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„Laughter-induced physiological Synchrony and Cooperation“

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Content

1 Introduction

Humans developed large societies and social networks, which are maintained by specific mechanisms. Our close relatives in the animal world, the primates, use grooming as a bonding mechanism. It releases endorphins and creates bonds between group members. It is theorized that humanity developed other behaviours that creates social bonding and allows even larger networks (Launay et al., 2016). In everyday life, we see connections between a mother and a child, between musicians in an orchestra, between a fighting couple, and even between strangers meeting for the first time (Palumbo et al., 2017). This phenomenon has been researched in the field of psychology for some time and is called synchrony.

Interpersonal Synchrony has various definitions. However, most researchers concur that it is a process in which individuals adjust to each other and temporally align (Hoehl et al., 2021). This mechanism evolved throughout time and is said to play an important part in human interaction, cohesion, and social bonding (Gordon et al., 2020). Synchrony between two people can be found across human culture and across species (Palumbo et al., 2017). In social interactions, people have been found to affect each other’s states and behaviours because of basic resonance mechanisms (Behrens et al., 2020; Vanutelli et al., 2017). These states can be emotional, mental, or general arousal, and are temporally limited and dependent on the situation (Krumm et al., 2021). The resonance mechanisms provide an understanding of the actions and intentions of the interacting partners by creating a somatosensory framework of the partner’s emotional and mental state. Research suggests that a neural, behavioural, and physiological alignment is formed with the interaction partner (Behrens et al., 2020; Vanutelli et al., 2017). The exchange between individuals does not necessarily have to be positive for this unconscious alignment (Amiriparian et al., 2019). For example, people have been found to also synchronize in stressful situations or conflict (Gordon et al., 2020). Synchrony has been found as early as infancy, between a parent and the child. As synchrony integrates biological processes and social signals, it appears to be an important mechanism that facilitates the social development of the child (Feldman, 2007). Being able to synchronize with another person has a great impact on pro-sociality and social cognition in later life for the development of self-regulation, and empathy for example (Feldman, 2007; Gordon et al., 2020).

1.1 Physiological Synchrony

Physiological synchronization is linked to the autonomous nervous system (ANS). It can be measured by skin conductance, heart rate or respiratory sinus arrhythmia for example. The ANS takes part in regulating our cardiovascular, respiratory, and glandular systems and has also been linked to social interactions and prosocial behaviours (Palumbo et al., 2017; Sariñana-González et al., 2019).

1.1.1 Autonomous Nervous System

When we feel hungry, we eat. We feel thirsty, we drink. We feel the urge to go to the toilet, we do so. Responsible for these and other signals from our body is the autonomous nervous system (Karemaker, 2017). Being part of the peripheral nervous system, it regulates bodily functions like the heart rate, blood pressure, digestion, respiration and maintains homeostasis. The autonomous nervous system can be divided anatomically into three systems, namely enteric, sympathetic, and parasympathetic (Waxenbaum et al., 2023).

The enteric nervous system regulates gastrointestinal function and is the largest of the three systems. It can work independently from the central nervous system; however, it is deeply connected to the brain, and they mutually influence each other (Rao & Gershon, 2016).

The sympathetic nervous system (SNS) is responsible for upholding homeostasis, but also to mediate a fight or flight response of the body against stressors (Scott-Solomon et al., 2021). For example, in subjectively stressful situations our breathing and heartbeat quicken, and we start to sweat. The SNS regulates these reactions primarily via the blood vessels. In most cases, if the sympathetic signal increases, the blood vessels narrow (vasoconstriction). As mentioned above, the SNS is also involved in upholding homeostasis, and therefore is always in an active state (Waxenbaum et al., 2023).

The parasympathetic nervous system (PNS) primarily entails the vagus nerve, which is heavily involved in digestion and conserving energy. In contrast to the SNS, the PNS works through dilating blood vessels (vasodilation). However, most signals of the PNS are still excitatory and rarely inhibitory. Contrary to popular belief the SNS and PNS are not antagonistic, but usually complement each other, or they simply work in different situations with different intentions (Jänig, 2006). For example, the SNS compliments the PNS in the respiratory cycle by dilating the airways during breath intake (Waxenbaum et al., 2023). We can measure the interpersonal synchrony of different bodily functions regulated by both ANS modalities.

1.1.2 Physiological Synchrony Measures

Measures of Physiological Synchrony can be of cardiovascular activity (e.g. heart rate, respiratory sinus arrhythmia, inter-beat interval…), respiratory activity (e.g. respiratory rate), electrodermal activity (e.g. skin conductance), or thermal activity (e.g. skin temperature). Breathing rate and respiratory sinus arrhythmia are primarily influenced by the PNS and count as more specific physiological synchrony measures (Palumbo et al., 2017). Heart rate, on the other hand, is a more general measure and equally influenced by SNS and PNS (Behrens et al., 2020; Palumbo et al., 2017).

Heart rate synchrony can be measured via the inter-beat interval (IBI) for example (Gordon et al., 2020), which is used in the present study. IBIs are the temporal spaces between heartbeats and are measured in milliseconds (Browne, 2016). Our heart rate, and therefore IBI, is an indicator of our arousal. If we are positively or negatively excited it increases, and if our arousal is low, it decreases. Mitkidis et al. (2015) conducted a study using a public goods game, where participants had to divide resources between each other. They found in their study that dyads with a higher level of heart rate synchrony significantly predicted higher expectations of their partner's generosity in the public goods game. These findings suggest that the measured synchrony may be a marker for interpersonal trust. Mitkidis et al. (2015) argued, that an increased heart rate represents a higher awareness of the interaction partner. And synchrony may represent reciprocation in that respect. (Mitkidis et al., 2015).

It could be argued that synchrony merely reflects the experience of a shared environment (Danyluck & Page-Gould, 2019). Working on the same tasks, watching the same videos or other external stimuli may lead to physiological synchrony, but cannot be interpreted as a social-physiological alignment (Palumbo et al., 2017). One of the main functions of the ANS is maintaining homeostasis. SNS and PNS work together to achieve this balance again if the context changes. For example, in a new situation, we need to be alert, are excited, or feel stress, which is associated with increased activity in the SNS. If we are relaxed, or a task requires us to divide our attention, an increase in PNS activity can be observed. This means that psychological states correlate with changes in physiological states, influenced by the current situation and context (Danyluck & Page-Gould, 2019).

However, Behrens et al. (2020) tested for this hypothesis. Interestingly, they found that dyads, who interacted with each other showed a higher synchronization than random individuals who shared the same environment but did not interact. This speaks against the notion that physiological synchrony is only a product of a shared environment (Behrens et al., 2020). But what facilitates synchronization with an interaction partner?

1.2 Stimuli for synchrony

Humans are able to synchronize with artificial stimuli like a metronome or music and natural stimuli as well, like a person they talk to. Especially complex, rhythmic stimuli with some amount of variability and emotional meaning have been found to prompt synchronization and facilitate coordinated behaviour (Hoehl et al., 2021). In this study, laughter is explored as one way to synchronize with each other. Intuitively, we use laughter in everyday life to connect with a stranger, or we open a presentation with a joke to connect with the audience. And as laughter is inherently rhythmic and emotional, it could serve as a potential stimulus for synchronization.

