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The Impact of Laughing Together on Physiological Synchrony in Children

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Contents

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1. Theoretical background

1.1 Laughter

Imagine a life without laughter – an almost impossible task. Laughter is fundamental human behavior and deeply rooted in human evolution. Studies on the phylogeny of laughter have shown that all primates have a form of laughter expression, suggesting that the basis for laughter stems from common ancestors between humans and non-human primates (Davila – Ross et al., 2009). Additionally, many animal species were shown to exhibit a form of play vocalization that resembles a form of proto-laughter, among them parrots (Schwing et al., 2017), dolphins (Blomqvist et al., 2005) and rats (Panksepp & Burgdorf, 2003). Laughter-like vocalizations were also found as a response to tickling in apes and rats, and many carnivore and ape species display a type of proto-laughter that is characterized by panting or rapid, labored breathing and serves to communicate non-threatening intentions (Panksepp & Burgdorf, 2000; Scott et al., 2022; Winkler & Bryant, 2021). Human laughter has the special characteristic that it is produced by an exclusively egressive (exhaling) airstream, as compared to the laughter vocalizations of other primates which are characterized by egressive-ingressive sounds (Davila-Ross et al., 2009). Another unique feature of human laughter is that it is the only laughter that is contagious purely by itself – human laughter contagion is so strong that laughter can be elicited even by the sound of recorded laughter. Chimpanzees also exhibit laughter contagion, but only during play situations (Scott et al., 2022).

Laughter is a deeply social phenomenon. People are 30 times more likely to laugh if they are together with others compared to if they are alone (Scott et al., 2014). Laughter contagion is learned behavior – both in humans and chimpanzees, infants are more likely to produce spontaneous laughter rather than laughter as a response to others (Scott et al., 2022). In one analysis, laughter was found to make up 10% of vocalizations across a range of different conversations (Laskowski & Burger, 2007). Even in 3 to 4-year-old children, social laughter is already present, and they are 8 times as likely to laugh at a cartoon when they are in company rather than alone, despite not rating the cartoon any funnier (Addyman et al., 2018). Laughter occurs at a rate of approximately five laughs per 10 minutes of conversation (Scott et al., 2014). Contrary to popular belief, laughter is not merely a response to humorous utterances. More often than not, laughter is actually a merely social phenomenon and occurs without a previous humorous statement (Scott et al., 2022). It is hypothesized that in humans, laughter fulfills a similar function as does grooming in non-human primates, thus facilitating social coordination in larger groups as compared to other primates, since laughing together does not require physical touch and can therefore serve as a bonding mechanism for larger groups (Dunbar, 2022).

Recent research suggests that laughter has the primary social objective of signaling that a situation is harmless, and that within this signaling of non-threat it fulfills three distinct social functions (Wood & Niedenthal, 2018). The first function is to act as a social reward – producing laughter is rewarding, and hearing laughter produced by others is also rewarding (Bachorowski & Smoski, 2001; Wood et al., 2017). This phenomenon can be observed from a very early age onward – even babies repeat behaviors that make their caregivers laugh; and by the same token caregivers tend to repeat actions that elicit laughter from infants (Field, 1979; Rubenstein & Howes, 1979). A second function of laughter can be called "affiliation laughter". This laughter usually does not follow funny situations but is rather produced to ease social tensions and to mitigate awkward situations but does not feel rewarding to produce or to hear. Through this, it is a signal of non-threat and appeasement that aids to regulate social situations. A third function of laughter can be categorized as "dominance laughter". It can serve as a sanction for unwanted behavior and can be used to enforce group norms. This form of laughter often has a target that is "laughed at" and a group that is "laughed with" (Wood & Niedenthal, 2018). Tendency to laugh is a stable trait in individuals, meaning that some people simply laugh more than others do. In one recent study, more than half of the variance of the amount of laughter produced was to be attributed to the person laughing; and only 5 percent was due to the conversation partner of the person who laughed. Surprisingly, the amount of laughter negatively predicted subjective conversation enjoyment, fitting with the aforementioned theories of laughter as a social instrument (Wood et al., 2021).

Human babies start laughing at already four months of age, which makes laughter one of the first vocalizations produced by human infants – it emerges even before speech (Scott et al., 2022). The earliest trigger for laughter appears to be tickling, with tickle-induced laughter responses appearing already in 24 weeks old babies (Kilteni, 2025). Toddlers are able to use humour by subverting expectations (Airenti, 2016) and typically use laughter to signal to their parents that they are joking (Matthews, 2014). Children's laughter functions change substantially between 12 and 36 months and differ from adult laughter across all observed levels, including functional use (Cekaite & Andrén, 2019; Mazzocconi, 2019). In children of up to about 18 months, laughter mainly shows enjoyment of pleasant incongruities in playful contexts. At around 24 months, a new function of laughter emerges. This is the age where children start using laughter as a display of affiliation or friendliness, even without any incongruity present. In children around 36 months, laughter begins to regulate social incongruities, such as mitigating norm violations, marking the greatest extension beyond its original playful function (Mazzocconi, 2019).

Studies on laughter in social situations with children are comparatively rare, especially when compared to studies on humor production (Cekaite & Andrén, 2019). A US study conducted with 3-5-year-old children found that smiling was more common than laughter, but laughter became more prevalent with age (Bainum et al., 1984). Studies with preschool and primary school children showed that laughter was primarily used as a tool to seek peer's affiliation (Cekaite & Aronson, 2014; Cekaite, 2018).

There is some evidence for gender differences in the amount of laughter that people produce as well as in the situations where most laughter is produced. In conversations, typically the person who speaks produces the most laughter. This seems to be especially true for women (Scott et al., 2022). In 1993, Provine published a seminal study on laughter, in which he concluded that women laugh more than men (Provine, 1993). A newer study by Manson et al. (2013) also found higher rates of laughter in women than in men.

However, other studies were not able to replicate this finding. Martin and Gray (1996) found no gender differences in the amount of laughter of participants as they reacted to recorded audience laughter. Vettin and Todt (2004) also found no gender differences in the amount of laughter displayed by men and women in their study. Whalen (2010) investigated laughter frequency between husbands and wives and found no gender differences in the frequency of laughter.

It is possible that gender differences found in laughter had situational predictors. One seminal study found that women tend to produce the most laughter when interacting with a male partner, regardless of if they knew each other before the interaction or not. Men seem to produce most laughter when they are interacting with a friend, regardless of the friend's gender. This suggests that women are likely to use laughter as a tool to shape interpersonal relationships whereas for men laughter is more strongly tied to existing friendship bonds (Smoski & Bachorowski, 2003). Another study found higher rates of joint speaker laughter among women as compared to men. Additionally, in female pairs of unequal status, university students join the laughter of female staff much more often than vice versa (McLachlan, 2022).

To sum up, there seems to be some empirical support for the finding that women tend to laugh more than men, but this is also heavily dependent on the type of interaction.

In addition to the social aspects and functions of laughter, it also has biological effects. Laughter releases endorphins, most likely through the strenuous contractions of the diaphragm and the pain experienced when we gasp for air after bouts of involuntary laughter. The endorphin release heightens people's pain threshold and is thought to facilitate human bonding (Dunbar, 2022). Other physiological effects of laughter include heightened arousal as characterized by an increase in heart rate, skin conductance, and somatic activity (Whalen, 2010).

Numerous psychological effects are connected to laughter, such as reduced stress and anxiety, elevated mood and self-esteem, and even increased creativity (Mora-Ripoll, 2010). This makes laughter an effective tool for emotion regulation (Scott, 2014).

To sum up, laughter is a ubiquitous social phenomenon that has deep evolutionary roots and is found in all primates (Davila-Ross et al., 2009). In the form of proto-laughter it is even found in other animal species (Panksepp & Burgdorf, 2000). Laughter is present very early in infant development and is associated with many social outcomes (Bachorowski & Smoski, 2001; Mazzocconi, 2019). It functions as a signal of non-threat and affiliation and is thought to have a crucial function in human bonding, replacing grooming through physical contact that is common in other primate species (Wood & Niedenthal, 2018; Dunbar, 2022). Since laughter is an important mechanism in social bonding, the current study aims to investigate the connection between laughter and another mechanism that is crucial in human bonding, namely interpersonal synchrony.

