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Investigating the Influence of Laughter on Interbrain Synchrony and Prosocial Behaviour

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Abstract

This thesis investigated whether shared laughter enhances interpersonal neural synchrony (INS) between previously unacquainted individuals and whether increased INS subsequently promotes prosocial behaviour. Grounded in relational neuroscience, laughter was hypothesized to function as a rhythmic and emotionally contagious signal facilitating neural alignment, particularly in the inferior frontal gyrus (IFG) and temporoparietal junction (TPJ). A between-subjects experimental design compared laughter and control conditions in 40 dyads (80 participants; age: 18-25 years). INS was assessed using functional near-infrared spectroscopy hyperscanning during unstructured interaction phases. Prosociality was measured through participants' willingness to provide financial gifts and helping behaviours toward their interaction partner relative to close friends. Contrary to expectations, results revealed no significant main effects of laughter on INS across the four regions of interest. However, a significant Group × Time interaction emerged in the left IFG, where control dyads demonstrated progressive neural synchronization while laughter dyads showed attenuated synchrony development over time. No significant relationships were observed between INS and prosocial intentions across any brain region. These results suggest that neural synchrony induced by laughter may not translate into INS or immediate prosocial behaviour within brief interactions between strangers. The findings highlight the relevance of the relational context, as well as the duration and type of interaction, in synchrony research. For future research, methodological adaptations are therefore recommended that address the temporal dynamics and context of the social-cognitive effects of laughter.

Keywords: *laughter, interpersonal neural synchrony, fNIRS hyperscanning, prosocial behaviour, inferior frontal gyrus, temporoparietal junction*

Introduction

"Laughter is the shortest distance between two people"
(Borge, as cited in Grothe, 2018).[1]

The Power and Universality of Laughter

Laughter is one of the most recognizable nonverbal expressions across human societies (Sauter et al., 2010; Provine, 2011). It emerges quite early in life, often within the first months of life (Gervais & Wilson, 2005) in pre-linguistic infants and is observed across disparate cultures, indicating that its core functions are biologically prepared rather than entirely dependent on cultural learning (Gervais & Wilson, 2005; Provine, 2011). Laughter is intelligible across cultures, indicating its role as a universal signal of emotional and affiliative intent (Sauter et al., 2010). Merely hearing someone else laugh can trigger laughter in one and the likelihood of laughing increases many times over when in the presence of others (Provine, 2001).

From a phylogenetic perspective, laughter is thought to stem from play vocalizations in primates, retaining structural features that signal non-threat and affiliation (Davila Ross et al., 2009). Over evolutionary time, it acquired increasingly complex social functions (Provine, 2001). Human laughter, however, is distinguished by its volitional flexibility: Cortical control over vocalization enables both spontaneous (Gervais & Wilson, 2005) and deliberately produced laughter, which allows individuals to modulate their laughter based on social intent and the communicative context (Bryant & Aktipis, 2014; Gervais & Wilson, 2005; Pisanski et al., 2016). Although commonly associated with humour and amusement, empirical research demonstrates that most of the laughter in everyday life occurs in social contexts serving bonding, agreement, or the regulation of conversational dynamics (Vettin & Todt, 2004; Bryant & Aktipis, 2014).

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[1] Although the quote is widely attributed to Victor Borge, no verifiable primary source could be located. According to Grothe (2018), it originated as "the smile is the shortest distance between two people" which Borge consistently used in interviews (e.g. in 1977 *New York Daily News)* and his autobiographical scripts.

The acoustic regularities of laughter account for its communicative power. Characterized by rhythmic bursts that vary systematically in pitch, intensity, and temporal dynamics, laughter conveys affective states and facilitates rapid recognition and emotional transmission across social partners (Vettin & Todt, 2004; Bryant & Bainbridge, 2022). Importantly, this capacity to align affective states is independent of semantic content, allowing laughter to convey affiliative intent across linguistic and cultural boundaries (Sauter et al., 2010). By entraining attention, affect, and physiological rhythms in listeners, laughter may promote interpersonal alignment.