1.2.1 Laughter and its Importance

Laughter is a phenomenon, that connects us all. It is found in every culture and even different species, because like other emotional vocalizations, it stems from our ancestors and the need to signal threat, distress, or play for example (Bryant & Bainbridge, 2022). However, even if laughter can be found in different mammals, human laughter is distinctly different. The laughter of great apes for example consists of a series of exhalation-inhalation sequences, while human laughter only contains short bursts of exhalation (Dunbar, 2022; Scott et al., 2022). Laughter is one of the first vocalizations that babies learn (Wood et al., 2022), and it develops further over time. For example, infants are not able to catch laughter contagiously yet (Scott et al., 2022).

There are different subtypes of laughter with various definitions. However, one main distinction is being made between spontaneous and volitional laughter. Spontaneous laughter is triggered by an external humorous stimulus. It elicits an involuntary contraction of the orbicularis oculi muscles, situated in the eye socket, and is called Duchenne Laughter (Law et al., 2018). This phenomenon occurs involuntarily and is highly contagious (Dunbar, 2022; Scott et al., 2022). In contrast, volitional or social laughter is produced at will by oneself, using controlled vocalizations like “ha, he, ho” (Law et al., 2018). People are able to distinguish between spontaneous and volitional laughter above chance when listening to individuals laughing (Bryant & Bainbridge, 2022).

Intuitively, laughter is associated with enjoyment. We surround ourselves with people, that make us laugh, watch funny videos or we tell jokes to make others laugh (Wood et al., 2022). However, laughing can have other functions than expressing amusement. In the research field of emotion psychology, it is theorized that emotions are not only regulated inside an individual (intrapsychic) but also regulated interactively between two or more people. This self- and relationship regulation is closely interlinked and dependent on one another (Bänninger-Huber & Salvenauer, 2022). On one hand, being self-regulated is a requirement for a successful engagement with another person. On the other hand, can an interaction have a positive effect on one's ability to self-regulate in this moment. Laughter can play an important role in that. When making a mistake we might laugh or smile in order to appease the other person and reestablish the relationship (Bänninger-Huber & Salvenauer, 2022). Laughing often is used to regulate negative emotions. In stressful, embarrassing, or uncomfortable situations laughter might help us regulate these negative emotions (Bänninger-Huber & Salvenauer, 2022). Various studies could find a positive effect of laughter on health. For example, in 5th-grade students who participated in laughter therapy, an increase in overall happiness could be found (Ozturk & Acikgoz, 2022). Cancer patients taking part in laughter therapy reported reduced pain (Morishima et al., 2019). Further Eraydin & Alpar (2022) found a significant increase in life satisfaction and psychological well-being and a decrease in reported anxiety in nursing students, who took part in laughter therapy.

Interestingly, laughing has also been found to have negative effects and can be a form of aggression and rejection e.g., laughing at someone or Schadenfreude. The product of laughter being positive or negative seems to depend on internal and external factors. For example, the mood of the people involved (internal), and size of the group, or how familiar the individuals are with each other (external) (Klages & Wirth, 2014). In conclusion, laughter is considered an important element of affective regulation (Bänninger-Huber & Salvenauer, 2022). As laughter is inherently rhythmic and emotional, there could be a connection between laughing together and interpersonal synchrony, which is best promoted by rhythmic, emotional external stimuli (Hoehl et al., 2021). But what advantages could it have to be able to synchronize with each other?

1.3 Effects of Synchrony

Physiological synchrony has been linked to different interpersonal social or emotional behaviours e.g., empathy, and could be indicative of social and emotional exchange (Behrens et al.; Vanutelli et al., 2017). It has been found to have a communicative benefit and affiliative benefit. Furthermore, as mentioned before, synchrony makes it easier to predict someone's intent, which is crucial for efficient cooperation (Hoehl et al., 2021). Therefore, synchronization of the ANS may be involved in higher-order social processes like affiliation and cooperation (Danyluck & Page-Gould, 2019). However, as mentioned above, physiological synchrony has also been found to occur in situations with negative arousal, resulting in empathetic distress. This distress comes with egoistic motivations, rather than prosocial, cooperative behaviour (Hoehl et al., 2021). In alignment with this ambiguity of research concerning physiological synchrony, some studies found effects of synchrony of the heart rate on cooperation (Hoehl et al., 2019; Mayo et al., 2021; Trainor & Cirelli, 2015), while others could not find such a relationship (Behrens et al., 2020).

1.3.1 Cooperation

Cooperation is one of the most important phenomena of human evolution. It is the glue of small groups and big societies (Behrens et al., 2020; Michael et al., 2016) and may be one of the reasons for our success as a species (Melis, 2013). Every day we are required to cooperate successfully, not only with our closest social circle but also with strangers (Rand & Nowak, 2013). Cooperation is a form of joint action that is carried out by two or more individuals

(Vanutelli et al., 2017). Joint action can be defined as a social interaction, in which individuals coordinate their actions in time and space in order to create a change in the environment (Michael et al., 2016). An individual takes a great risk of exploitation when deciding to cooperate (Behrens et al., 2020). So how do we determine if our counterpart is likely to cooperate and decide to cooperate ourselves? Usually, past behaviour or knowledge about the other person's beliefs and values is a good source of information, and we can make predictions about future behaviour. People are more likely to cooperate with a partner if they have seen them act prosocial before (Levine et al., 2018). But what if we do not have prior experience with our counterpart?

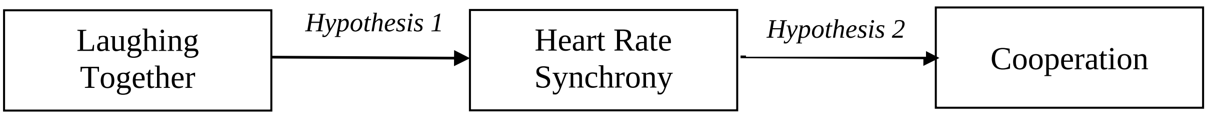
Many studies, using economic games to measure trust and cooperation, have shown that it is necessary to signal trustworthiness and an intent to cooperate to the partner. Dyads showing higher synchrony were more likely to trust their partner and decide to cooperate. Synchrony may act as a form of communicating mutual intent to cooperate. However, there is also a possibility, that synchronization happens as a by-product of cooperation and not as a factor for cooperative success (Mitkidis et al., 2015). Verdiere et al. (2020) for example, found in their study an increase in physiological synchrony between participants in a challenging task, but no relationship with task performance.

2 Research Questions

When we laugh together, we seem to feel instantly closer to our interaction partner and it may help us form a bond between each other that can help us to work together. The mechanism behind this may be interpersonal synchronization. Summarized, laughter seems to have qualities to promote interpersonal synchrony, and various studies suggest a relationship between synchrony and cooperative success. However, especially research of physiological synchrony has been very ambiguous. Therefore, in this study, I aim to investigate the relationship between physiological synchrony, promoted by laughing, and cooperation between strangers.

Hypothesis 1: Dyads that laugh together show significantly higher heart rate synchrony.

Hypothesis 2: There is a positive relationship between interpersonal synchronization of the heart rate and cooperative success.



3 Method

This study is part of an ongoing EU-funded project which aims to explore the effects of laughing together. It was conducted in the Lab of the “Wiener Kinderstudien” at the University of Vienna. The project was approved by the ethics committee of the University of Vienna, Austria. Participants took part voluntarily and they could stop at any time. Participating is not associated with any risks. All participants filled out an informed consent form and were debriefed about the aim of the study after participating.