1.2 Interpersonal Synchrony

It is difficult to overstate the extent towards which humans are social beings. Our everyday lives are shaped by other people and interpersonal relationships and interactions to such an extent that being in isolation can function as punishment or even torture. This makes it somewhat surprising that most psychological research to date has focused on individual traits, states and processes. In recent years, however, there has been an emerging stream of research that has started focusing on how we interact and are influenced by interactions with each other (Schilbach et al., 2013). It has been argued that the shift from psychological and neuroscientific research approaches that focus on the individual in isolation towards research that focuses on two or more people in interaction can be compared to the Copernican shift in our view of the universe. Much like the Earth is just one of many celestial bodies interacting with others in a complex system, so is every human being simply a part of a much larger and more intricate network (Hasson et al, 2012*).* However, despite an increase in research efforts in the field that Redcay and Schilbach call "2nd person neuroscience", many questions remain unanswered and additional research is warranted (Redcay & Schilbach, 2019).

Interpersonal synchrony, sometimes also described as coherence, entrainment or linkage refers to a state of concurrent coordinated activity between two or more individuals (Cross et. al., 2019; McCraty, 2017; Thorson et al., 2021). This state can exist at the behavioral, physiological and neural level. Synchrony is mutual, dynamical and temporally related (Chetaouani et al., 2017). Interpersonal synchrony is a widespread and crucial social phenomenon. Research findings suggest that interpersonal synchrony can lead to a wide variety of outcomes that are often related to bonding, communication and prosociality (Mayo et al., 2021; Mogan et al., 2017). Moreover, synchrony has been found between dyads as well as in bigger groups of people (Wiltermuth & Heath, 2009).

It has been suggested that biobehavioral synchrony is a vital part of human attachments and works in a bottom-up way (Feldman, 2017). According to Feldman's model, synchrony in the physiological or neural domain is first triggered through social action such as a joint gaze or rhythmic movements. The model further posits that biobehavioral synchronization is a crucial process in mammalian socialization, wherein the mother's mature brain synchronizes with and thereby regulates the infant's immature brain, consequently helping and enabling important learning processes. The attachment processes that infants learn through their parents are later repeated in other social contexts (Feldman, 2016 & 2017; Levy et al., 2021).

Interpersonal synchrony is ubiquitous in everyday (social) life and has therefore been linked to a wide variety of outcomes. For example, interpersonal synchrony was shown to influence prosocial behavior and cooperation, trust and affiliation, perceived similarity, cognitive performance, study success, positive affect, therapy outcomes, emotion regulation and was even linked to heightened pain thresholds. (Cirelli, 2018; Goldstein et al., 2018; Hove & Risen, 2009; Hu et al., 2022; Mitkidis et al., 2015; Pan et al., 2021; Rabinovich & Knafo-Noam, 2015; Rabinovich & Meltzoff, 2017; Reinero et al., 2021; Tschacher & Meier, 2020; Wass et al., 2019).

Despite the many positive outcomes and correlates of synchrony, it can also have adverse effects. A recent study found that when participants synchronized their breathing to another person, the dyad's heart rate became more synchronous, but by the same token intrapersonal synchrony between respiration and heart rate decreased. This effect was greater when interpersonal synchronization was stronger. These suggest that interpersonal synchronization might involve a trade-off with intrapersonal synchrony, leading to self-decoupling (Konvalinka et al., 2026). In a similar vein, Galbusera et al. (2019) found that while interpersonal movement synchrony was associated with increased positive affect, it also weakened self-regulation of affect. Thus, it seems like interpersonal synchrony might come at the cost of intrapersonal coupling and self-regulation.

While interpersonal synchrony might entail a trade-off with intrapersonal coupling, it is connected to a multitude of beneficial outcomes in the domains of communication (e.g. Pan et al., 2021; Stephens et al., 2010) and social bonding (Hove & Risen, 2009). Some of the benefits of interpersonal synchrony will be detailed below.

1.2.1 Synchrony and Communication

Research has shown content-specific linkage between listener's and speaker's EEG recordings, pointing towards listener's neural activity being linked directly to speaker's verbal activity (Kuhlen et al., 2012). Therefore, interpersonal neural synchrony (brain-to-brain synchrony) could also be viewed as a process of linking the neural system of a listener to the motor system of a speaker (Hasson et al., 2012; Stephens et al., 2010). During regular real-life interactions this process is reciprocal (Hoehl et al., 2021). This can help to explain why synchrony has been generally connected to communication and communicative outcomes (e.g. Schippers et al., 2010).

Auditory speech signals are one way for our brains to synchronize, but they usually do not happen in isolation, and our brains also use other stimuli to synchronize, such as visual speech signals like mouth movements or even gestures (Hasson et al., 2012). Notably, neural synchrony was also found in gestural communication during a game of charades. Thus, verbal communication is not necessary for neural entrainment (Schippers et al., 2010).

Interpersonal neural synchrony between a speaker and a listener has been found to be connected to greater story comprehension (Stephens et al., 2010). In another study, there was evidence that neural synchrony between a student and an instructor helped to some extent in compensating the learning deficits caused by sleep deprivation (Pan et al., 2021). These findings point towards the fact that neural synchronization is an important mechanism in communication. However, synchrony has also been found to have benefits in the domain of social bonding, as described in the following subchapter.

1.2.2. Synchrony and Social Bonds

Interpersonal synchrony and affiliation seem to be connected through a bidirectional link. Several studies have shown that synchrony is more readily achieved between interaction partners who already know each other (Pan et al., 2017; Reindl et al., 2018), and by the same token achieving interpersonal synchrony also increases affiliation between interaction partners (Hove & Risen, 2009).

It is relatively easy to generate interpersonal synchrony in groups and dyads and potentially generate affiliation, rapport and group cohesion. Studies in infants have found that behavioral synchrony increases liking and prosocial sharing (e.g. Trainor & Cirelli, 2015). The same results were found for children (e.g. Rabinovich & Meltzoff 2017b; Wan & Zhu, 2021) and adults (e.g. Rennung & Göritz, 2016). These results are in line with the suggestion of the biobehavioral model of synchrony that suggests interpersonal synchrony as one of the key factors in human affiliation and bonding (Feldman, 2017; Levy et al., 2021) with deep roots in human ontogeny. For this reason, the present study aims to find a link between interpersonal synchrony and laughter, since both phenomena are linked to positive consequences in social bonding outcomes. Since both synchrony and laughter are present early in human development and play a vital role in human attachment and bonding (Dunbar, 2022; Feldman, 2017), it is interesting to look at interpersonal synchrony from a developmental perspective.

1.2.3 Interpersonal Synchrony in Development

A number of studies have focused on synchrony between parents and infants and between parents and children. Synchrony seems to play an important role in emotion regulation, specifically parents helping to regulate children’s emotions. Moreover, synchrony is also crucial in shaping children’s attachment with and bond to their primary caregiver(s) (Ham & Tronick, 2009; Markova et al., 2019; Markova & Ngyuen, 2023).

In infants, moving synchronously with an experimenter was found to increase affiliation and prosocial behavior (Trainor & Cirelli, 2014). Infants are more likely to seek proximity with an experimenter that they have previously been moving synchronously with (Tunçgenç et al., 2015), and they are more likely to help an experimenter retrieve a dropped object when they had been mimicked by that person before; i.e. experienced movement synchrony with the experimenter (Carpenter et al., 2013). Synchrony in infants has also been associated with social learning. One study with mothers and infants separated the dyad briefly while the mother underwent a modified version of the Trier Stress Test as a form of social evaluation. After their reunion, physiological activity between the mothers and infants synchronized, and the infants whose mothers had been in the social evaluation condition showed greater avoidance of the experimenters than the infants in the control group, indicating aversion towards the people who caused the mother's stress (Waters et al., 2014).

