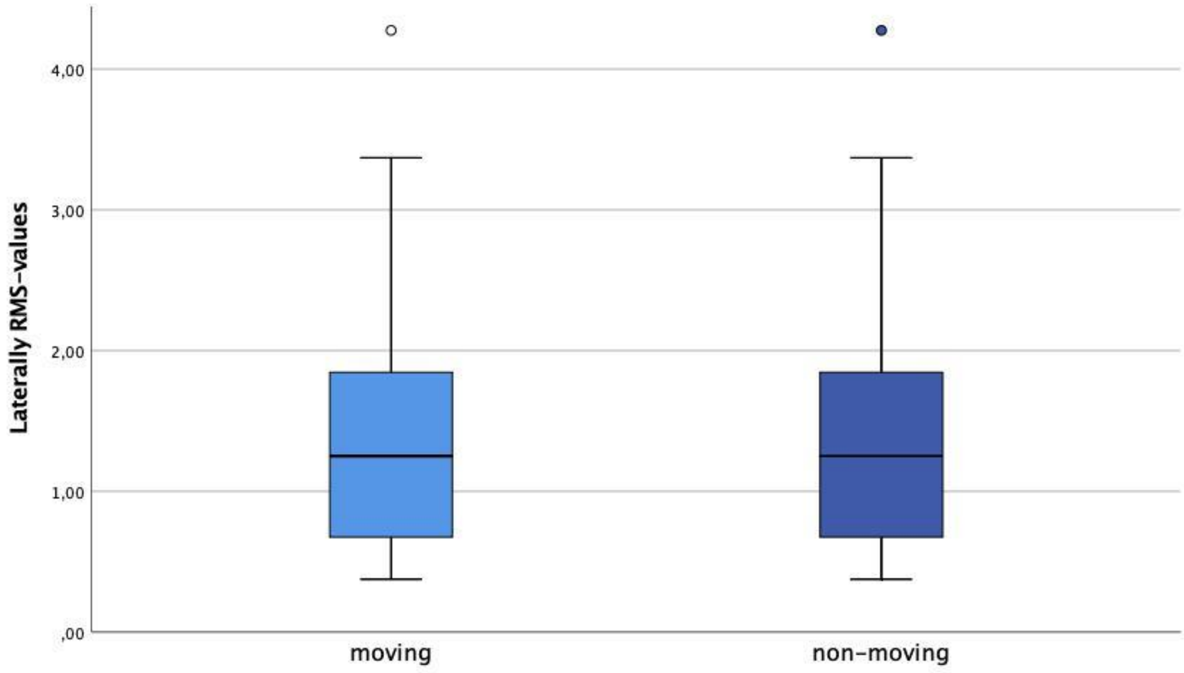


*Figure 13: Swaying amplitude (RMS) during presentation of a moving and non-moving avatar.*

No differences were found for the MPF. Mood ratings (MDBF) assessed at the beginning of the experiment had no influence on the swaying parameters.

### Affect Grid

An ANOVA with repeated measurements showed that emotion induction actually changed the subjective emotional state. A significant interaction between *category* (valence, arousal) and *order of condition* (ratings after emotion induction: baseline, positive, negative) was found: $F(2.000,138.000) = 6.825$, $p = .001$, $\eta^2 = .090$ (see Table 11).

*Table 11: Affect grid ratings, means and SD*

| Category | Condition | *M (SD)* | *95% CI* | |
|---|---|---|---|---|
| | | | *Lower bound* | *Upper bound* |
| valence | baseline | 5.75 (1.54) | 5.26 | 6.30 |
| | positive | 6.62 (1.53) | 6.06 | 7.03 |
| | negative | 3.83 (1.76) | 3.54 | 4.57 |
| arousal | baseline | 5.73 (1.33) | 5.17 | 6.17 |
| | positive | 6.31 (1.53) | 5.71 | 6.72 |
| | negative | 5.17 (1.75) | 4.64 | 5.64 |

Another significant interaction was found between *category* (valence, arousal) and *gender*: $F(1.000,138.000) = 4.403$, $p = .038$, $\eta^2 = .031$. Mean values indicated higher ratings for men in the category *valence* ($M = 5.69$, $SD = 1.70$) than for women ($M = 5.25$, $SD = 2.05$), while women rated higher in the category *arousal* ($M = 5.81$, $SD = 1.62$) than men did ($M = 5.54$, $SD = 1.57$). A conducted t-test revealed a significant difference the scale *valence* and *arousal* in women:

$t(104) = -2.936$, $p = .004$ (see Figure 14):