3.1 Study Design

This study took place in a laboratory setting with a duration of maximum 120 minutes. Same-sex dyads were formed beforehand, with participants who do not know each other and with an age difference of a maximum of 4 years. One experimenter was responsible for the technical set-up and was out of view for the participants most of the time. Two additional experimenters were responsible for the front part, which included instructing the participants and setting up the equipment and materials.

As a first step participants were shortly introduced, and everything was set up. Then they filled out questionnaires behind a privacy screen, and after the manipulation phase began: In order to elicit laughter in the experimental group, participants played a funny word game and watched funny animal videos. For the word game, participant A received a gapped text and participant B a list of possible words. Without knowing the topic of the gapped text, this participant B was asked to randomly choose one word for each gap, which participant A wrote into the gaps. After filling every gap, participant A is asked to read the text out loud. In the Laughter Condition this result in a very funny text, in the Control Condition the text ends up normal and boring. In the second round, participant B received the gapped text, and participant A randomly chose the words.

For the animal videos, different videos were tested in the piloting phase of the study and two videos, which were considered funniest were then used for the testing phase. The funny animal videos consist of short clips, containing mishaps and funny situations of different animals. The control group received two neutral animal videos, which showed short clips of different animals in content and neutral poses. To ensure a minimum of manipulation, in case the participants do not find the word game or the videos funny, the background laughter of the funny animal videos was kept, and participants were able to hear it. So even if the participants themselves did not laugh, they were mutually exposed to laughter. Afterwards followed the 10-minute free interaction phase, where the participants could interact with each other, without the experimenters present in the room. Then they filled out more questionnaires and lastly, they played a cooperative game together (Fig. 1).

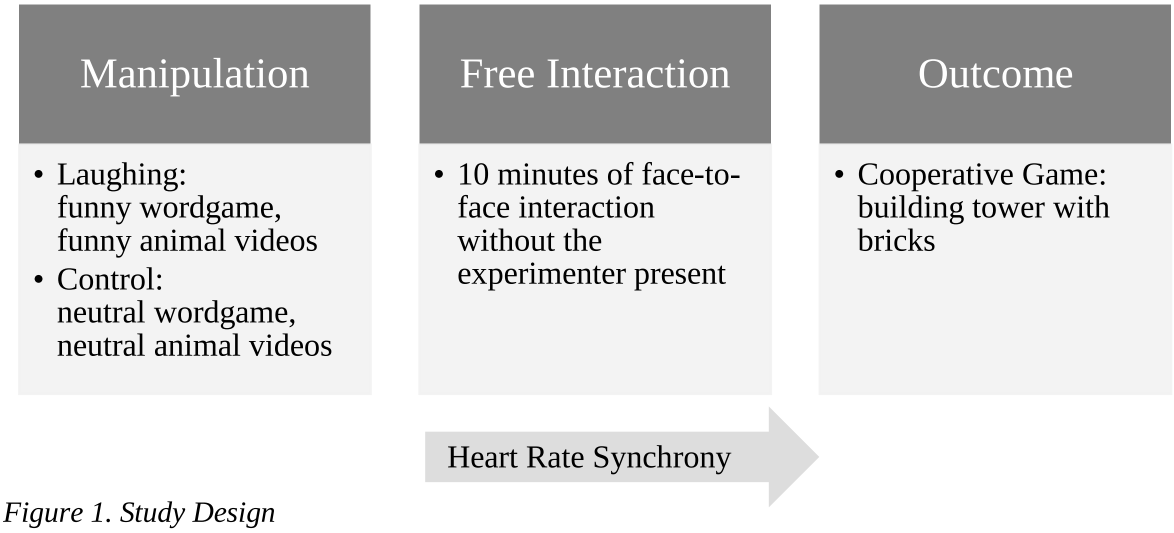


Figure 1. Study Design

3.2 Sample

Participants were recruited using flyers, the University online recruitment system (SONA), and the *Vienna Cognitive Science Hub Study Participant Platform*, as well as via various social media platforms (convenience sampling). For this reason, most participants were university students, a big part of them being psychology students. To be eligible to participate in the study, participants needed to be between 18 and 25 years of age and without any psychological or neurological diagnosis. Therefore, they had to complete a psychiatric pre-screening beforehand, which screened for Depression, Social Anxiety, and Autism Spectrum. As compensation for their participation, participants received 15€ or course credits.

The required sample size was a priori calculated with a power analysis using G*Power 3.1 (Faul et al., 2009). For the first hypothesis, analysing if dyads who laugh together show higher synchrony, a small to medium effect size of .20, according to Cohen's (2013) criteria, was assumed. For achieving a power of .80 (a = .05) for a one-tailed t-test a minimum sample size of 620 was indicated. For the second hypothesis, according to a meta-analysis by Mayo et al. (2021), an effect size of .16 of the relationship between physiological synchrony and group performance can be assumed. This expected effect size is considered small, using Cohen's (2013) criteria. The analysis indicated a minimum sample size of 237 participants for a power of .80 (α = .05) for a linear regression. However, due to time and resource constraints, these numbers could not be attained for the present study. Thus, a careful interpretation of the results was performed.

3.3 Measures

Physiological Synchrony. During the free interaction phase, physiological synchrony was measured by heart rate with an electrocardiogram (ECG). The heart rate was recorded with a 50Hz sampling frequency, using a smarting system (mBrainTrain). Three electrodes were attached, two on both the left and right side of the thorax, approximately 5cm under the collarbone, and a third electrode on the left side of the abdomen, approximately 5cm under the breast. In the first step, the recorded ECG data was converted into CSV format using MATLAB R2023b and Node.js (v18.18.2). Using a peak detection algorithm from NeuroKit2 (Makowski et al., 2021) the inter-beat interval (IBI) was calculated in Python 3.12, and afterward, the R-peaks were manually corrected using a custom dashboard hosted at https://www.ibxx.at/ibi_v2/ (Wunderwald, 2023a). Following the method of Gordon et al. (2020), the discrete IBIs were transformed to a continuous function, using cubic spline interpolation (Wunderwald, 2023b). This mathematical technique is used to estimate values between observed IBIs to ensure continuity and smoothness, as shown in Figure 2 (Kong et al., 2021).

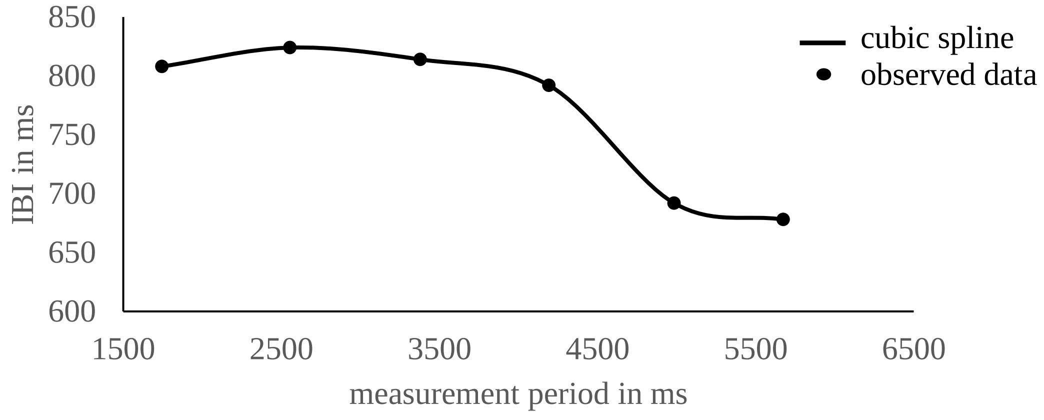


Figure 2. Cubic Spline Interpolation

The continuous function is sampled at a fixed sampling interval of 500ms in order to enable cross-correlation between participants. In a next step, the first and last minute of the 10-minute free interaction phase were excluded, because in that time, the experimenters might still be leaving or entering the room and participants are still settling. The remaining 8 minutes were split in two (Fig. 3) because there is a possibility, that the level of synchronization between the participants might change in this timespan. The first timeframe is closer to the manipulation phase and therefore might be a result of the laughter manipulation more likely, than any synchronization at a later time. However, the second timeframe is closer to the cooperative task and might have a greater influence on their success, than any synchronization before. For this reason, it is imperative to look at the two timeframes individually and compare them.