In preschool-aged children, social interactions with peers become increasingly important to shape their development (Harris, 1995). Therefore, the question of how synchrony shapes children's development is an interesting one. It has been shown that in four-year-olds, being in behavioral synchrony with each other makes them more helpful and cooperative (Kirschner & Tomasello, 2018; Rabinovich & Meltzoff, 2017a; Tunçgenç & Cohen, 2018). Rhythmic coordination was also found to increase general prosocial behavior in 5-year-olds, not just towards the interaction partner but also towards strangers (Wan & Zhu, 2021). Moreover, it also increases prosocial sharing in four-year-olds (Rabinovich & Meltzoff 2017b). Interpersonal movement synchrony has also been shown to give cues about group membership in 8-year-olds (Good & Russo, 2016), even though it also increases prosociality towards outgroup members (Reddish et al., 2016). Another study found that synchronous rhythmic interaction influences perceptions of similarity in 8 to 9-year-old children, pointing towards the fact that synchrony can enable attitudinal shifts and thereby improve social interaction (Rabinovich & Knafo-Noam, 2015). These results indicate that interpersonal synchrony might play a vital role in the development of social functioning, in line with the biobehavioral model of synchrony (Feldman, 2017; Levy et al., 2021). Because of the crucial role of interpersonal synchrony in the development of social functioning, this study aims to find a link between interpersonal synchrony and laughter, which is also an important mechanism of social cohesion (Dunbar, 2022). Previous studies on peer synchrony between children have focused solely on behavioral synchrony (with the exception of Goldstein et al., 1989). This study aims to find a connection between laughter and physiological synchrony in children. Physiological synchrony refers to synchronous activity of various processes of the autonomic nervous system and has been linked to affect contagion and emotion co-regulation (Coutinho et al., 2021; Waters et al., 2017). The following chapter will provide a brief overview of the autonomic nervous system and its functions. Since physiological synchrony underlies various processes of the autonomic nervous system, understanding the basics of the autonomic nervous system helps in understanding physiological synchrony.

1.3 The Autonomic Nervous System

In vertebrates, the autonomic nervous system, or ANS, refers to all the parts of our nervous system that we cannot voluntarily control. It regulates the function of all innervated organs and tissues except for striated muscle fibers, which are controlled by the somatic motor system. The ANS is responsible for controlling the cardiac muscle and the blood vessels to regulate blood flow and blood pressure, regulating oxygen intake through the lungs and bronchi, innervating secretory glands (e.g. salivary glands and tear ducts), regulating digestion and metabolism, and is connected to immune system functioning (Bear et al., 2026).

While actions of the central nervous system (CNS), which controls our motor system, tend to be concise and fast, functions of the ANS tend to be multiple, widespread, and comparatively slow (Bear et al., 2026). The ANS is made up of three parts – the enteric nervous system, the sympathetic nervous system and the parasympathetic nervous system (Jänig, 2022).

The enteric nervous system (ENS) is responsible for regulating gastrointestinal processes. It consists of more than 100 million neurons, which makes it the largest part of the ANS. The ENS can operate independently from the CNS, but is very connected to processes of the CNS, to the point where diseases are hypothesized to be able to spread from the gut to the brain (Rao & Gershon, 2016).

The parasympathetic nervous system, or PNS, is generally associated with rest and recovery (Karemaker, 2017). Its activity is connected to maintaining bodily functioning and working gradually in support of long-term well-being. The PNS is responsible for functions like energy storage, growth, immune response and digestion (Bear et al., 2026). It is innervated primarily by the vagus nerve and functions mainly through vasodilation, which is the dilation of blood vessels (Jänig, 2022). Parasympathetic activity causes the heart rate to slow down (Bear et al., 2026).

The sympathetic division of the ANS, also referred to as sympathetic nervous system (SNS) is primarily responsible for fight, flight, or fright response (Karemaker, 2017). Its functioning is strongly connected to processes that mobilize energy for the short term (Bear et al., 2026). Additionally, it also maintains homeostasis, meaning that it is responsible for regulating, among other things, immune function, body temperature and blood glucose levels (Scott-Solomon et al., 2021). High SNS activity speeds up our heart rate (Bear et al., 2026).

The pervasive myth that PNS and SNS work in antagonistic ways is not true (Jänig, 2022). A more accurate description would be that both systems work in complementary ways or that they simply have different responsibilities and are active in different situations. For example, sympathetic activation of the pupils causes dilation, whereas parasympathetic activation of the pupils causes constriction. However, most organs are not dually innervated by both the SNS and the PNS, but only by one of these nervous systems (Karemaker, 2017). As mentioned above, autonomic processes are the basis of physiological synchrony. The following chapter will provide an overview of physiological synchrony.

1.4 Physiological Synchrony

The term physiological synchrony has no concise definition and is used to refer to interpersonal synchrony of various processes in the ANS. It can be measured for example through electrodermal activity (EDA), cortisol levels, respiration, blood pressure, prolactin or through different measurements of the heart, such as interbeat interval (IBI), heart rate (HR), heart rate variability (HRV) and respiratory sinus arrhythmia (RSA) (Coutinho et al., 2019).

Interpersonal physiological synchrony has been researched in a wide range of contexts and situations, for example in romantic couples, between mothers and children, in cooperation and trust games, and even between therapists and patients (Danyluck & Page-Gould, 2019; Woody et al., 2016; Mitkidis, 2015; Tschacher & Meier, 2019).

Physiological synchrony is typically associated mostly with the broad areas of relationship quality and bonding, affective state matching and co-regulation, and team performance and cooperation (Danyluck and Page-Gould, 2019; McCraty, 2017; Palumbo et al., 2017; Wood et al, 2021). For example, a study between therapists and clients looked at synchrony in heart rate, respiration, and heart rate variability and found evidence for synchrony in all of these measurements. Moreover, they found that higher synchronies correlated with higher alliance ratings by both clients and therapists (Tschacher & Meier, 2019). Another study found that participants' HR synchrony in a public goods game predicted the participant's expectations about their partners, which was seen as an indicator of trust-building processes (Mitkidis et al., 2015). Notably, there is evidence that the meaning and correlates of physiological synchrony change depending on whether synchrony is experienced in measures of the ANS more related to the SNS or PNS (Mayo et al., 2021). A brief account of the differences in synchrony between these two systems will be given below.

1.5 SNS vs PNS Synchrony

The lack of a clear definition of physiological synchrony has been criticized, as well as the fact that most studies on the topic did not differentiate between sympathetic nervous system

(SNS) and parasympathetic nervous system (PNS) synchrony. Such a distinction would be crucial, however, as interpersonal synchrony in the SNS and PNS occur under different circumstances due to the distinct functions of those two systems. Moreover, studies point towards the fact that synchrony in the SNS and PNS differ in their respective meanings (McCraty, 2017; Mayo et al. 2021).

According to a meta-analysis of studies on ANS synchrony, SNS positive (in-phase) synchrony is mostly correlated with positive relationship outcomes, while PNS in-phase synchrony is often connected to worse relationship outcomes. In-phase synchrony refers to both interaction partner's autonomic activity increasing or decreasing at the same time. Anti-phase synchrony is present when one person's autonomic arousal increases and the other person's arousal decreases simultaneously. The authors suggest that the different outcomes of SNS and PNS synchrony are due to the different types of psychological state that SNS synchrony and PNS synchrony embody. SNS activity is mainly a sign of arousal, so a mutually high SNS activity might mean that both interaction partners are engaged in the interaction and are enjoying it. Sympathetic synchrony is measurable for example with EDA, pre-ejection period (PEP) or cardiac sympathetic index (Mayo et al., 2021). SNS synchrony is associated with social affiliation (Danyluck & Page-Gould, 2019).