Laughter is a common and significant part of social life, but it has received less attention than other aspects of social understanding and communication. Much of the earlier research has focused on its role in humour appreciation or health promotion, often overlooking its wider functions as an affiliative and synchronizing mechanism (Provine, 2016; Bryant & Bainbridge, 2022). Recent advances in social neuroscience such as the use of naturalistic studies and dual-brain imaging – known as hyperscanning – have renewed interest in studying how people interact in real time, rather than looking at brain activity in isolation (De Felice et al., 2025; Redcay & Schilbach, 2019).When individuals interact socially, hyperscanning reveals patterns of interpersonal neural synchrony (INS) that go beyond what would be expected from simply sharing the same experience (Hasson et al., 2012). In this light, laughter is attracting increasing attention not merely as an expression of internal states, but as a complex nonverbal signal that effectively fosters social cohesion and actively shapes interaction within groups (Arévalo-Pachón et al., 2022; Caruana et al., 2022; Dunbar et al., 2012; Navarro et al., 2016), presumably through mechanisms involving INS. Laughter's capacity to connect individuals is evident from its earliest appearances, when it becomes a fundamental means of engaging in and shaping social exchange. Thus, understanding the laughter role early in the life cycle is crucial, as it lays the groundwork for later social capacities.

Laughter in Development and Social Communication

Laughter is socially scaffolded beginning in early infancy. It emerges spontaneously at around 3-4 months in response to others' actions (Addyman & Addyman, 2013; Martin & Ford, 2018), even in children who are blind or deaf from birth (Provine, 2001). Within the first year, it serves as a central medium in reciprocal affective exchange with caregivers, where, among other important functions, it plays a role in the joint regulation of the development of emotional states (Mireault et al., 2015). Research underlines that laughter is primarily a social signal, in infants (Addyman & Addyman, 2013) as well as in preschool children (Addyman et al., 2018). The latter laugh significantly more when exposed to humorous stimuli in the presence of peers than when alone, with no notable difference between dyads and larger groups.

In adult conversation, laughter is rarely triggered by jokes – one of many potential triggers (Dunbar 2022) – it more often punctuates speech to manage conversational flow, signal agreement, diffuse tension, or convey affiliative intent (Vettin & Todt, 2004; Bryant & Bainbridge, 2022). Scott et al. (2014) emphasise that laughter's interactional functions not only express belonging and affection but also contribute to control emotional states in conversations. However, it is important to distinguish between the diverse information conveyed by laughter. Researchers attribute the question of how we use laughter to its origin in context (Scott et al., 2014). Vettin and Todt (2004) differentiate between spontaneous laughter, arising involuntarily in response to genuine affective stimuli, and deliberate laughter, produced strategically. Evidence from experimental studies suggests that spontaneous and volitional laughter are produced by different vocal systems and are both acoustically and perceptually distinguishable (Bryant & Aktipis, 2014). Laughter also occurs frequently among strangers, suggesting that it is not only influenced by relational proximity, but also the context of interaction (Devereux & Ginsburg, 2001; Vettin & Todt, 2004). Laughter is a common occurrence in conversation, with a large amount of laughter occurring immediately after the speaker's utterance according to Vettin and Todt (2004). Their findings highlight high intra-individual variability in the acoustic parameters of laughter, such as pitch and duration, underscoring its versatility. Deliberate laughter is not an involuntary reflex and can be used flexibly as a socially constructed signal. Such vocal parameters enable laughter to function as a relational signal, modulate social hierarchies, demonstrate group membership, and facilitate the alignment of affective states between partners. Thus, laughter does not just accompany social interaction but actively structures and guides it.