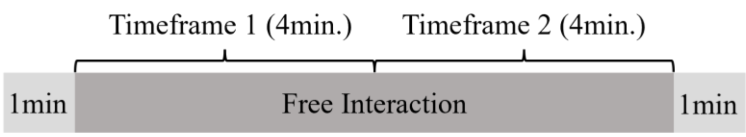


Figure 3. Timeframes of ECG in the Free Interaction Phase

To calculate the IBI synchronization between the participants within a dyad, a cross-correlation was performed (Wunderwald, 2023b) with a temporal lag of up to +/-3 seconds [data point lag = -6 to +6] to find the maximum dyadic correlations of the IBI data between participants (Gordon et al., 2020). The outcome represents the maximum level of synchrony between each dyad.

Cooperation. To quantify cooperation, the participants played the interactive game "Burg Ritter" (HABA; Tiggermann, 2006), where they had to build a tower, using a contraption that must be navigated together. This contraption consisted of an elastic band, to which two strings were attached, for each person to hold. By pulling on the strings, the participants could dilate the elastic band, put it around a brick, and lift it to the designated place. The elastic band was renewed before every testing, to ensure that it did not wear out. For every round, the participants received a template for a tower consisting of 4 bricks. At first, there was a practice round, followed by 4 rounds with a time limit of 45 seconds. To quantify cooperation in the dyads, a cooperation score was calculated. A smaller cooperation score signifies better cooperative success, and a higher score signifies less success.

$$cooperation = \frac{\text{total time spent on task}}{\text{total amount of bricks stacked}}$$

Other Measures. More data was collected within this study but has not been used for this project. These measures include fNIRS, video, audio, and different questionnaires.

4 Results

The analysis was conducted using the statistics program IBM SPSS Statistics Version 29.0.1.0 (171). The final sample consisted of 22 female dyads and 19 male dyads after excluding 1 dyad because of an experimenter error in the manipulation phase. 21 dyads were in the laughter condition and 20 dyads were in the control condition. The mean age of the participants was 21.42 years.

In a first step, dyads were analysed for a difference in their mean heart rate synchrony for the first half of the free interaction phase and the second half, using a paired sample t-test. Normality for the data can be assumed (Shapiro Wilk, p = .166). The dyads showed no significant difference in heart rate synchrony in the different timeframes (t(39) = .094, p = .926). Therefore, the maximum heart rate synchrony over both timeframes for each dyad was used in all further analysis.

4.1 Hypothesis 1

To statistically analyse, if dyads, who laugh together show a significantly higher level of heart rate synchrony (hypothesis 1), an independent sample t-test was conducted. To conduct a parametric test like the t-test, various assumptions have to be met, because it is prone to bias. The dependent variable is interval scaled, and groups are independent. Normality can be assumed (Tab. 1), and equality of the variances has been found (Tab. 2). All assumptions have been met, therefore the analysis for the t-test was continued.

Table 1

Test of Normality (Shapiro-Wilk)

		W	**p**
Synchrony	Control	.962	.579
	Laughter	.977	.872

Note. Significant results suggest a deviation from normality.

Table 2

Test of Equality of Variances (Levene's)

	F	df_1	df_2	p
Synchrony	.156	1	39	.695

Note. Significant results suggest an inequality of variances.

The dyads that laughed together showed no significantly higher synchrony of the heart rate ($t(39) = -.794$, $p = .432$) despite the laughter group (M = .184, *SD* = .064) attaining higher scores than the control group (M = .169, SD = .059) as depicted in Figure 4.

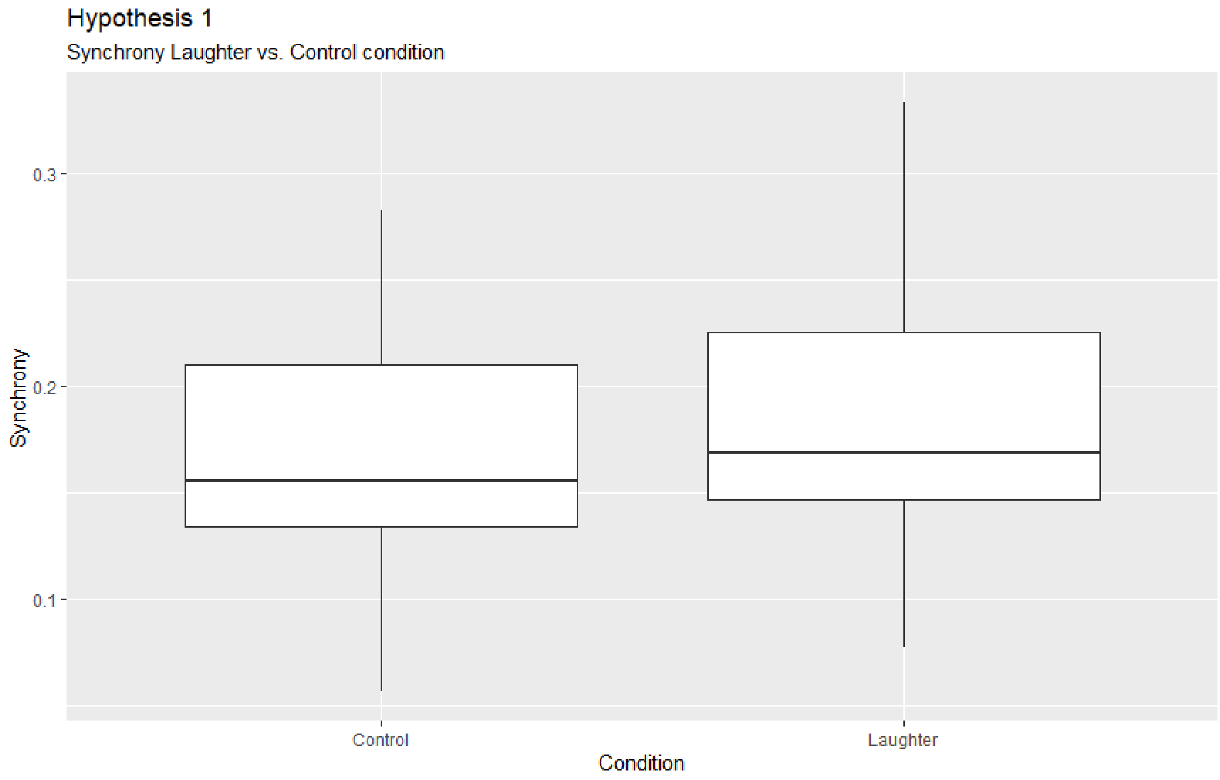


Figure 4. Group differences in heart rate synchrony

Note. Y-axis represents the strength of the cross-correlation (0 = not synchronized; 1 = fully synchronized)

4.2 Hypothesis 2

A linear regression analysis was performed to examine the association between physiological synchronization of the heart rate and cooperative success, as outlined in hypothesis 2. Outliers were analysed according to the criteria following Field (2018). For Cook's Distance, any value above 1 indicates a problematic influence on the model. For Mahalanobis Distance, which shows the distance of every observation from the mean value of all observations, a value greater than 11 is relevant for a sample greater or equal 30. The cut-off for Centered Leverage Value are values greater than $3(k + 1)/n$, in which k is the number of predictors and n is the number of cases (Field, 2018). No outliers could be identified (Tab. 3).