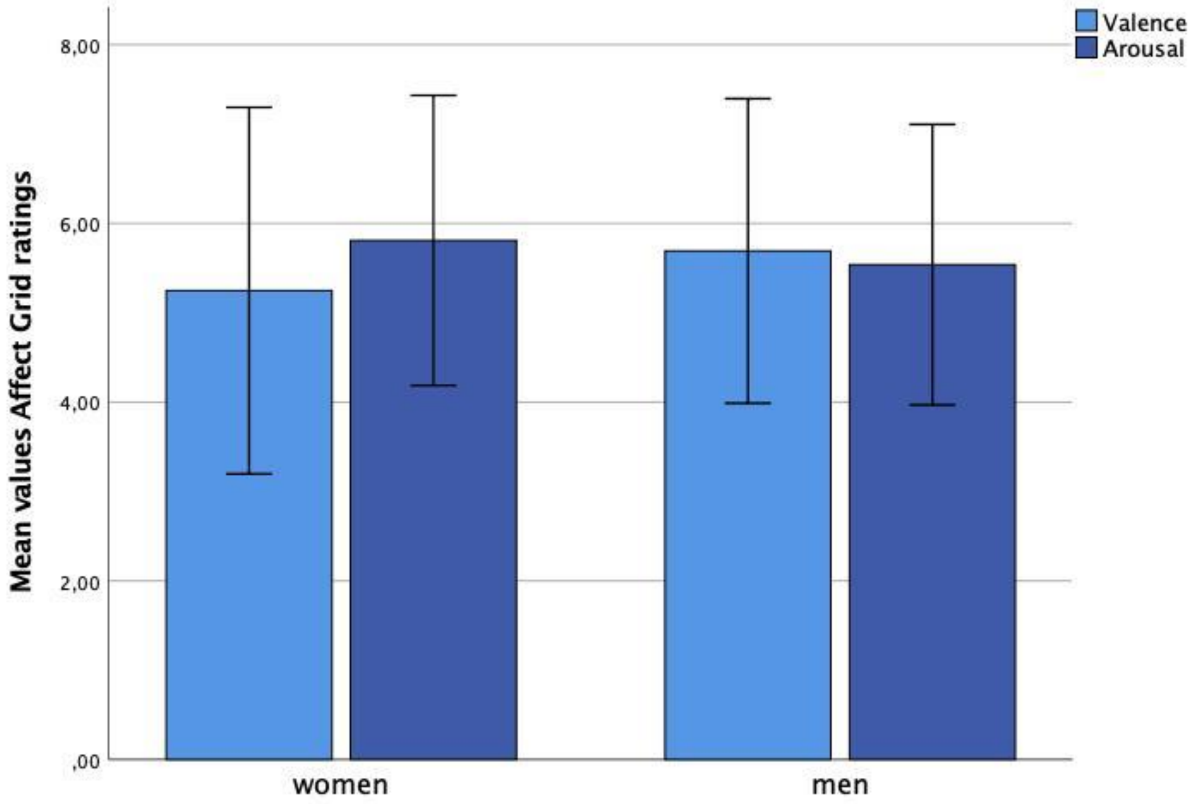


*Figure 14: Means (SD) of emotional states ratings (Affect Grid) for men and women respectively.*

## Questionnaire

### *QCAE*

A t-test showed that women scored higher than men in both categories. CE: $t(45) = 2.167$, $p = .036$; women ($M = 52.22$, $SD = 5.64$), men ($M = 48.60$, $SD = 4.59$) and AE: $t(45) = 2.644$, $p = .011$; women ($M = 28.47$, $SD = 2.83$), men ($M = 26.27$, $SD = 2.25$) (see Table 12).

*Table 12: Differences in affective (AE) and cognitive empathy (CE) ratings between women and men*

| | Women | | Men | | | |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *t*-test | *p* |
| affective empathy | 28.47 | 2.83 | 26.27 | 2.25 | 2.644 | .011 |
| cognitive empathy | 52.22 | 5.64 | 48.60 | 4.59 | 2.167 | .036 |

*MDBF*

Again, the three scales of the MDBF differed significantly from each other, $F(1.845,40.000) = 14.408$, $p < .001$, $\eta^2 = .260$; the highest ratings were found for the scale *good-bad* ($M = 15.47$, $SD = 3.38$), followed by *rest-restlessness* ($M = 13.70$, $SD = 4.85$), and *vigilant-fatigue* ($M = 12.01$, $SD = 4.36$) (see Table 13).

*Table 13: Means (SD) and Mean Difference (SEM) between the MDBF scales 1) good-bad, 2) vigilant-fatigue, 3) rest-restless.*

** p < .05, ** p < .001*

| MDBF scale | *M* | *SD* | *Mean Difference* | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. good-bad | 15.47 | 3.38 | - | | |
| 2. vigilant-fatigue | 12.01 | 4.36 | -3.74 (.77)** | - | |
| 3. rest-restlessness | 13.70 | 4.85 | -1.79 (.59)* | 1.95 (.72)* | - |

Gender had no influence on the ratings of the MDBF questionnaire, no main effect or interaction was found.

*Correlations*

There were two trends towards significance; namely a negative correlation between the scale *CE* (cognitive empathy) and *baseline phase* (non-moving) during negative emotion induction: $r = -.33$, $p = .029$, $n = 43$, and another between *CE* and *moving phase* during negative emotion induction, that almost reached significance level: $r = -.33$, $p = .029$, $n = 43$ (see Figure 15).