PNS activity is high when people feel safe and relaxed and thus there is no need for their SNS which is responsible for the "flight or fight" – response to be active. This means that a mutually low PNS activity might mean that both interaction partners do not feel safe and relaxed and are thus unable to engage deeply in the social interaction (Mayo et al., 2021). Interpersonal synchrony of high PNS activity is an indicator of both parties being relaxed and is connected with positive affect and social outcomes (Waters et al., 2017).

Interpersonal synchrony in the HR of people is a measure of both SNS and PNS activity that has been associated with many positive interpersonal outcomes. A seminal study in the eighties found out that HR synchrony is higher when two people have a closer relationship to each other (Goldstein et al., 1989). HR synchrony was also associated with higher marital satisfaction in a task where a couple had to discuss a conflict (Thomsen & Gilbert, 1998), and with daily positive affect in couples (Ferrer & Helm, 2013). An interesting study by Asher et al. (2021) investigated HR synchrony in dyads with one individual suffering from social anxiety disorder. They found out that compared to healthy control dyads, the dyads where one person had social anxiety disorder experienced less synchrony in conversations aimed at generating interpersonal closeness. This is interesting to consider, as it might mean that in certain situations, low HR synchronization can point to a person not feeling a high level of connectedness with their conversation partner. Conversely, a study on interaction between romantic partners found that romantic couples who had identified as high in marital distress had higher HR synchrony than nondistressed couples. The difference in physiological synchrony was most pronounced when a conflict was discussed. This suggests that higher HR synchrony can also have unfavorable outcomes. For example, it could reflect a state of both partners being “locked in” a conflict and unable to take a step back, thus exacerbating the conflict (Levenson & Gottman, 1983).

Physiological synchrony is also associated with the concept of affect contagion. One study on physiological synchrony between mothers and infants, where the dyad was separated and the mother had to undergo a social stress test, found that upon reunion, infants of distressed mothers synchronized their HR to match the HR of the distressed mother (Waters et al., 2014). This is also known as stress contagion. While this might initially seem like a disadvantage, it is hypothesized that this form of emotional contagion from the mother to the infant is part of a social learning paradigm in which infants gain information about their environment based on their mother’s reaction to it (Waters et al., 2014).

Affect contagion of positively valent emotions is also connected to physiological synchrony. This effect tends to be moderated by relationship closeness. In one study, physiological synchrony (HR and HRV) and affect contagion of friend and stranger dyads was assessed. It was found that in friend dyads, physiological synchrony and affect contagion was greater than in stranger dyads (Lin et al., 2024). Another study investigated physiological synchronization between mothers and infants in conditions of both positive and negative affect. In the positive affect condition, mothers were separated from their infants and performed a relaxation task. Upon reunion, the PNS activity as measured RSA of mothers and infants synchronized. In the negative emotion condition, mothers were assigned a stressful task and after reuniting with their children, the dyad’s SNS activity (measured by PEP and IBI) synchronized. This effect was moderated by physical contact – if mothers and infants touched during the reunion phase, SNS synchrony was stronger (Waters et al., 2017).

Physiological synchrony has also been associated to dyadic co-regulation in close relationships. For instance, Helm et al. (2014) found that romantic partners’ RSA activity during a task was associated with their partner’s earlier RSA responses. This effect was stronger in couples who reported greater relationship satisfaction. Another study investigated HR and HRV synchrony during conversations of romantic partners and found evidence for in-phase HR synchrony and anti-phase HRV synchrony (Coutinho et al., 2021). The authors theorize that in their study, HR (a general ANS measure) synchrony reflected positive affect matching while the anti-phase synchrony in HRV (a PNS measure) was interpreted as a marker for dyadic co-regulation. When one partner's HRV arousal decreased (lower HRV), the other partner's arousal increased (higher HRV). This suggests complementary regulatory roles that can alternate in an interaction. The fact that HR and HRV differed in how synchrony was exhibited shows that physiological synchrony can act differently across different autonomic channels (Coutinho et al., 2021). Another study found evidence of dyadic co-regulation between parents and infants. The researchers investigated HR, HRV and movement synchrony in parents and infants. Overall, ANS activity of parents and infants was not synchronized during the day. However, when infant arousal was high, parents increased their own arousal to match that of their child. The degree of parent autonomic reactivity was positively correlated to faster infant calming. Interestingly, when both parent and infant showed high autonomic arousal, parents reacted by decreasing their own arousal (Wass et al., 2019).

To sum up, physiological synchrony exists for different processes of the ANS and there is evidence that points towards the fact that the meaning of synchrony differs depending on whether it is connected to processes of the SNS, PNS, or more general ANS arousal. However, the interpretation of synchrony of different autonomic processes is relatively complex (Mayo et al., 2021). HR synchrony, which is a measure of general ANS activity, has often been connected to positive relationship outcomes (Ferrer & Helm, 2013; Thomsen & Gilbert, 1998).

In line with Feldman's model of biobehavioral synchrony, experiencing physiological synchrony first with caregivers and then with peers is an important tool for human bonding and social learning (Feldman, 2017). However, while much research has focused on physiological synchrony in parent-child dyads or adult dyads, studies on peer dyads in children remain few and far between (Goldstein, 1989). Nevertheless, researching this group would be crucial, as peer interactions become increasingly important for children, and synchrony is thought to have an important influence on the development of social behavior (e.g. Feldman, 2017; Harris, 1995; Kirschner & Tomasello, 2018). Therefore, this study aims to advance our understanding of physiological synchrony in children.

1.6 Research Question and Hypothesis

Much like laughter, synchrony is also hypothesized to be a human equivalent to primate grooming and to facilitate larger group sizes due to the fact that synchrony does not necessarily require physical touch and can thus be elicited in larger groups (eg. Dunbar, 2022; Launay et al, 2016). Moreover, the fact that synchrony and laughter are both rhythmic and social in their nature makes it seem likely that laughter might induce interpersonal synchrony (Hoehl et al., 2021).

Since interaction with peers gets more and more important for preschool aged children (Harris, 1995), and synchrony seems to have a big influence on the development of social behavior (e.g. Kirschner & Tomasello, 2018; Rabinovich & Meltzoff, 2017a; Rabinovich & Meltzoff, 2017b; Tunçgenç & Cohen, 2016), this raises the question if laughter induces synchrony in children and can thereby function as an important mechanism for bonding and the development of social skills in preschool aged children. Therefore, in this study I want to test the hypothesis that laughing together induces physiological synchrony in preschool-aged children. Because of the different possible meaning and correlates of different measures of physiological synchrony, in this study a general measure of ANS will be used – heart rate synchrony as measured through IBI. IBI is a well-studied temporal measure that depicts the time interval between two heartbeats. A faster heart rate means a decrease in IBI (Capraz et al., 2023). IBI was chosen in the current study because it has been extensively researched and has been used in other studies that investigated physiological synchrony (e.g. Capraz et al., 2023; Gordon et al., 2020; Reindl et al., 2022; Thomashin et al., 2022; Thorson et al., 2021).

The primary hypothesis of this study is as follows:

Laughing together increases IBI synchrony in five-year-old children.

2. Methods

The current study is embedded in a larger experimental paradigm (see also Karner, 2024; Kogler, 2025; Lorbert, 2025; Mitari, 2026; Pfatrisch, 2025; Sarnek, 2026; Schatzer, 2025; Stojan, 2024; Wieser, 2026) aimed at finding out the relationship between laughter and interpersonal synchrony. It was funded by a grant from the European Union and took place in the lab of "Wiener Kinderstudien" at the University of Vienna. The study was approved by the ethics committee of the University of Vienna. Participation was voluntary and participants could stop at any time. There were no risks associated with participating in this study.

2.1 Study Design

This study was conducted in a laboratory setting. Same-sex dyads of five-year-olds with a maximum age difference of six months were formed. It was made sure before the experiment that the children would be meeting each other for the first time. In every study, there were three experimenters present. One of the experimenters was responsible for the technical part of the study and spent most of the time behind a *separee* wall making sure the recordings were running smoothly. The two other experimenters were interacting with the children and were responsible for giving instructions and preparing the study equipment.