Beyond its ubiquity and frequent involuntary production, laughter is notably contagious (Provine, 2004). Its synchronizing potential is illustrated by "laughter epidemics," in which contagious laughter rapidly spreads through social groups, often without identifiable humour (Provine, 2001). Such phenomena may reflect emotional contagion, which can be loosely defined as the rapid and often unconscious transmission of affective states via shared channels of expression (Gervais and Wilson, 2005). The neural mechanisms linking laughter and social bonding are addressed in later sections. Provine (1992) was the first to show that even without humorous stimuli, simply hearing another person laugh easily elicits smiling or laughter in observers. Behaviourally, laughter contagion occurs in auditory perception and evokes both similar facial and vocal responses (Provine, 1992). Addyman et al. (2018) comparably report that minimal cues, such as mutual eye contact or physical mimicry, can trigger laughter in children, supporting the view that laughter is tied to embodied synchronization and may facilitate it.

Recent findings corroborate these effects, indicating that laughter can operate as a biologically grounded stimulus that induces shared affective states via rapid, automatic mimicry and resonance (Arévalo-Pachón & Cruz, 2022). This allows us to argue that laughter promotes emotional and behavioural synchrony in dyads and groups (Dunbar, 2012; Provine, 2004).

The Social Bonding Hypothesis of Laughter

Humans are deeply social beings, and the building and maintenance of interpersonal relationships is essential throughout our life. In recent years, research on human bonding has gained renewed importance (Feldman, 2017). Current findings from developmental and social neuroscience conceptualise social bonding as a dynamic process which arises from a multi-level synchronization between individuals (Zhao et al., 2024). Such synchrony occurs across affective, behavioural, physiological and neural domains (Feldman, 2017; Hoehl et al., 2021). In interaction it relies on the real-time coordination of expressive signals, embodied rhythms, and sensorimotor contingencies (Hoehl & Markova, 2018). Within this framework, bonding is understood as a mutually maintained state of interpersonal alignment that is also reflected in patterns of brain activation.

Laughter is distinctive in this context because it may engage this multi-level synchrony, simultaneously affecting emotional, behavioural, physiological, and neural processes. In line with Hoehl et al. (2021), this pattern reflects interactional synchrony, whereby coordinated multi-level activity both signals existing affiliation and actively contributes to its maintenance.

Its temporally structured and rhythmic structure (Vettin & Todt, 2004; Bryant & Aktipis, 2014) might help to facilitate interpersonal coordination, alternation, and joint regulation.

From an evolutionary perspective, Dunbar's (2003, 2012) social grooming hypothesis proposes that, over time, humans have developed multiple behaviours such as singing and dancing to promote social bonding. In this account, laughter stimulates the endorphin system, the same neurophysiological pathway implicated in primate social bonding. As human social networks grew beyond the size that could be maintained through physical grooming alone, laughter is posited to have evolved as an alternative bonding mechanism. Unlike grooming, which is dyadic and spatially constrained, laughter permits simultaneous emotional entrainment across multiple individuals (Dunbar, 2012; 2022). Furthermore, the contagious nature of laughter implies the existence of an evolved "laughter detector" mechanism that promotes affective synchrony and coordination within social groups. Navarro et al. (2016) elaborate on Dunbar's account by arguing that laughter is a augmented, more complete form of 'virtual grooming': whereas language provides for symbolic social cohesion, laughter adds a 'heavy physical massage' effect through embodied rhythm, coupled with an additional endorphin-mediated cognitive reward linked to tension release and problem-solving minimisation. These neuromolecular rewards make laughter a highly desirable signal in interactions, in which bonding is the desired outcome. In this sense, laughter is not only comparative to grooming in a tactile sense, it does one better by containing embodied, neurochemical and cognitive reinforcement in a single affiliative cue. They further propose that while laughter can occur spontaneously as an emotional response, it may also be strategically used to bring people back into agreement during small social disruptions, showing that it serves both a reflexive and intentional bonding behaviour. Whether such bonding generalises robustly to strangers absent joint history remains uncertain. Laughter may emerge in response to minor social disruptions restoring interpersonal alignment, especially in interactions where a positive outcome is desired.