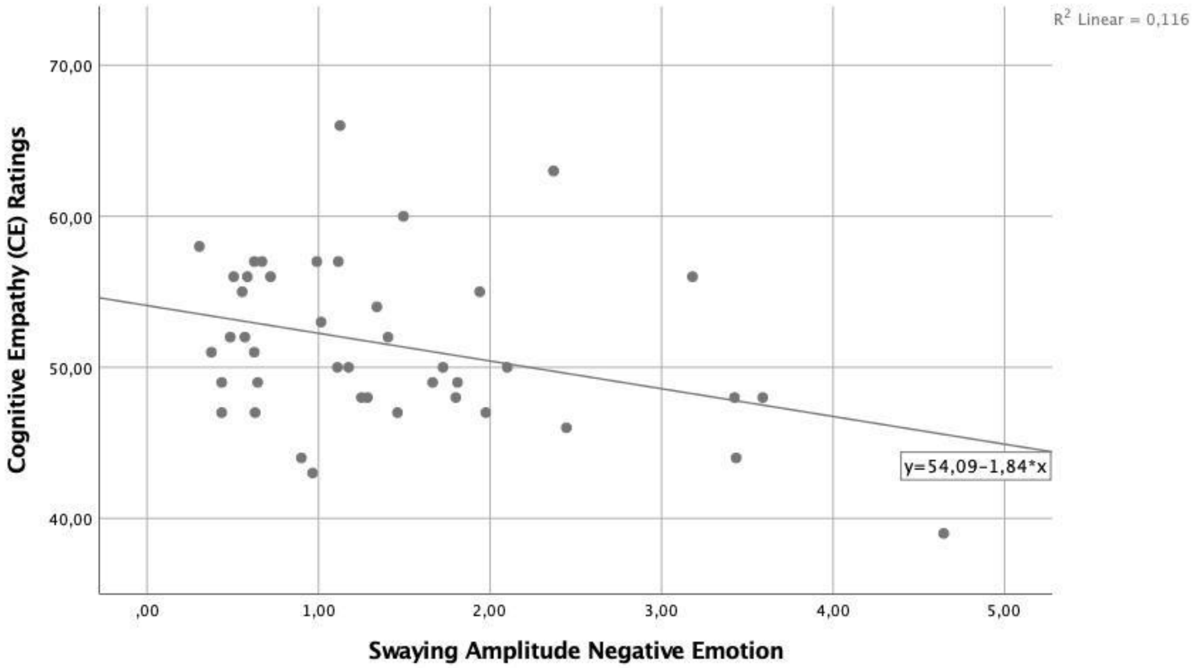


*Figure 15: Correlation between cognitive empathy (CE) ratings and swaying amplitude (RMS) during negative emotion induction*

## Discussion

The aim of the current study is to test the influence of the emotional state on the ability to coordinate movements. By using a standardized experimental set-up, a human-avatar body sway synchronization paradigm, positive and negative emotions were investigated. The results revealed no significant impact of the emotional state on the swaying amplitude or frequency. However, the results of the second experiment could be replicated: participants coordinated their body sway to a greater extent when presented with a moving compared to a non-moving avatar. The data of the affect ratings showed that emotional states were altered due to the presentation of emotional stimuli. Positive and negative emotions differed significantly from each other and from the baseline assessed prior to the experiment.

A previous study found a similar result on the effect of negative emotions: participants, after being induced with happy and sad mood, were exposed to different emotional faces. While sad participants rated the sad faces as more intense than happy participants, they did not mimic any faces. Contrary to the current study, however, happy participants mimicked all emotional faces to a larger extent (Likowski et al., 2011). In sum, previous research on the impact of emotions on interpersonal coordination is not entirely consistent. For example, while mimicry has been found to be enhanced through a positive mood (Likowski et al., 2011; Van Baaren et al., 2006), synchrony has not been affected (Fujiwara & Daibo, 2018). Therefore, the affective state of a person seems to not ultimately affect coordination behavior but rather depends on the context. I.e., one major difference in the experimental set-up of those studies is the participant's attention during the coordination task. In the mimicry study by Likowski and colleagues (2011), the participant's only task was to watch the, thereafter, unconsciously mimicked interacting partner, while in the synchrony study, the participant's focus was directed towards a conversation. Also, in the current experiment, the main attention was on the emotional stimuli. Although participants still coordinated their movements with the swaying avatar, their emotional reaction and possibly mimicry might have been directed towards the emotional pictures. Yet, no facial expression, elicited by the emotional stimuli, were measured, which could give more insight into this question.

Which leads me to my next point: it is important to distinguish between mimicry of emotional faces and body postures which allow to interpret the emotional state of the interacting partner and mimicry of other related movements. A fearful state might provoke mimicry of another fearful or angry person since it gives a valuable perspective of the situation, while a neutral face does not do so. In fact, induced fear led to a more fearful facial expression while watching fearful and angry faces, while neutral faces showed no effect (Moody et al., 2007).

In contrast to the first experiment, women and men did not differ in both the swaying behavior and the mood ratings. The fact that the gender effect of the second study could not be replicated reflects the inconsistencies shown by previous research. Moreover, it highlights the urgency to conduct additional research with a significant sample size in both groups.

Maybe the most exciting finding of this study is the correlations between the participants' ability to cognitively emphasize with others (perspective-taking) and the conditions during the negative emotion induction, namely a negative correlation between cognitive empathy scores and both the moving avatar and the non-moving avatar. This result is in line with the presumption that the environment serves as information; thus, negative emotions lead to rather cautious and reasoned behavior (Schwarz & Clore, 1996). Especially the negative emotion sadness increases the self-focused attention since it does not enhance further actions related to the environment and thereby decreases the natural swaying amplitude (Likowski et al., 2011). This effect is well-known as freezing behavior (Roelofs et al., 2010) and corroborates previous findings on the postural reactivity in response to unpleasant pictures (Azevedo et al., 2005; Facchinetti et al., 2006).