Table 3

Residuals Statistics

	Minimum	Maximum	Mean	Std. Deviation
Cook's Distance	.000	.432	.018	.068
Mahalanobis Distance	.018	6.480	.976	1.308
Centered Leverage Value	.000	.162	.024	.033

Note. Dependent Variable: Cooperation Score; N = 41

The assumptions for a linear regression are similar to the assumptions of the t-test. The predictor variable (heart rate synchrony) and the outcome variable (cooperation score) are interval-scaled, and the samples are independent. Evidence for normality of the residuals could not be found (Shapiro-Wilk, $p < .001$). Linearity between outcome and predictor variable can be assumed (Fig.4) and equality of variance is not clear (Fig.5).

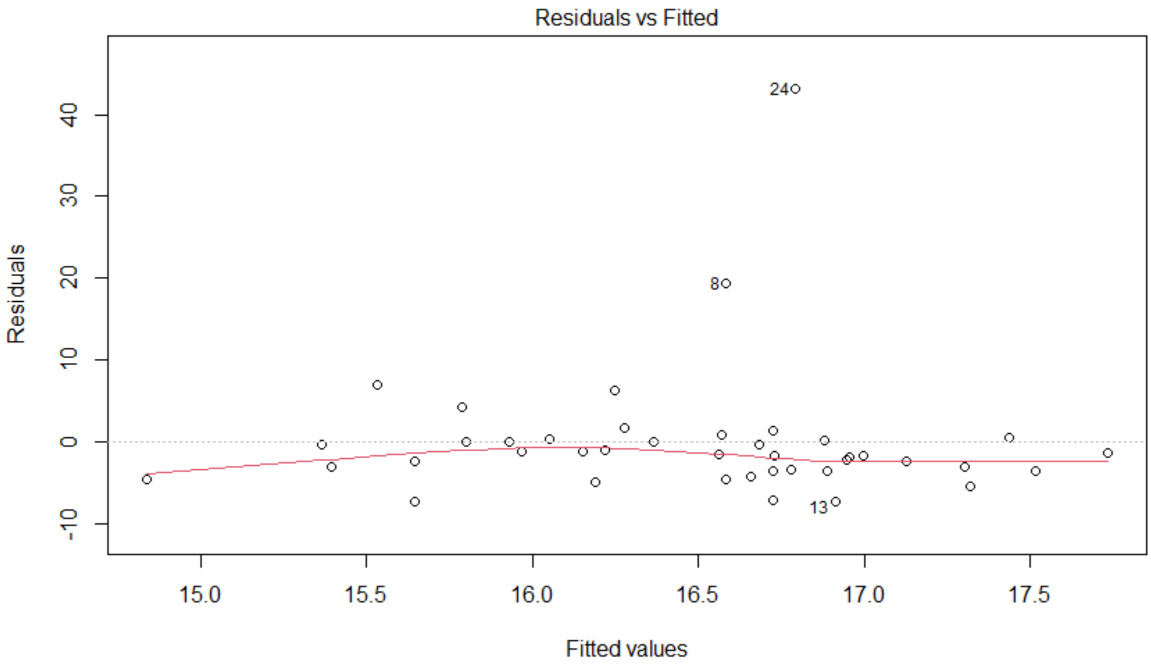


Figure 5. Scatterplot for Residuals and Predicted Values of the model

Because of the small sample size and to account for any violations of the assumptions, bootstrapping was used (Chernick, 2007). The bootstrapped linear regression model (1000 samples) was not statistically significant, indicating that the model does not provide a good fit for the data (Tab. 3).

Table 3

Linear Regression. Model fit

	Sum of Squares	df	Mean Square	F	Sig.
Regression	16.590	1	16.590	.237	.629
Residual	2727.028	39	69.942		
Total	2743.618				

Note. Dependent Variable: Cooperation; Predictors: (Constant), Synchrony

The model could only explain .6% of the variance in cooperative success ($R^2 = .006$). Furthermore, the Beta Coefficient was not significant, and the 95% Confidence Interval included 0, meaning that the predictor variable *heart rate synchrony* could not significantly predict cooperative success (Tab. 4).

Table 4

Linear Regression. Bootstrap for Coefficients

					95% Confidence Interval	
	B	**Bias**	**Std. Error**	**Sig. (2-tailed)**	**Lower**	**Upper**
Constant	18.326	.050	3.322	.005	13.001	26.370
Synchrony	-10.472	.411	12.836	.460	-41.741	14.253

Note. Bootstrap results are based on 1000 bootstrap samples

4.3 Explorative Analysis

Since no relationship between heart rate synchrony and cooperative success could be found in the results, cooperative success in the groups was looked at. Equality of variances was found (Levene’s test, p = .251), however, the assumption of normality was not met, with a significant Shapiro Wilk test (p < .001). Therefore, a non-parametric Mann-Whitney U-Test was conducted to see if the conditions generally differed in their success in the game. The groups did not show a significant difference in their cooperative success (U(39) = 254.500, p = .251). Interestingly, looking at the descriptive statistics and Figure 6, the laughter condition had in average less success (M = 16.656, SD = 10.43) in the cooperative game compared to the control condition (M = 16.288, SD = 5.457). A lower Cooperation Score signifies a better outcome. This difference is against expectations, however, not significant.