Parents accompanied their children to the laboratory and were asked to apply the ECG electrodes to their children before being requested to leave the lab and come back towards the end of the study. In the further course of the study, the experimental group watched funny animal videos and the control group watched animal videos that were rated as cute, but not particularly funny. The videos were grouped into two blocks (A and B) with a duration of 5 minutes per block. ECG was recorded during the whole experiment, and laughter was recorded via audio and video recordings and later coded by different raters. In this study, the ECG recordings and laughter scores of the second video block (block B) were used for further analysis. The reasoning behind this was that in block B, the participants already had 5 previous minutes of laughter manipulation before the measurement for block B started, so it was hypothesized that any laughter-induced difference in physiological synchrony would be greater and thus more easily measurable in block B.

This experiment was part of a larger study, so the overall study design was longer and included more measurements that are not relevant for the research question at hand and will not be described in detail.

2.2 Sample

The sample consisted of *N*=204 (104 female) five-year-olds who were assigned to dyads. The experimental group consisted of 61 dyads (*n*=122) and the control group was comprised of 41 dyads (*n*=82). The dyads were matched by gender and it was assured that the age gap for every pair was no more than six months. If children had neurological or chronical diseases, hearing problems, or were born prematurely they were excluded from the study. In the experimental group, two dyads had to be excluded due to one of the children having hearing problems, one dyad had to be excluded because the mother arrived late to the laboratory and the testing routine was disrupted, and one dyad had to be excluded because of technical difficulties showing the videos. 14 dyads had to be excluded due to faulty ECG recordings in at least one of the children. In the control group, 11 dyads had to be excluded due to faulty ECG recordings. This means that the final analysis was conducted with 43 dyads in the experimental condition and 30 dyads in the control condition. The final sample was thus N = 73 dyads and n = 146 participants (76 female). The average age of the children was 5.41 years (SD = .22; range = 5-6). The mean self-reported socioeconomic status of the children's parents was 6.90 (SD = 1.21; range 4 – 10). The scale ranged from 1 to 10, with 1 meaning a low perceived socioeconomic status and 10 meant a high perceived socioeconomic status.

Participants were recruited using the participant database of the *Wiener Kinderstudien* laboratory. The children came to the laboratory accompanied by a parent or legal guardian, and the parent or guarding filled out an informed consent form at the beginning of the study. Additionally, the parent or guardian was also asked to fill out a sociodemographic survey, the Parent Version of the Positive and Negative Affect Scale for Children (PANAS; Großheinrich, 2020) for the children and the Short German version of the Children's Behavior Questionnaire (De La Osa et al., 2014). After the experiment, the parents were debriefed by the experimenters.

As compensation for their participation, the children were given stickers and a certificate and allowed to choose one of several available games to take home. The parents were given 10€ to offset transportation costs.

2.3 Measures

Physiological synchrony. Physiological synchrony was measured by heart rate with a three-channel electrocardiogram (ECG). Smarting devices (mBrainTrain) were used for recording the ECGs, and a 50hz sampling frequency was employed. The electrodes were applied to the children by their parents and two were placed on the left and right side of the thorax underneath the collarbone, and a third electrode was placed on the left side of the abdomen. The measures taken by the smarting devices were divided into different segments for the different parts of the experiment. For the current analysis, ECG data was used from the second part of the video segment (block B), so the last five of the ten minutes. The raw smarting data was first transformed into .csv data using MATLAB 2025a and Node.js vs20.12.2. Following this, IBI was calculated using Python 3.12 and a peak-detection algorithm from Neurokit2 was used on the data (Makowski et al., 2021). Subsequently, the peaks were inspected and manually corrected using a custom dashboard called ibxx_v2 (Wunderwald, 2023a). After manual correction, the files were exported from the dashboard as .js files and transformed into .csv files using a python script. Subsequently, the .csv files were interpolated using a cubic spline interpolation script (Wunderwald, 2023b). Cubic spline interpolation is a mathematical technique that can be used to estimate values between IBIs. It works by finding a smooth curve (a spline) passing through a set of datapoints and ensures continuity and smoothness. After interpolation, the files were z-score-standardized and then cross-correlated using a zero-lag cross correlation algorithm in Python 3.12. The formula used to calculate synchrony is shown below. After synchrony was calculated, the data was imported to IBM SPSS Statistics (Version 31.0.0.0). Further analyses were carried out in SPSS.

$$synchrony = \frac{1}{N}\sum_{t} z_1(t)z_2(t)$$

Laughter. Laughter was recorded with audio and video recordings and coded by five separate coders based on amount and intensity of laughter. Every dyad was coded by two coders, so inter-rater reliability could be calculated. Both the amount of laughter as well as the intensity of laughter were coded. Laughter was coded using the Eudico Linguistic Annotator (ELAN; Version 6.7; Brugman & Russel, 2004) and defined according to criteria by Mazzocconi and Ginzburg (2022). According to these criteria, laughter starts when an auditive signal, facial expression, or bodily movement connected to laughter is observed. Laughter stops on an inhale or when the laughter-related movement stops. Ironic laughter and laughter that occurred during verbal utterances was coded, but bouts of laughter that were shorter than 300ms were not coded. For the analysis, a mean of the ratings of both coders was calculated and used.

Other measures. Since this study was part of a larger experimental paradigm, other measures were taken as well during the experiment. They include fNIRS, liking, prosociality, bonding, and questionnaire data filled out by the parents (described above).

3. Results

3.1 Hypothesis testing

Laughter was coded by five different coders. Interrater reliability (Krippendorff's α) was calculated between five pairings of coders for both amount and intensity and ranged from 0.63 to 0.99, with 80% of α scores greater than 0.85.

In this study, the main interest was in the amount of laughter and its influence on physiological synchrony. Since laughter was coded for every dyad for both the experimental and control groups, it was decided not to use the assigned group for the analysis, but rather perform the statistical analysis simply based on how much the dyad laughed together. Thus, a regression analysis was conducted with synchrony as the dependent variable using IBM SPSS Statistics (Version 31.0.0.0). The originally hypothesized regression model had two predictors, amount of laughter and intensity of laughter, and included an interaction term: (amount + intensity) + (amount x intensity) + error = synchrony. However, tests for model prerequisites found that multicollinearity was not given in this regression because predictors correlated with each other (VIF = 13,27). Thus, a simpler regression model with only one predictor was chosen. The model that was finally used was *amount + error = synchrony*.

All model prerequisites for the linear regression were fulfilled, except normal distribution of residuals. The residuals were graphically mostly normally distributed but had some outliers in the tails, and the Shapiro-Wilk test that was performed was significant at $p < 0.001$. However, since regression is generally a robust method it was decided to proceed with the regression analysis.

The regression that was performed analyzed $N = 73$ dyads (38 female dyads) and had an outcome of $R^2 = .035$; $F(1, 71) = 2.578$, $p = .113$ and is not significant at $\alpha = .05$. Results are shown in table 1 and figure 1.

Table 1

Regression Analysis: Amount of Laughter and Physiological Synchrony

Predictor	B	SE B	β	t	p	95% CI for B
Constant	-.019	.017	__	-1.128	.263	[−0.053, 0.015]
Amount of Laughter	.015	.009	.187	1.606	.113	[−0.003, 0.033]

Note. $N = 73$. $R^2 = .035$. Adjusted $R^2 = .021$. $F(1, 71) = 2.578$, $p = .113$. CI = confidence interval.