Furthermore, it has been suggested that the degree of mimicry is influenced by the ability to engage visually and attentively (Achaibou et al., 2008) and that the postural control is not only influenced by emotional but also by attentional processes (Perakakis et al., 2012). Thus, negative emotional stimuli might have redirected the participants' focus away from the moving avatar, which led to an "uncoupling" of the coordinated movements.

As found in the second experiment, the participants' general mood state at the beginning of the experiment did not correlate with their coordination behavior and, more importantly, not with the participants' mood ratings after emotion induction. This finding fosters the assumption of Miles et al. (2010), who consider self-assessed mood to represent a rather explicit mood state which may not mentally be connected to the follow-up task. Overall, similar to experiment one and two, participants rated their mood more positive than rested or vigilant. Also, in line with experiment two are the findings that the ability to empathize with others was not correlated with either the swaying amplitude or the frequency; women and men, however, scored differently. According to previous research, women rated higher than men in both empathy categories (e.g., Jolliffe & Farrington, 2006; Reniers et al., 2011).

Likewise, no effect was found on the participants' swaying frequency (MPF). This fact might be due to the same reason mentioned in study two: the avatars swaying frequency resembled the natural body sway, which has been proposed to be below one Hz (Funato et al., 2016).

While the current study did not find further evidence for the influence of emotions on the ability to coordinate behavior, it could, however, shed some light on the relation between emotions and the ability to take someone's perspective. It showed that individuals in a negative emotional state inhibited their natural tendency to engage in interpersonal coordination movements, whereas no such effect was found by the positive emotion. According to the *Sensorimotor Simulation Theory*, by simulating a perceived emotionally negative situation, a somatic response mechanism activates either a protective behavioral response (Lelard et al., 2013) or a freezing behavior (Roelofs et al., 2010). This study provides further evidence for the considered close relation between perceiving the observed emotional state and empathic skills.

### Limitations

To better understand the influence of the own emotional state, independently of the emotional state of the interaction partner, on the likability to engage in interpersonal coordination behavior, future studies could present the emotional stimuli and the coordinated movement task in consecutive order. By doing so, participants would not be presented with two attention-demanding tasks at the same time.

Moreover, while measuring the participants' body sway gives insight into coordination movements in response to the swaying avatar, an additional quantification of the facial expressions due to the observation of emotional stimuli would allow a more specific interpretation.

Finally, to make a clearer statement about a differentiated gender effect, larger sample sizes of both genders are crucial.

# General Discussion

Emotions allow an individual to perceive and express an inner physiological state to oneself (Frijda, 2010) and to others (Ax, 1953). It serves as an informant from the environment (Schwarz & Clore, 1996) and is a crucial tool for social communication (Levenson, 2003) because an emotion, even if expressed in the most subtle form, can be recognizable to others (Kret, 2015).

## Summary

This thesis attempted to unpuzzle the embodiment theories, not only the influence of emotions on the own bodily expression, but also the implications on interpersonal behavior. The investigation of bodily expressions by measuring the swaying behavior was chosen for two reasons: a) as a subtle bodily expression, the natural body sway reacts upon non-conscious emotional and motivational tendencies, and b) it can be reliably assessed by using the technology of motion capture (Chang et al. 2019, 2020) or of a force plate (Reynolds & Osler, 2014).

The first experiment focused on the effect of emotions on the natural body sway. By doing so, it investigated whether simulating an observed emotion alters the behavioral response in other than the observed body parts, which would corroborate the *Sensorimotor Simulation Theory*. While the results revealed no direct effect, women and men were found to respond quite strongly in the opposite direction. Men increased their natural body swaying amplitude in response to both emotions, women decreased their swaying in accordance with negative emotions.

The second experiment was used to design a human-avatar body sway synchronization paradigm as a reliable set-up for well-controlled synchrony studies, such as the third study. In fact, participants were found to move beyond their natural body sway when being presented with the medio-lateral swinging avatar. At the same time, there was no such effect when presented with a moving neutral object (a same-sized column). Apart from that, participants did not increase their swaying amplitude when both objects stood still.

Built on the second experiment, the third experiment investigated whether the own emotional state affects the likability to engage in interpersonal coordination. While no such effect could be shown, the results of the second study could be replicated. Moreover, it revealed a negative correlation between the participants' ability to take someone's perspective and their swaying behavior during the negative emotion induction. This effect is well-known as freezing behavior.

## Embodiment & Sensorimotor Simulation Theory

The term embodiment is generally used for cognitive and affective information processes that interrelate with the body's sensory and motor experiences of the body. Simply by imagining motor movements, emotional situations, or by directing attention to body parts, a similar physiological state is activated. As such, it has the possibility to extend from perceiving the own emotional state to perceiving the emotional state of another individual (Lelard et al., 2019). This has been considered to activate sensorimotor simulation and to be closely related to empathic skills. The process can involve interpersonal coordination but does not have to (Ross & Atkinson, 2020). While the causal relationship between coordination behavior and sensorimotor simulation is still not completely clear, it is likely that both the simulation process and mimicry of the emotional expression are involved in understanding an observed emotional expression (Ross & Atkinson, 2020).