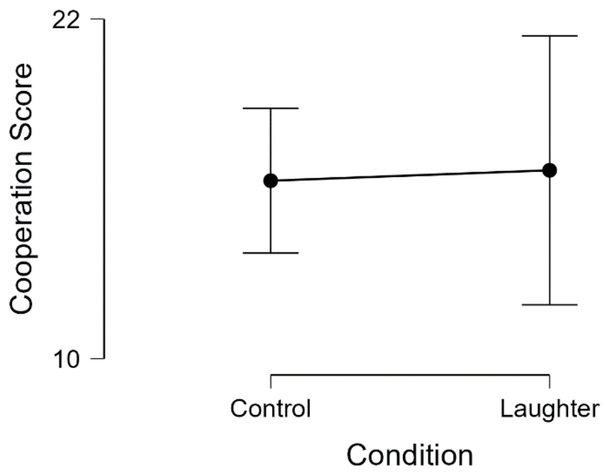


Figure 6. Cooperation Score computed of bricks stacked, and time spent on task

Because of the study's results, some preliminary data of the coded laughter during the free interaction phase of the study, where the participants had 10 minutes to interact with each other alone, was examined. 26 participants were in the Control condition and 24 in the Laughter condition. The laughter of the participants has been coded by a different team of the study project using the annotation tool ELAN (Version 6.7; Brugman & Russel, 2004). The criteria for coding laughter is based on Mazzocconi & Ginzburg (2022): Laughter starts when an audio, facial expression, or body movement related to laughter is observed. It stops when an audible or visual breath intake is perceived, or the movement stops. The difference to a smile is the co-occurrence of the above-mentioned movements. Ironic laughter or laughter during speech was coded, however, laughter under 300ms was not. Equality of variances was given (Levene's test, p = .082) and assumptions of normality have not been met (Shapiro Wilk test, p < .001). To analyse if the groups differed in their amount of laughter during the free interaction phase, a Mann-Whitney U-test was conducted. The participants in the different conditions did not show a significant difference in their total laughter (t(48) = 374.000; p = .253). Interestingly, although not reaching significance, the control group showed a higher mean amount of laughter (N = 26, M = 27.285, SD = 33.517) compared to the laughter group (N = 24, M = 27.385, SD = 20.760) as depicted in Fig. 7. It could be argued that the conditions not showing a difference in their duration of laughter levelled out the effect of the manipulation phase, leading to no differences in synchrony or cooperative success between groups.

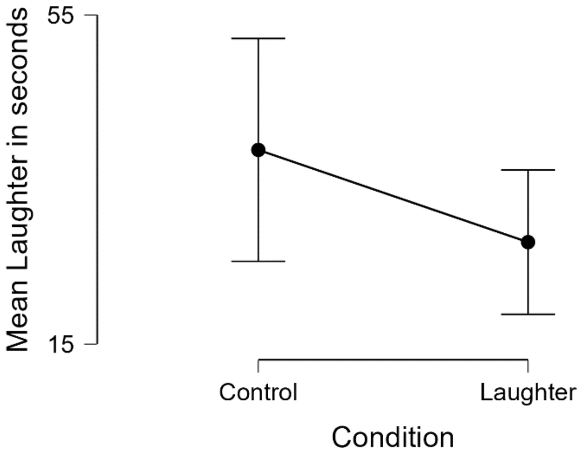


Figure 7. The average amount of laughter compared

To further explore these results for interpersonal synchrony, data from the questionnaires has been looked at. It has been theorized that synchronized individuals feel a sense of closeness and the psychological boundaries between the self and the other person tend to become weakened (Mogan et al., 2017). The Inclusion of Other in the Self Scale (IOS; Aron et al., 1992) is a single-item, pictorial measure of closeness and was used to account for the participants' subjective feeling of synchrony. For the statistical test equality of variances was found (Levene's test, $p = .084$), however the assumption of normality was not met (Shapiro Wilk test, $p < .001$). A Mann-Whitney U-Test was conducted. There was no significant difference in subjective synchrony between the Laughter group and the Control group ($U(78) = 961.000$, $p = .108$), meaning that the dyads in the different conditions did not feel subjectively more or less aligned with their partner, which is in accordance with the results from the main analysis.

Furthermore, participants were asked to rate how much they liked their interaction partner on a 7-point Likert Scale in three items to look at the influence of sympathies between participants (Lakin & Chartrand, 2003). A higher score signifies a higher liking of the interaction partner. A sum score of the three items was computed and assumptions for an independent sample t-test were examined. Equality of variances was found (Levene's test, $p = .852$), however, the assumption of normality was not met (Shapiro Wilk test, $p < .001$). Looking at a Mann-Whitney U-Test, the groups did not report a significant difference in their liking of their interaction partner ($U(78) = 959.500$, $p = .124$).

To check the manipulation phase, and especially if a general preference or dislike for funny animal videos could have a possible influence, the participants had to report, how funny they consider this type of videos overall. Equality of variances was found (Levene's test, $p = .275$), however normality cannot be assumed (Shapiro Wilk test, $p = .012$) Groups reported a significant difference in their general liking of funny animal videos ($U(36) = 108.000$, $p = .036$), with the Laughter Condition reporting a higher general liking of funny animal videos ($M = 4.35$, $SD = 1.442$) than the Control Condition ($M = 3.22$, $SD = 2.439$). One assumption for this result could be that just having watched funny animal videos, the participants of the Laughter Condition tended to rate their general liking higher, than the Control Condition, which watched neutral animal videos. This could indicate some effect of the intended manipulation.

5 Discussion

The purpose of this study was to gain a better understanding of the function of laughter in relation to physiological synchrony and their influence on cooperative behaviour. Results of this study could not support the hypothesis that people, who laugh together, show a higher level of heart rate synchrony. Furthermore, there is no supporting evidence of a positive relationship between heart rate synchrony and cooperative success. This pattern of results is consistent with previous literature, which shows an ambiguous effect of physiological synchrony on cooperation. Behrens et al. (2020) and Verdiere et al. (2020) could find no effect of heart rate synchrony on cooperation, whereas other researchers have found a significant relationship (Hoehl et al., 2021; Mayo et al., 2021; Trainor & Cirelli, 2015). One explanation for these varying results could be the quality and difficulty level of the cooperative task. Verdiere et al. (2020) argue, that physiological synchrony increases with task difficulty and workload. In their study, they could only find significant heart rate synchrony in the most difficult condition. Additionally, this high mental load resulted in less cognitive resources and lead to less cooperation, and in turn negatively influenced performance outcomes (Verdiere et al., 2020). In conclusion, results of different studies should be carefully compared, keeping in mind their operationalization.

Although no evidence for an effect of laughter on heart rate synchrony and cooperation was found in the present study, it is appropriate to not disregard this theory too quickly and recognize several potential limitations.

5.1 Limitations

The greatest limitation is definitively the sample size, which was only a fraction of the suggested sample size by the a priori power analysis. Looking at the descriptive statistics, the results seem to have a tendency towards the underlying hypothesis, but not reaching significance. The laughter condition showed slightly higher levels of heart rate synchrony. In contrast, descriptive statistics for the second hypothesis spoke against the hypothesis. Dyads in the laughter condition were on average less successful in the cooperative task. However, both hypotheses were not statistically significant, and therefore, can not be accepted. Additionally, the sample is not very representative of the general population, as most participants were university students, a large part being psychology students.

Furthermore, it would be important to take a closer look at the manipulation phase, and if it genuinely elicits more laughter in the laughter condition. Some people might not consider animal videos or word games funny. In the case of this study the laughter condition generally finds animal videos funnier than the control condition. But it must be said that they reported this after watching the videos, which could explain the difference in the groups. After watching neutral and possibly boring animal videos, the control group might have rated their liking of funny animals considerably lower. Another limitation that has to be taken into consideration is that adults might be hesitant to let themselves laugh in the context of a study. They did not know that the research topic was laughter, and a study is general considered a serious environment, where it is not common to laugh.

Now it is additionally interesting to look at the laughter of the dyads in the 10 minutes they were left alone. During this free interaction phase, the conditions showed no difference in the duration of laughter, meaning both groups laughed a similar amount in the 10 minutes before the cooperative game. As mentioned in the explorative analysis, this could have cancelled out the effect of the manipulation phase and led to no differences in synchrony and cooperation. If this were the case, different synchrony levels at the beginning and the end of the Free Interaction phase would have been expected. However, there was no difference found. Meaning, right after the Manipulation phase, there was not a higher synchronization in the Laughter condition.