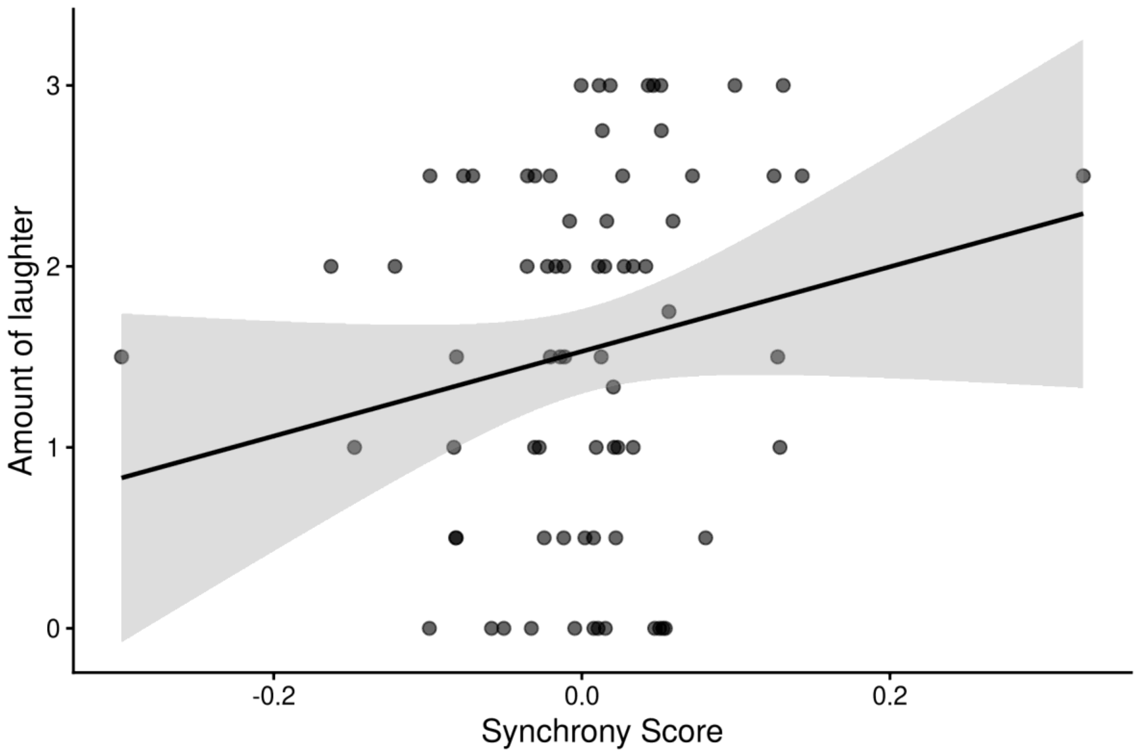

Figure 1: Regression Analysis of Physical Synchrony.
$N = 73$. $R^2 = .035$. Adjusted $R^2 = .021$. $F(1, 71) = 2.578$, $p = .113$

3.2 Explorative Analysis

Since the regression analysis was not significant, I was interested in looking at the difference between the two groups in terms of their synchrony scores, to find out if there was actually any difference in physiological synchrony between the laughter group and the control group. Therefore, a *t*-test was performed. The QQ-Plots show a mostly linear distribution with some outliers in both groups. Levene's test was not significant (p = 0,302). Welch's *t*-test is reported because of some deviances from normal distribution as well as two extreme outliers. Additionally, the results are supported by a Mann-Whitney *u*-test.

The t-test for synchrony scores showed a group mean of -.02 in the control group and .02 in the experimental group. *t* was -1.749 and *p* was .042 on the one-sided test and .085 on the two-sided test. Results of the t-test are reported in table 2 and figure 2.

Table 2

Independent samples t-test comparing control and experimental groups on synchrony score

Control *M* (*SD*)	Laughter *M* (*SD*)	*t*	*df*	One-tailed *p*	Two-tailed *p*	Cohen's *d*
-.02 (.07)	.02 (.09)	-1.749	68.522	.042	.085	-.403

Figure 2: T-test of Synchrony Score
t = -1.75, df = 68.5, p = 0.085

Additionally, an ANOVA was performed to explore the impact of gender on laughter, since there is literature pointing towards the fact that there are gender differences connected to laughter (Manson et al., 2013; Scott et al., 2022; Smoski & Bachorowski, 2003). The ANOVA had amount of laughter as the dependent variable and group and gender as fixed factors. Levene's test for homogeneity of variances was not significant, meaning we can assume homogeneity of variances. The normality assumption was not fulfilled, but it was decided after analyzing the graph that the deviation from normality was small enough to be negligible, and thus the ANOVA was calculated. There was a significant Group × Gender interaction, $F(1, 69) = 4.689$, $p = .034$. Simple-effects analyses showed that among boys, the experimental group ($M = 2.09$) scored higher than the control group ($M = 0.94$), mean difference = 1.15, 95% *CI* [0.50, 1.80], $p < .001$, $\eta p^2 \approx 0.15$. Among girls, the group difference was not significant ($Mdiff = 0.17$, 95% *CI* [−0.46, 0.80], $p = .588$, $\eta p^2 \approx 0.00$). Gender contrasts with estimated marginal means were not significant but showed a trend towards boys laughing more than girls ($p = .07$). These results show that gender does seem to have an influence on laughter, albeit only in interaction with the experimental condition that children were assigned to. The results of the ANOVA and the simple effects interactions are shown in tables 3-5 and in figure 3. The influence of gender on laughter is in line with previous research (Scott et al., 2022; Smoski & Bachorowski, 2003).

Table 3

Two-way ANOVA for Amount of Laughter

Effect	Type III Sum of Squares	df	Mean Square	F	p	ηp^2
Gender	.035	1	0.035	.039	.845	0.001
Group	7.678	1	7.678	8.544	.005	0.110
Gender x Group	4.214	1	4.214	4.689	.034	0.064
Error	62.005	69	0.899	__	__	__

Table 4

Simple Effects of Group within each Gender

Gender	df	Mean Squares	F	p	ηp²
Male	1	11.308	12.584	< .001	0.154
Female	1	0.266	0.295	.588	0.004

Table 5

Simple Effects of Gender within each Group

Group	df	Mean Squares	F	p	ηp²
Control	1	1.481	1.649	.203	0.023
Laughter	1	3.041	3.384	.070	0.047

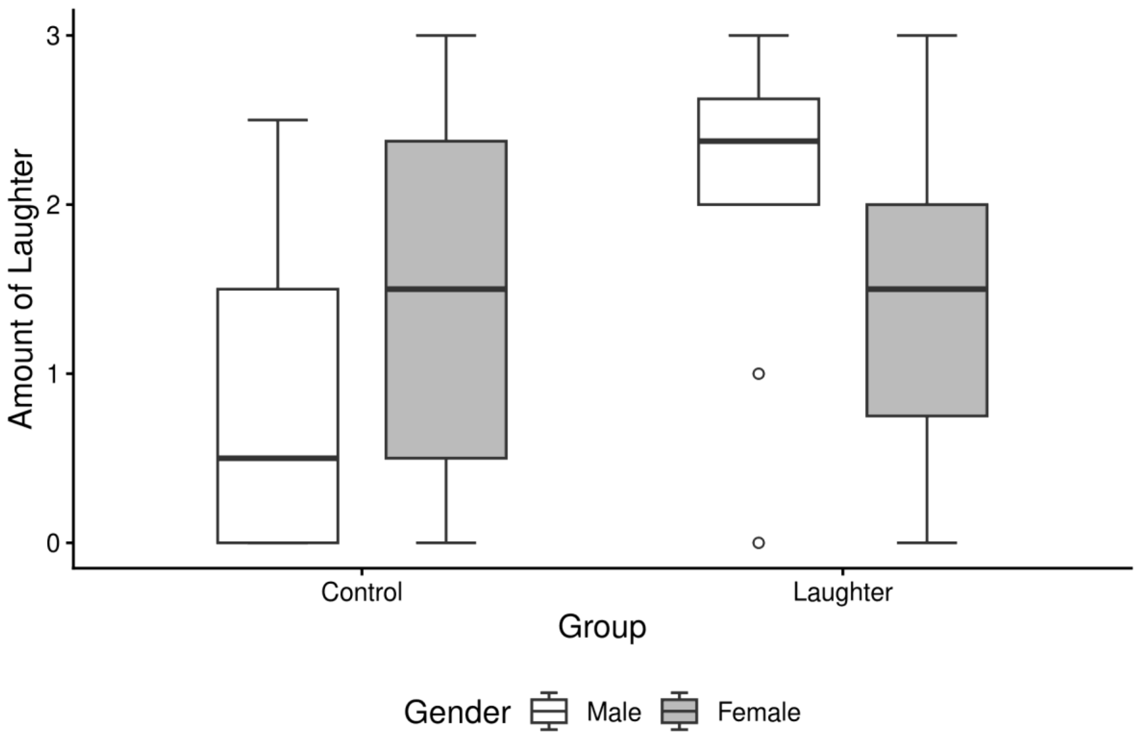

Figure 3: Results of Gender x Group in a two-way ANOVA.
N = 73, F(1,69) = 4.69, p = .034, ηp² = .064.