Evidence for simulating the own or someone else's emotional state comes from studies investigating the model of empathy for pain. The authors suggest that pain elicits clear affective- (imagination of an own painful experience) and motor- (avoidance behavior) components (Price, 2000). Hence, simulating a painful situation that elicits differential motor responses (Lelard et al., 2013), has been proposed to explain one factor of embodiment (Lelard et al., 2019). Additionally, the embodiment is seen to play a crucial role in interpersonal communication. Because it activates imagined or overserved motor responses, especially in a social context, it allows understanding a person's intentions. In sum, merely perceiving emotional stimuli induces a consistent automatic response. To effectively test the *Sensorimotor Simulation Theory*, however, studies need to take into account other body parts than the observed ones. Because emotions impact not only parts but rather the whole body, perceiving an observed emotion should be retrieved from any other body part. To the best of my knowledge, only one study was looking into this. Moody et al. (2018) presented angry and fearful faces while the muscular activity of the participants' faces and particular of the participants' forearm was investigated. They found muscle patterns were activated in the face, more importantly, however, also in the forearm, respectively to the observed emotion. Building on those findings, the experimental design of the first study aimed to extend the knowledge of "unrelated" muscle activity to a behavioral response, i.e., postural activity. Although no "straight-forward" evidence could be detected, women and men reacted differently.

### Bodily Expressions of Emotions

The fact that women and men responded differently to positive, mainly, however, to negative emotions, has already been suggested by one previous study. Hillman and colleagues (2004) found postural reactivity in response to negative pictures. Images of attack and mutilation provoked an anterior movement in men, proposedly an approach tendency, while women were found to express a posterior movement that equals a defense mechanism. The decrease of the swaying amplitude of women in the first study can be interpreted as freezing behavior in response to exposure to negative stimuli, which is also known to be part of the defense mechanism (Roelofs et al., 2010). Apart from the study mentioned above, most research on postural control did not take gender differences into account, despite many indices for possible opposed behavioral reactions on emotional stimuli and on motor abilities. For instance, women are known to express emotions in the face (Kring & Gordon, 1998; LaFrance et al., 2003; Sonnby-Borgström et al., 2008) more profoundly.

On the other hand, despite any emotional alterations, men seem to generally show greater adjustments to keep their postural control (Ekdahl, 1992). One significant difference might be the fact that women and men react differently to various emotions. For instance, men are known to respond to anger (A. H. Fischer et al., 2004; Grossman & Wood, 1993; Kring & Gordon, 1998) and erotic (Karama et al., 2002) more strongly, while women’s skin conductance and heart rate reacted more sensitively to sadness (induced through movies) than physiological parameters of men (Fernández et al., 2012). Moreover, men react to emotions like pleasure and amusement more physiologically, while women rather rate several emotions (e.g., sadness) as more intense (Deng et al., 2016). This is in line with the results of the first experiment: men showed an increased swaying amplitude during both emotion inductions, specifically, however, in response to the positive emotion, whereas women rated the negative emotion as more intense. This, in combination with the decrease in swaying amplitude of women, corroborates the interpretation of freezing behavior. Besides that, it is in line with a statement of Kret and De Gelder (2012), who suggest a major difference between men and women is their willingness to report about their emotional state, such that women rather express their emotions through facial expressions and communication, while men express emotions in action-related behavior. In fact, women have been found to rate unpleasant pictures (e.g., M. M. Bradley et al., 2001) or affective scenarios as more intense (Tobin et al., 2000). Throughout experiments one and two of the current thesis, men rated higher in positive questionnaire categories, whereas women scored higher in the rating arousal and negative valence. Taken together, there are major indications that women and men differ in their behavioral reactions in response to emotional stimuli. This matter is corroborated by studies on affective neuroscience, which found women and men to differ significantly in the recruitment of neuronal networks (Kret & De Gelder, 2012).

Yet, it is noteworthy that studies exist which found women and men to experience emotions in a physiologically equal manner. For instance, heart rate, skin conductance, respiratory rate, and muscle activity of the corrugator during the presentation of affective film clips were not affected differently between women and men. Women, however, rated unpleasant movies as less pleasant and more arousing than men (Codispoti et al., 2008). On the other hand, Feldman Barrett et al. (1998), who report gender differences of the global ratings of emotional disposition, did not find any rating differences of instantaneous emotional experiences during social interactions. Similarly, no gender effects were found in a study investigating freezing behavior in response to acoustic startle probes and emotional pictures (Dichter et al., 2002).

Gender-independent studies revealed that threat, mostly induced by putting participants on an elevated platform, is one cause for a freezing response. Another line of research studied the freezing response caused by emotionally unpleasant stimuli. However, while many authors report a reduction of swaying amplitude and an increase of swaying frequency (associated with freezing behavior), overall, the results are still quite inconsistent. For instance, the opposite finding of the above mentioned, an increased amplitude of the body sway in the anterior-posterior axis towards painful stimuli, has been interpreted as approach and cooperative behavior (Gea et al., 2014). And a freezing-like reaction in response to positive, affiliative pictures has been associated with an immobility in context with attachment as a predisposition of social bonding, which is generally known for mammals (Facchinetti et al., 2006).