Furthermore, the testing had a duration of two hours, in which the participants wore an fNIRS device for approximately 1.5 hours, which can get uncomfortable, because of the springs holding the optodes to the scalp. A lot of the participants complained about being uncomfortable and were rushing to be done. Therefore, they might not have been in the right state to be able to build synchrony with their interaction partner. For example, Miles et al., (2010) examined contextual influences on behavioural synchrony and found that dyads, where one participant showed up late to the experiment, showed significantly lower behavioural synchrony. It could be argued that the context and overall state of the participants might also have an influence on their physiological synchronization. Additionally, the validity of the game as a measure of cooperation could be questioned. Besides cooperation, this game might require compliance and communicative skills. Dyads might solve this task using different strategies, that require varying skills and behaviours.

5.2 Future Research

Some researchers suggest an epiphenomenal perspective regarding synchrony. They mention that the observed alignment of two individuals could be the result of sharing the same sensory environment during their interaction (Danyluck & Page-Gould, 2019; Mitkidis et al., 2015). Indeed, similar environmental input and working on the same task can be expected to lead to similar physiological responses with some latencies, which could falsely be interpreted as synchrony. Correlational studies will not shed light on the relationship of these phenomena, and if synchrony promotes cooperation or it is just an epiphenomenon of it. Future research should focus on evidence of causality, explore this phenomenon with more adequate sample sizes and check the validity and reliability of the measure for cooperation. Multiple measures of physiological synchrony could lead to a more holistic picture of its effects. It could also be very interesting to look at laughter, synchrony, and an effect on cooperation with friends, instead of strangers and compare these two groups.

Summed up, no definite conclusions about the interaction of laughter, physiological synchrony, and cooperation can be drawn from the present study. This highlights the complexity of social interactions and the difficulty of observing the underlying mechanisms.

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7 List of Figures

8 List of Tables

9 List of Abbreviations

ANS	Autonomous Nervous System
ECG	Electrocardiogram
fNIRS	functional near-infrared spectroscopy
IBI	Inter-beat interval
PNS	Parasympathetic Nervous System
SNS	Sympathetic Nervous System

10 Appendix

10.1 Abstract

Laughter is a universal phenomenon that plays a significant role in human social interactions. While laughter is a fast-rising research field, its purposes and functions are yet to be understood fully. It has been linked to effectively communicating positive affect and cooperative intent in interactions. Cooperation is a fundamental aspect of human society, requiring individuals to align their intentions and actions. Previous research suggests that synchronization enhances cooperative outcomes. Especially complex, rhythmic stimuli with some amount of variability and emotional meaning have been found to prompt synchronization. Laughter, being rhythmic and emotional, therefore has the potential to induce interpersonal synchrony and facilitate cooperation. This study aimed to investigate the relationship between laughter-induced heart rate synchrony and cooperative behaviour between strangers. The study involved 41 same-sex dyads of strangers, with an average age of 21.42 years. One group engaged in laughter-inducing activities, while the other served as a control. Physiological synchrony was measured using an electrocardiogram (ECG), focusing on heart rate synchronization. Cooperative behaviour was assessed through a tower-building game. The data was analysed using statistical methods, including t-tests and linear regression. Laughter seemed to not affect synchrony between strangers. Furthermore, no relationship between heart rate synchrony and cooperative success could be found.

10.2 Zusammenfassung

Lachen ist ein universelles Phänomen, das eine bedeutende Rolle in den sozialen Interaktionen der Menschen spielt. Obwohl Lachen ein schnell wachsendes Forschungsfeld ist, sind seine Zwecke und Funktionen noch nicht vollständig verstanden. Es wurde mit der effektiven Kommunikation positiver Affekte und der Absicht zu kooperieren in Verbindung gebracht. Kooperation ist ein grundlegender Aspekt der menschlichen Gesellschaft, der von Individuen erfordert, ihre Absichten und Handlungen aufeinander abzustimmen. Bisherige Forschungsergebnisse legen nahe, dass interpersonelle Synchronisation den Erfolg in Kooperationen erhöht. Insbesondere komplexe, rhythmische Reize mit einer gewissen Variabilität und emotionaler Bedeutung, haben sich als förderlich für die Synchronisation erwiesen. Da Lachen rhythmisch und emotional ist, hat es das Potenzial, zwischenmenschliche Synchronie zu induzieren und die Kooperation zu erleichtern. Diese Studie hatte zum Ziel, die Beziehung zwischen durch Lachen hervorgerufene Synchronität der Herzrate und kooperativem Verhalten zwischen Fremden zu untersuchen. Die Studie wurde mit 41 gleichgeschlechtlichen Dyaden durchgeführt, welche ein durchschnittliches Alter von 21.42 Jahren hatten. Eine Gruppe wurde in der Manipulations Phase zum Lachen gebracht, während die andere Gruppe als Kontrollbedingung nicht motiviert wurde zu lachen. Physiologische Synchronität wurde mithilfe von einem Elektrokardiogramm (EKG) gemessen, wobei der Fokus auf der Synchronität der Herzrate lag. Das cooperative Verhalten der Dyaden wurde durch ein Turmbauspiel bewertet. Die Daten wurden unter Verwendung statistischer Methoden, wie t-Test und linearer Regression, analysiert. Lachen scheint die Synchronität zwischen Fremden nicht zu beeinflussen. Darüber hinaus konnte keine Beziehung zwischen Herzraten-Synchronität und kooperativem Erfolg festgestellt werden.

10.3 Funny Word Game 1 in German

Ratschläge für das neue Baby

Wenn Sie sich auf Ihr neues Baby vorbereiten, können Sie sich (1) ________ (Gefühl) und (2) __________ (Gefühl) fühlen. Hier sind einige (3) _________ (Adjektiv) Tipps, die Ihnen bei der Vorbereitung helfen. Packen Sie Ihre Krankenhaustasche mindestens (4) _________(Anzahl) *Tag/Tage* vor Ihrem Geburtstermin. Vergessen Sie nicht, *Ihre/Ihren* (5) __________ (Nomen) und *Ihr/Ihre/Ihren* (6)____________ (Nomen) einzupacken. Bevor Ihr Baby eintrifft, sollten Sie alle (7) ___________ (Nomen) in Ihrem Haus babysicher machen, um die *empfindliche(n)* (8)___________ (Körperteil) Ihres Babys zu schützen. Denken Sie schließlich daran, gemeinsam zu (9) __________ (Aktivität), bevor das Baby kommt. Wenn Sie diese Tipps befolgen, wird die Elternschaft so leicht fallen wie (10) ____________ (Essen) essen.