4. Discussion

The aim of this study was to find out if laughing together impacts interpersonal physiological synchrony in 5-year-old children. Laughter is crucial in human bonding and has been suggested to have replaced grooming through direct physical contact, as is common for most primate species, in humans. This is thought to have enabled humans to form larger-sized groups than other primates (Dunbar, 2022). Laughter is present very early on in infant development and deeply social in its nature. The rhythmic and social characteristics of laughter make it seem likely that it induces interpersonal synchrony (Hoehl et al., 2021). Synchrony is the temporary alignment of neural, behavioral or physiological activity between two or more individuals. Synchrony is related to a variety of social outcomes and is thought to play a crucial role in infant and child socialization (Feldman, 2017). In this study, I was specifically interested in the association between physiological synchrony and laughter and thus looked at synchrony of the heart rate which was measured using IBI.

In the current study, no significant link between laughter and physiological synchrony could be found. The linear regression that was performed for laughter and synchrony resulted in $R^2 = .035$; $F(1, 71) = 2.578$, $p = .113$ and was not significant at $\alpha = .05$.

One possible reason for this discrepancy with regard to the existing literature is a methodological difference: many of the extant studies on physiological synchrony used a form of synchrony calculation that involves some temporal lag, usually +- 3 to 5 seconds (e.g. Asher et al., 2021; Coutinho et el., 2019; Prochazkova et al., 2021). In the current study, however, synchrony was calculated with zero temporal lag, meaning that there was no "leeway" in either temporal direction. It is possible that this methodological difference in synchrony calculation leads to different results. Zero-lag synchrony of IBIs describes concurrent autonomous activity, while synchrony that allows for some temporal lag describes a leader-follower dynamic of autonomic coupling. For example, in one recent study on mothers and children playing a labyrinth game together, it was found that the mothers matched their ANS responses to their children, indicated by a temporal lag of 2 s between them (Capraz et al., 2023). In the present study, however, the focus was not on whether one of the children was leading the other one, but on concurrent cardiac activity.

Another potential explanation for this is that synchrony is also context dependent. It is difficult to say whether synchrony between people is evoked through a common activity (e.g. laughter) or by simply being in the same environment together (e.g. a laboratory setting) (Danyluck & Page-Gould, 2019; Mitkidis et al., 2015; Palumbo et al., 2017). Perhaps previous studies accidentally exaggerated the amount of synchrony that participants experienced by not considering contextual factors of synchrony. It is possible that in other studies, the laboratory environment was simply more conducive to creating interpersonal synchrony. The limitations of the laboratory environment of the present study will be detailed below.

An additional reason why the current finding does not match with the existing literature is that we do not know how many studies look into the topic of physiological synchrony, find no significant effects and simply disappear into the dreaded "file drawer".

Furthermore, the current literature on physiological synchrony focuses usually either on synchrony between adult participants or parent-child dyadic synchrony (e.g. Danyluck & Page-Gould, 2019; Wass et al., 2019; Waters et al., 2014; Woody et al., 2016). Studies on physiological synchrony between children are few and far between. Not much interest in the physiological synchrony of child dyads has been taken since the seminal study by Goldstein et al. (1989). In that study, greater synchrony was found between dyads of children who were friends as opposed to dyads who were not friends with each other. However, synchrony was defined simply as having the same number of heartbeats per minute, regardless of the timing of the heartbeats. In the current study, the definition of physiological synchrony was relatively strict, as mentioned above. This might explain why Goldstein et al., (1989) were able to find synchrony between child dyads in their study, while in the current experiment, synchrony was not evident. Another reason why the present results differ from Goldstein et al. (1989) might be that in the Goldstein study, the children were friends with each other, whereas in the present study, the children were meeting each other for the first time. Synchrony is achieved more easily between friends (Lin et al., 2024; Reindl et al., 2018), so the fact that the children were unacquainted with each other before the study might have impaired their ability to synchronize.

A *t*-test of physiological synchrony that was performed as part of the exploratory analyses showed a significant difference between groups only for the one-sided test, which in this case assumed that the control group *M* would be smaller than the experimental group *M*. This is in line with the literature. Synchrony scores in this study range from -1 to 1, with 1 meaning perfect synchrony of the heart rates and 0 meaning no correlation. Negative scores show anti-phase synchrony, which means that when one person's scores rise the other person's scores drop. It must be noted, however, that the difference between both groups is relatively small and the standard deviations comparatively big, so that a two-tailed test resulted in $p = .085$

and therefore does not show a significant group difference at $\alpha = .05$. From this we can conclude that although some difference seems to be present between the groups, it is mostly negligible, and overall synchrony scores are also relatively low.

A significant gender – group interaction was found in the exploratively conducted ANOVA. There is no statistically significant difference in laughter scores of girls between control and experimental groups. The girls laughed a similar amount in the condition with the not-funny animal videos and in the condition with the funny animal videos. In contrast, the boys' laughter behavior was markedly different. In the control condition, they laughed very little, whereas in the experimental condition, they laughed more than the girls in the same condition and a lot more than the boys in the control condition. Since the girl's amount of laughter did not differ between control and experimental conditions, the laughter manipulation seems to only have worked on the boys. There are several possible reasons for this.

The girl's similar amounts of laughter throughout the conditions might reflect the fact that they predominantly used affiliation laughter to ease possible tension, rather than laughing as a consequence of the videos actually being funny to them (Mazzocconi, 2019; Wood & Niedenthal, 2018). There are also gender differences in humor-related brain activation (Azim et al, 2005; Chan, 2016). Thus, there is the possibility that the boys laughed more because there are differences in positive affect gain elicited by the videos. In other words, they might have simply found the videos funnier than the girls did.

Another possibility is that the gender differences in the children's laughter reactions are consequences of gendered parenting. A recent systematic review investigated the developmental outcomes of gendered parenting and found that parents did treat their children differently depending on their gender. Differences were found in parent vocalizations, play behavior, in the type of toys they provided and in how they socialized their children. These differences in parenting behavior were reflected in behavioral outcomes in children's development (Morawska, 2020). This suggests that perhaps girls and boys are rewarded for different types of behavior. For example, maybe girls are rewarded more for showing social affiliation laughter and therefore have a higher baseline of laughter in the control condition, despite the video not being funny. By the same token, since the boys had a low baseline of laughter in the control condition, maybe they were parented in a way that did not reward social laughter.

4.1 Limitations

There are several limiting circumstances that might have led to the research not yielding a significant result. One reason is the mismatch between effect size and sample size. The final sample size that was analyzed was $N = 73$ dyads, so the *smallest effect size of interest* (SESOI) is $F(1, 71) = 3.976$ (Faul et al., 2009; Lakens, 2017). In the current study, however, the effect size F was smaller than that at $F(1, 71) = 2.578$. However, even a much bigger sample of $N = 1000$ dyads would have needed an effect size of $F > 3.850$.