The contradicting findings over a large number of studies led authors to conclude that postural responses of emotional visual stimuli depend on two major factors: on the emotional state of the participants prior to the experiment and on the stimulus itself (Lelard et al., 2019). Furthermore, methodological inconsistencies between the experimental set-ups have been criticized, i.e., a too-short sampling duration (Horslen & Carpenter, 2011).

Putting inconsistencies temporarily aside, the above-mentioned findings allow us to conclude that emotional states of others can be recognized through a simulation process which, in turn, leads to an equivalent behavioral response in combination with a shift of the own inner emotional state. This ability not only facilitates an accurate reaction, suitable for the specific situation but also helps to understand a person's intentions. Hence, it is not surprising that the concept of sensorimotor simulation has been associated with interpersonal interactions, specifically coordinated movements.

### Interpersonal Coordination & Emotions

A vast amount of research studied the phenome of interpersonal coordination, which can be distinguished between interpersonal synchrony (i.e., individuals move in a more or less exact timing) and behavior mimicry (i.e., one individual copies movements of an interacting partner). It has been stated that by mimicking an emotional face, the same emotion can be elicited in the mimicker. This effect, well-known as emotion contagion, is another part of the *Sensorimotor Simulation Theory* (Ross & Atkinson, 2020). One line of research on emotion contagion prevents participants from responding to mimicry behaviorally. For instance, Strack and colleagues (1988), who forced or prevented a smile by letting participants hold a pen in their mouth, found them to judge cartoons as more or less humorous. Additionally, blocking mimicry in the observer was found to lead to a less accurate recognition of happiness; however, no impairment was found for any other emotion (Oberman et al., 2007). Another line conducts research involving autistic individuals. Emotions have been found to be recognized accurately despite the absence of spontaneous mimicry (for a review see: Hess & Fischer, 2013). The authors conclude that mimicry facilitates emotion recognition of subtle and less intense emotional expressions. Moreover, by eliciting a corresponding emotional state, emotion recognition seems to be closely linked to the ability of perspective-taking. However, not only the emotion of the interacting partner changes someone's likeliness to engage in coordinated movements or facial mimicry. There are indices that own emotions or mood states affect the way someone behaves. Based on the idea that emotions convey information from the environment (Schwarz & Clore, 1996), a person in a positive emotional state is expected to engage in automatic, unconscious action tendencies, while a person in a negative mood would rather act more cautiously and reasoned (Van Baaren et al., 2006). This concept holds for some mimicry studies; e.g., Van Baaren et al. (2006) found participants in a positive mood (either self-assessed or experimentally induced) to mimic a confederate more intensely than participants in a negative mood. This effect could not yet, be verified in synchrony studies: neither positive nor negative mood correlated with the degree of synchronization (Miles et al., 2010). A study that specifically tested for a possible influence of the emotional state found that synchrony was not facilitated or diminished by a prior induced emotion (Fujiwara & Daibo, 2018). With these two concepts in mind, emotion contagion through simulation and affect as information, the insignificant results of the third experiment could be explained by the following reasons:

a) Participants' emotional responses could have been directed towards the emotional stimuli. Since both tasks were presented simultaneously, they might have shown other non-measured behavioral responses. For example, a more anterior body posture during the positive emotion induction and a more posterior posture during the negative emotion induction would not have altered their general RMS amplitude. Participants could also have expressed their emotional state in their faces which was not recorded during the experiment. Therefore, simulating the observed emotion could have led to other non-measured behavioral responses.

b) Both tasks, emotion induction and the coordinated movement task, could have withdrawn attention from each other. Previous research found that the degree of mimicry is influenced by the ability to engage visually and attentive (Achaibou et al., 2008), and suggested that postural control is not only influenced by emotional but also by attentional processes (Perakakis et al., 2012). These findings are corroborated by the negative correlation between the ability to empathize with others and the swaying amplitude of study three. Therefore, negative emotions led to a freezing behavior, and by withdrawing attention from the avatar, coordinated behavior was "uncoupled".

c) Since the exact coupling structure between the avatar and the participants was not assessed, no clear statement about the form of interpersonal coordination can be made, i.e., interpersonal synchrony or behavior mimicry. The lack of emotional influence on the coordinated movements could be in support of synchronized behavior. There is, however, no distinct evidence.

Yet, one enlightening correlation has been found, which serves as a final explanation; d): the participants' ability to take someone's perspective (cognitive empathy) was negatively correlated with their swaying amplitude during the negative emotion condition. Kret (2015) discusses how empathy facilitates understanding the emotional state of others. For example, highly empathic women responded stronger to a smiling or crying baby with facial mimicry and feel the observed emotion more strongly than low empathic women (Wiesenfeld et al., 1984). The same holds for the current results: participants who scored higher in the empathy questionnaire perceived the negative stimuli as more intense. The fact that the highly empathic individuals were less likely to move beyond their natural swaying amplitude is well-known as freezing behavior and corroborates previous findings on the postural reactivity in response to unpleasant pictures (Azevedo et al., 2005; Facchinetti et al., 2006). This finding could further be explained by the notion that perceived negative emotions lead to cautious and reasoned behavior because in the environment, might be something wrong (Schwarz & Clore, 1996). However, not all negative emotions can be treated equally. Likowski et al. (2011) criticize that this theory does not specify the negative emotion's quality. According to the authors, only emotions like anger and fear are elicited to allow an individual to act in response to a dangerous environment. Hence, a fearful state has been found to direct an individual's attention away from itself and towards the surrounding (Derryberry & Tucker, 1994). In line with this: a fearful emotional state facilitated mimicry of fearful and angry faces (Moody et al., 2007). Sadness, in contrast, does not enhance further actions since a sad mood state decreases the attention to the environment and increases self-focused attention. The authors' results underline this statement: after watching a sad film clip, participants were less likely to mimic happy, angry, sad, and neutral facial expressions (Likowski et al., 2011). The perception-action model explains that observing an emotion expressed by others spontaneously activates the own conceptual knowledge for this emotion (Preston & De Waal, 2002). According to this, the observed negative stimuli of the third study increased a sad emotional state in the participants, which consequently increased their self-focused attention and, by doing so, led to freezing behavior and to an "uncoupling" between the coordinated movements.