1. hungrig, ängstlich, überreizt, schmutzig, peinlich berührt, eifersüchtig, unnötig, betrunken, schläfrig, unbedeutsam, krank, high, erregt, schlecht
2. durstig, aufgebläht, absurd, schuldbewusst, rachsüchtig, mörderisch, notgeil
3. extreme, unnötige, scharfe, psychopathische, dumme, interessante, wertlose, unehrliche, falsche, schlecht gemeinte, nicht erprobte, gelogene, perverse
4. 800, einen halben, 48, 420
5. Kinder, Babyzähne, Alkohol, schmutzige Unterhosen, Panikraum, Haustiere, Ersatzunterhose, Lenkradsperre, Löffel, Kamera, Ersatzreifen, Badehose
6. Nasenhaar, Toilettenreiniger, Scheidungspapiere, Bowlingkugel, Nasenhaartrimmer, Fernbedienung, Wettscheine, Fahrradpumpe, Duschgel, Nachbarin, Rollkragenpulli, rutschfeste Socken
7. Kartoffeln, Öfen, Zimmer, Messer, Leichen, Fliesen, Wände, Lampen, Fernseher, Rasenmäher, Falltüren, Kerker, 12 Toiletten
8. Nieren, Zehennägel, Riesenstirn, Augäpfel, Finger, linke Augenbraue, Ohrläppchen, Bizeps, Sixpack, Arschmuskeln
9. ertrinken, töten, schlafen, weinen, feiern, quengeln, meckern, staubsaugen, Fenster putzen, Rasenmähen, saufen, zweifeln, investieren in Bitcoins
10. Marienkäfer, Rasierklingen, Würmer, Kokain, Hunde, Käsleberkässemmel, Fliegen

10.4 Funny Word Game 2 in German

Weihnachtsmann Brief

Lieber Weihnachtsmann, Ich war dieses Jahr *ein/eine* sehr (1)____________(Adjektiv) (2)______________ (Nomen). Ich habe *meine/meinen/meiner* (3)______________ (Verwandten) bei der Aufgabe *im/in der* (4)____________ (Nomen) geholfen. Ich (5)_____________ (Verb) *den/die* (6)_____________ (Nomen) und putze (7)___________ (Nomen) jeden Tag.

Ich würde dieses Jahr wirklich gerne auf der (8)___________ (Adjektiv) Liste stehen! Ich würde mich über *eine neue/ einen neuen/ ein neues* (9)______________ (Nomen) zu Weihnachten freuen. Wenn du auch (10)______________ (Nomen) in meine Socke stecken könntest, die an

der/dem (11)____________ (Ort) hängt, wäre das (12)_______________ (Adjektiv). Fröhliche Weihnachten!

1. aggressiv, geil, krank, schlecht, gut, hungrig, eifersüchtig, unterbezahlt
2. Stripper, Junge, Mädchen, Priester, Kindergärtner, Mutter, McDonalds-Angestellte, Steuerberaterin
3. liebende Mutter, nervige Kinder, tote Oma, Sugar Daddy, kleiner Bruder, freche Schwester, reiche Tante, Cousin 10. Grades
4. Haus, Militär, Abtreibungsklinik, Kirche, Hundepark, Friedhof
5. reite, atme … ein, zerstöre, greife, liebe, ertränke, gehe, breche
6. Jesus, Familie, Hunde, Obdachlosen, Anus, Stofftiere, Häuser
7. das Bett, die Genitalien, den Schornstein, die Fingernägel, die Leichen
8. glücklichen, frechen, guten, ekligen, seltsamen
9. Katze, Freund, Freundin, Leben, Organ, Mutter
10. einen geilen Fisch, ein Buch über Körperteile, eine Dose Bohnen, eine Ameisenfarm, ein Baby, eine tote Oma
11. schwulen Sexclub, Kirche, Prostituierten, Bücherregal, bärtigen Dame
12. erstaunlich, dumm, arrogant, unanständig, schmutzig, nicht hilfreich, clever, komisch, lustig

10.5 Neutral Word Game 1 in German

Montageanleitung

Für die Montage unseres Produktes setzen wir das Vorhandensein von (1)_______________ (Nomen) voraus um den (2)_______________(Adjektiv) Aufbau, ohne Unfallgefahr, zu gewährleisten. Zuerst müssen die vorhandenen (3)_______________(Nomen) auf in der/dem (4)_______________ (Nomen) großräumig markiert werden um den Umfang des Projektes einzuschätzen. Dabei muss auch der spätere Abstand der (5)_______________(Nomen) geachtet werden, um am Ende auftretende Probleme zu vermeiden. Um die Stabilität zu gewährleisten, halten Sie einen Abstand von (6)_______________(Zahl) ein. Die besten Ergebnisse werden beim (7)_______________ (Verb) im Anschluss erzielt. Spannen Sie eine (8)_______________(Adjektiv) Schnur entlang des gewünschten Verlaufs. (9)_______________(Verb) Sie die Bauteile gemäß des geplanten Aufbaus ein. Zusätzlich zu unserer Standardreihe bieten wir Ihnen (10)_______________(Adjektiv) Ersatzteile an, welche Sie über unseren (11)_______________(Nomen) bestellen können.

1. Materialkenntnis, Sicherheitsschuhen, Schutzbrillen, Schutzhandschuhen, zwei Personen, Praxiserfahrung, Gehörschutz
2. sicheren, risikofreien, fehlerfreien, schnellen, reibungslosen, unkomplizierten, mühelosen
3. 3.Mittelpunkte, Meilensteine, Pole, Wendepunkte, Grenzpunkte, Standpunkte, Tiefpunkte
4. Aufbauzone, Gegend, Bereich, Umkreis, Areal, Grund, Abschnitt
5. Eckstücke, Wandanschlüsse, Befestigungsschellen, Winkel, U-Teile, Rohre, Pfeiler
6. 500 mm, 700 mm, 800 mm, 3 cm, 4 cm, 7 cm, 1 m
7. testen, strecken, nachziehen, biegen, glätten, falten, knicken
8. runde, gelbe, starke, dicke, belastbare, flexible, stabile
9. Legen, setzen, stellen, drehen, stapeln, graben, sortieren
10. geräuschdämmende, abgeschliffene, dehnbare, isolierende, reflektierende, leuchtende, gezackte
11. Webshop, Katalog, Telefonservice, Internetauftritt, Kundendienst, Besucherservice

10.6 Neutral Word Game 2 in German

Lerntypen

Viele Menschen sind visuelle Lerntypen – sie nehmen Informationen am besten über (1)____________ (Nomen) auf. Diese Form der Informationsübermittlung ist in letzter Zeit immer beliebter geworden – das bekannteste Beispiel ist wohl (2)______________ (Social-Media Plattform). Nicht jeder hat immer Zeit, in aller Ruhe (3)_________________ (Nomen) zu lesen. Heutzutage müssen Informationen aller Art jederzeit überall (4)_______________ (Adjektiv) und (5)_____________ (Adjektiv) verfügbar sein. Eine (6)__________________(Adjektiv) Möglichkeit sind (7) ____________ (Zahl) Sekunden Videos, die sich ohne großen Aufwand auf dem Smartphone oder Tablet anschauen lassen. Die Kombination von (8)_______________(Nomen), (9) ________________(Nomen) und (10)___________________(Nomen) macht es möglich, viele Informationen parallel zu kommunizieren. Eine Video-Anleitung sollte alle erforderlichen Informationen vollständig, aber auf das Nötigste reduziert in (11)______________ (Adjektiv) Form enthalten.

1. Videos, Bildmaterial, Bildform, Zeitschriften, Dokumentationen
2. Netflix, Snapchat, Instagram, YouTube, TikTok, Twitter
3. Anleitungen, Nachrichten, Bücher, Magazine, Artikel, Essays
4. attraktiv, effektiv, aufbereitet, anschaulich
5. schnell, smart, kompakt, sicher, klar
6. praktische, tolle, angenehme, leichte, gute, super
7. 10, 20, 30, 40, 50, 60, 70, 80, 90, 100
8. Text, Wörtern, Buchstaben, Sätzen
9. Bild, Formen, Farben, Licht
10. Ton, Musik, Geräuschen, Sound-Effekten
11. praktischer, angenehmer, effektiver, kompakter, guter, sicherer