It is also possible that the experimental setting itself limited participant’s ability to create and experience meaningful amounts of synchrony. As mentioned before, during the experiment there were also other measures taken, such as fNIRS, so the children had to wear fNIRS caps that were typically reported to be uncomfortable, and both the ECG and fNIRS devices were connected with many different cables, causing a situation where the children had to sit relatively still for most of the experiment, usually at least one hour out of the two hours that the children were at the laboratory. This task of not leaving their chairs for a longer duration of time was difficult for many of the children. This was paired with the fact that many children seemed to be frightened with the experimental procedure as such at least at the beginning, since they came into a strange environment, the parents had to leave, and they were connected to a number of cables and devices which might have alienated them. A study conducted on the contextual influences of physiological synchrony found that participants showed significantly less behavioral synchrony with an interaction partner who arrived late to the laboratory than when both participants arrived in time (Miles et al., 2010). Therefore, context seems to have an influence on the emergence of synchrony, and a more negatively valent overall state of participants could potentially inhibit interpersonal synchrony.

It is important to note that in this study, only cisgendered boys and girls were invited, which reproduces the normative gender binary. However, gender identity is much more complex and multilayered than that. By separating the children into boys and girls, we might not depict everyone’s gender identity in the best possible way, and we are also ignoring the existence of genderqueer and inter* children. This is an important limitation of the study that should be noted, and in future research paradigms hopefully there will be more accurate ways of portraying gender as a complex, fluid and multifaceted construct.

4.2 Future Research

In future studies, it might be advisable to use a simpler study design so that different measurements do not overcomplicate the experimental process.

It would also be interesting to look at different types of physiological synchrony in the same study and compare them. In the current study, heart rate was measured with IBI and resulted in a measurement of general ANS synchrony. In future studies, measures more specific to SNS synchrony and PNS synchrony should be taken concordantly with ANS synchrony to give us a better understanding of the different types of physiological synchrony and how they interact. In a similar vein, future research should carefully take into consideration the type of synchrony that is investigated (i.e. whether it is concurrent or lagged synchrony). To a large extent, this has previously been neglected in studies on the topic, despite the specific type of synchrony having an influence over and changing the meaning of a dyad's synchrony score (Helm et al., 2018).

Additionally, future research with children should also compare physiological synchrony between children who already know each other and are perhaps even friends with each other and children who are strangers to each other as in the current study. Previous literature suggests that physiological synchrony is higher in adults who are friends (Lin et al., 2024). The same has been found for children, albeit with a relatively lax method of synchrony calculation, as mentioned above (Goldstein et al., 1989). Therefore, it would be interesting to try and replicate these findings in a research paradigm with a stricter definition of synchrony.

5. Conclusion

The current study investigated if laughing together elicits physiological synchrony in dyads of five-year-olds. The study was conducted because both synchrony and laughter are vital components of human socialization and bonding. By researching interpersonal synchrony from a developmental perspective, we can get insight into the influences of synchrony on socialization in children, at an age where peer interactions become increasingly important for them. In the present study, synchrony of a general ANS measure, IBI, was investigated. No significant link was found between the amount of laughter and the presence of dyadic synchrony as measured by IBI, and synchrony scores were low overall. There are several possible explanations for this. On the one hand, it is possible that the experimental setting itself limited the children's ability to create synchrony with each other, as they might have been too stressed by the experimental procedure to match their autonomic states to each other.

On the other hand, this study is one of the first studies to ever investigate physiological synchrony in child dyads, and maybe a different research paradigm than the one used in the present study would have been necessary for this specific target group. Additionally, in the current study, only a measure of general ANS synchrony (IBI) was taken. It is possible that if the children were both stressed or uncomfortable with the experimental procedure, perhaps they experienced mutually low PNS arousal, which was not measured.

An ANOVA that was exploratively conducted to explore the impact of gender on laughter found a significant gender x group interaction in the children's laughter scores. Girls laughed an equal amount in the control and experimental groups, while the boy's baseline in the control group was very low, while they laughed a lot in the experimental group. This is thought to be partly due to differences in child socialization that occur due to gendered parenting (Morawska, 2020) and partly due to brain differences in humor processing (Azim et al., 2005).

In future studies, an experimental paradigm that does not inhibit the creation of interpersonal synchrony should be used, and measures of SNS and PNS synchrony should be taken concordantly. In conclusion, the research topic of child peer physiological synchrony is an interesting one that merits future studies, albeit with certain precautions in study design.

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7. List of Figures

8. List of Tables

9. List of Abbreviations

ANS	autonomic nervous system
EDA	electrodermal activation
ENS	enteric nervous system
HR	heart rate
HRV	heart rate variability
IBI	inter-beat interval
PNS	parasympathetic nervous system
RSA	respiratory sinus arrythmia
SNS	sympathetic nervous system

10. Appendix

10.1 Abstract

This study investigates the relationship between laughter and physiological synchrony in preschool-age children. Physiological synchrony is a phenomenon in which certain bodily processes in two or more individuals become temporarily aligned with each other. It can be caused, for example, through mutual engagement and shared context. Physiological synchrony has numerous positive relationship outcomes, such as increased affiliation, liking, and trust. The aim of this study was to find out if laughing together can induce physiological synchrony in five-year-old children. $N = 73$ same-sex dyads of five-year-olds watched either funny or not particularly funny animal videos in a laboratory setting while their heart rates were being recorded with ECG devices. Laughter was coded by amount and the raw ECG data was used to calculate interpolated IBIs. A z-standardized cross-correlation of synchrony scores was performed. Finally, a regression analysis was carried out to find out if laughter had a significant effect on synchrony scores. The regression showed no significant effect of laughter on interpersonal synchrony (R^2 =.035, $F(1, 71) = 2.578$, $p = .113$). Implications and directions for future research are discussed.

10.2 Zusammenfassung

Diese Studie untersucht den Zusammenhang zwischen Lachen und physiologischer Synchronie bei Kindern im Vorschulalter. Physiologische Synchronie ist ein Phänomen, bei dem bestimmte körperliche Prozesse bei zwei oder mehr Personen vorübergehend aufeinander abgestimmt verlaufen. Sie kann beispielsweise durch gemeinsame Beschäftigung und einen geteilten Kontext entstehen. Physiologische Synchronie geht mit zahlreichen positiven Beziehungsoutcomes einher, wie etwa erhöhter Verbundenheit, Sympathie und Vertrauen. Ziel dieser Studie war es herauszufinden, ob gemeinsames Lachen bei fünfjährigen Kindern physiologische Synchronie auslösen kann. *N* = 73 gleichgeschlechtliche Dyaden von fünfjährigen Kindern sahen sich in einem Laborsetting entweder lustige oder nicht besonders lustige Tiervideos an, während ihre Herzraten mithilfe von EKG-Geräten aufgezeichnet wurden. Das Lachen wurde hinsichtlich Häufigkeit kodiert, und die Rohdaten des EKG wurden zur Berechnung interpolierter Interbeat-Intervalle (IBIs) verwendet. Anschließend wurde eine z-standardisierte Kreuzkorrelation der Synchroniewerte durchgeführt. Schließlich wurde eine Regressionsanalyse vorgenommen, um zu prüfen, ob Lachen einen signifikanten Effekt auf die Synchroniewerte hatte. Die Regression zeigte keinen signifikanten Effekt von Lachen auf die interpersonale Synchronie ($R^2 = .035$, $F(1, 71) = 2.578$, $p = .113$). Abschließend werden Implikationen der Ergebnisse sowie Ansatzpunkte für zukünftige Forschung diskutiert.

10.3 AI Declaration:

In this study, ChatGPT (OpenAI, GPT-5.3) was used to write the code for the z-standardization and cross-correlation of synchrony scores. The code that ChatGPT wrote was double-checked by a lab member for its correctness and then executed using Python 3.12.

Figure 1 and Figure 2 were created in RStudio (version 2026.04.0+526) using code generated by Claude (Opus 4.7).