Interpersonal coordination is based on a complex reciprocal mechanism that depends on fine social skills. Thus, it seems likely to expect women and men to perform differently. Study two found an exploratory indication for a gender difference. The results, however, need to be interpreted cautiously due to its limited small sample size; especially men were underrepresented. Besides, it could not be replicated by the third experiment. Based on her review study, Lehane (2015) concludes that gender differences are context-depending. For instance, while men are more likely to mimic an attractive interacting partner, the mimicking behavior of women is more influenced by the partner's social status (Van Straaten et al., 2008). Since interpersonal behavior is thought to be deeply rooted in the evolutionary process, this allows both women and men to benefit from potential reproductive relationships (Lehane, 2015). Apart from that, previous research on gender difference mainly investigated mimicry behavior of emotional faces, which in fact, might be processed differently between the genders. As mentioned above, women and men are triggered by different emotions. In the case of mimicry, women seem to be more likely to mimic joyful, sad, or fearful expressions, while men rather engage in angry mimicry (Soussignan et al., 2013). Overall, the findings of the second study suggest that men, who have been found to be motor experts (M. Cheng et al., 2017), coordinated their movements with an avatar. In contrast, women, who are better at recognizing emotional faces (Hess & Bourgeois, 2010), did not mimic the movements of the neutral-looking avatar.

## Social Communication

Humans are proposed to be one of the most social species, who spend most of their time with other social beings, directly or indirectly (de Gelder & Van den Stock, 2011). During most of those encounters, the conscious or unconscious exchange of emotional information is a crucial element of the interaction (Kret, 2015). Emotions serve as messengers which allow communicating an inner physiological state, first of all, to oneself. The expression of fear elicits a cascade of physiological responses which facilitate a fight-and-flight reaction (Ax, 1953). Whether cognition is involved before, after, or simultaneously to the physiological reaction, the response should be the same, as emotions have earlier been suggested to be action-related (Frijda, 1986, p.71). In the case of an encounter with a bear, this reaction is urgently needed. Secondly, expressing the inner emotional state serves as information for others, who either react simultaneously to the observed threat (Chartrand et al., 2005), for example, the bear, or respond to the observed emotion when directed towards it (Reisenzein & Horstmann, 2018, p. 465). For instance, an angry body posture or face elicits a faster reaction than a neutral stimulus (Valk et al., 2015).

Emotions can be expressed and observed in various forms, ranging from facial, bodily, and vocal expressions to more subtle physiological changes, such as changes of skin color, olfaction, or pupil dilation. Those physiological reactions, in turn, elicit a number of autonomic reactions, such as alteration of skin conductance and temperature or gaze fixation and pupil dilation (Kret, 2015).

Taking the consequences of unsuccessful emotion recognition into account, it is not surprising that humans are experts in reading those messengers. Even the most subtle sign of a shifting emotional state of an interacting partner is behaviorally copied, translated into a similar emotional feeling, and followed by an appropriate response. For instance, pupil dilation has been found to respond to manipulated pupil size of an interacting partner. Pupil-mimicry has been suggested to indicate social interest and liking (Kret, 2015). This ability does not only allow an individual to react to the situation accordingly and foresee the other's intention, but it also gives the possibility to communicate back. A synchronized movement pattern, in turn, signals an agreement with and an affiliation towards the interacting partner, thereby reinforcing social bonds. Turned around, disaffiliation can be expressed through uncoupling of imitated movements or facial expressions.

This complex and sensible system of human social communication is influenced by a variety of individual traits and behaviors. Yet, it takes a successful part in most social interactions and thereby usually stays unrecognized.

## Limitations & Outlook for Future Research

One major limitation of the current thesis is the fact that the observed gender differences can only be interpreted cautiously. Sample sizes were rather small, and especially men were underrepresented, particularly in studies two and three. Moreover, it is crucial for future studies to control emotion-inducing stimuli according to gender differences carefully. Possibly, emotions in women are triggered through joyful or fearful social stimuli, such as positive and negative images of children. In contrast, men might react stronger to threatening cues, especially when they come from other men (Kret & De Gelder, 2012). This also implies the influence of different qualities of negative and positive emotions on both genders. Future studies should investigate several qualities of emotions. For example, we would expect fear to rather trigger women than men, and anger to provoke a stronger behavioral response in men. Besides, to overcome possible implications of presented emotional stimuli, other emotion induction methods could be used. Recalling an emotional event might evoke a similarly strong emotional state in both genders.

The second important limitation accounts only for studies two and three. To distinguish interpersonal synchrony from behavioral mimicry, a more precise measurement technique would have been required. To assess whether the swaying amplitude of the avatar and the participant become mutually synchronous over time, the amplitude and frequency of both needed to be coupled. This process between two moving individuals coordinating either in in- or anti-phase has mathematically been described by the Haken-Kelso-Bunz paradigm (HKB) (Haken, Kelso, & Bunz, 1985) and empirically been investigated (for an overview see: Schmidt & Richardson, 2008). Previous synchrony studies used, for example, video recordings combined with motion analysis software (Fujiwara & Daibo, 2018), magnetic tracking systems (Richardson et al., 2007), or acceleration sensors (M. Cheng et al., 2017).

Furthermore, the results of studies two and three are limited through the experimental set-up. Measuring the participants' body sway gives insight into coordination movements in response to the swaying avatar. However, the presentation of the emotional stimuli could have also caused a change in the postural control. Thus, to disentangle the cause for the behavioral reaction, a presentation of the emotion induction task and interpersonal coordination task in consecutive order would be beneficial. In that way, it could be excluded that one screen withdraws the attention from the other screen. Moreover, additional quantification of other swaying parameters, such as the standard division of displacement as an indication for an approach or avoidance or of the facial expressions due to the observation of emotional stimuli, would allow a more specific interpretation.

Besides the variation of emotional stimuli, future studies should include characteristic populations, such as patients with post-traumatic stress disorder (PTSD) or autistic spectrum disorder (ASD), for further understanding the reciprocal relationship between emotional expressions and emotion recognition.

## Implications and Conclusion

The aim of the present thesis is to unveil how positive and negative emotions affect subtle bodily reactions and to what extent the inner emotional state changes the ability to interact with others. The results showed that women and men respond differently to emotion induction. Men responded more strongly to both emotional states with a greater swaying amplitude; additionally, they were more likely to coordinate their movements with a moving avatar. On the other hand, women were more likely to rate their emotional state as more intense. This major difference conveys with Kret and De Gelder's (2012) suggestion that women rather express emotions through facial expression and interpersonal communication, while men tend to express their emotional state through action. During negative emotion induction, the swaying amplitude decreased, however, only in highly empathic participants. This behavior due to unpleasant stimuli is well-known as a freezing response (Roelofs et al., 2010).

The findings of the present thesis shed some more light on the complex but sensible system of human social communication and its underlying mechanism. Even though one is not always aware of recognizing and interpreting emotional signals, it is still a crucial mechanism for successfully living together. Moreover, it is important knowledge when it comes to challenging or conflicting social situations. And even more when information can get deflected through communication technologies. For instance, a missing eye contact in a video chat or a delayed reaction due to a slow internet connection impairs interpersonal coordination and leads more easily to miscommunication than face-to-face communication. This, in fact, might be more important today than ever before, since modern media are omnipresent and pave the way for new communication possibilities in many working environments and private homes. Therefore, knowing how sensitively humans react to even subtle emotional expressions and how strongly humans are connected through this ancient interpersonal bond could improve social communication and living in various contexts. Although human social communication is often taken for granted, it is a precious value we would not want to forgo.

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**Anlage 4**

EIDESSTATTLICHE VERSICHERUNG

Ich erkläre hiermit an Eides Statt, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Die aus anderen Quellen direkt oder indirekt übernommenen Textpassagen, Daten, Bilder oder Grafiken sind unter Angabe der Quelle gekennzeichnet.

Bei der Auswahl und Auswertung folgenden Materials haben mir die nachstehend aufgeführten Personen in der jeweils beschriebenen Weise entgeltlich / unentgeltlich geholfen; dies ist auch in der Dissertation an den entsprechenden Stellen explizit ausgewiesen:

1. Robert Bauer – Datenauswertung (Exp. 1)
2. Melinda Herfert – Datenerhebung (Exp. 2 u. 3)
3. Anna Wengel – —— // ——
4. Arne Engelhart – —— // ——
5. Lisa Horn – Studiendesign (Exp. 2 u. 3

Weitere Personen waren an der inhaltlich-materiellen Erstellung der vorliegenden Arbeit nicht beteiligt. Insbesondere habe ich hierfür nicht die entgeltliche Hilfe von Vermittlungs- beziehungsweise Beratungsdiensten (Promotionsberater oder anderer Personen) in Anspruch genommen. Niemand hat von mir unmittelbar oder mittelbar geldwerte Leistungen für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen.

Die Arbeit wurde bisher weder im In- noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegt.

[*falls zutreffend*: Im Rahmen der gemeinsamen Betreuung durch eine ausländische Universität wird die Arbeit gleichzeitig an der ...........-Universität/Fakultät vorgelegt.]

Ich versichere an Eides Statt, dass ich nach bestem Wissen die reine Wahrheit gesagt und nichts verschwiegen habe.

Vor Aufnahme der obigen Versicherung an Eides Statt wurde ich über die Bedeutung der eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unrichtigen oder unvollständigen eidesstattlichen Versicherung belehrt.

Wien, 4.5.2021

Ort, Datum, Unterschrift

Clara Scheer

Unterschrift des die Versicherung an Eides Statt aufnehmenden Beamten