These functional accounts are complemented by converging neurobiological evidence. Manninen et al. (2017) demonstrated that social laughter increased positive mood and calmness as well as activated brain regions associated with social bonding and reward. These neural responses mirror the neurochemical effects of tactile contact in affiliative contexts. On this basis, the authors argue that laughter functions as a low-cost form of grooming for reinforcing bonds in

large groups. This dynamic role corresponds with Gvirts and Perlmutter's (2020) mutual alignment model, which conceptualises bonding as a bidirectional process maintained through continuous feedback loops between partners' behavioural and neural states. Laughter, with its rhythmic timing and affective contagion, fits this framework by both reflecting current alignment and actively restoring it during interaction.

While we tend to laugh more with friends and close partners, the role of laughter in interactions with strangers is less well understood. Some studies report that stranger dyads exhibit heightened laughter frequency and duration during initial interactions, potentially reflecting social monitoring or politeness norms (Devereux & Ginsburg, 2001). In contrast, Vettin and Todt (2004) found no significant difference between stranger and friend dyads, suggesting that conversational context may moderate this relationship. Van Vugt et al. (2014) add that even unreturned laughter can initiate alignment and facilitate coordination in a social interaction. The occurrence of laughter among strangers therefore supports the idea of its capacity to facilitate bonding even in the absence of prior shared history, supporting its role as a universal bonding mechanism. This makes it particularly suitable for investigating the neural underpinnings of synchrony in social interactions.

Yet these methodological capabilities of fNIRS hyperscanning reveal tension on a theoretical level. The wavelet coherence utilized in INS research allows investigation of neural dynamics at sub-second temporal resolution, while bonding processes mediated by endorphins identified by Dunbar (2012) and demonstrated by Manninen et al. (2017) unfold over much longer temporal scales. Because these two types of temporal dynamics can be drastically different, it raises important questions about the mechanisms that fNIRS may be able to detect or not detect. While hyperscanning is a novel and effective method for testing moment-to-moment neural coordination, it could miss the slow neurochemical processes that may also serve a similar function in bonding and jointly producing laughter's affiliate effects. Both mechanisms might operate in parallel, each fostering social bonds through distinct pathways, yet our methods can only examine one. Acknowledging this limitation is an important part of considering both positive or null findings of the present study.

Despite these constraints, recent empirical findings from hyperscanning studies demonstrating that cooperative behaviours, including laughter, reliably evoke synchronization regions centrally involved in social cognition and bonding processes (Czeszumski et al., 2022, Zhao et

al., 2024). Shamay-Tsoory et al.'s (2019) "Herding Brain" model provides a neural framework for this effect, describing alignment as a feedback loop integrating error-monitoring, observation-execution, and reward systems. Laughter is well positioned to activate multiple components of this loop simultaneously, through shared motor output, affective contagion, and positive reinforcement, thereby strengthening alignment across partners. However, the precise mechanisms by which laughter's aligning effects translate into prosocial outcomes remain active areas of research (Gvirts & Perlmutter, 2019). The following section examines how such alignment manifests at the neural level, focusing on recent advances in hyperscanning.

Interpersonal Neural Synchrony

Interpersonal neural synchrony refers to the temporal alignment of neural activity across individuals engaged in real-time interaction (Hasson et al., 2012). It has emerged as a central construct in contemporary social neuroscience. As such, it is increasingly viewed not only as a correlate, but as a potential mechanism implicated in empathy, trust, and mutual understanding which are foundational capacities to the development of social bonds (De Felice et al., 2025). INS is typically operationalized as statistically significant coherence between the cortical signals of two or more individuals (Czeszumski et al., 2020).

Neuroimaging studies consistently identify the inferior frontal gyrus (IFG), temporoparietal junction (TPJ), and superior temporal gyrus as among the brain regions most consistently implicated in INS (Nguyen et al., 2021; Zhao et al., 2024; Moffat et al., 2024). These areas are centrally involved in processes such as theory of mind, emotion recognition, and perception-action coupling, thereby reinforcing the proposition that synchronized neural dynamics underpin interpersonal understanding. More specifically, INS is thought to index shared attentional focus, mutual prediction, and the real-time mapping of others' mental and emotional states (Gvirts & Perlmutter, 2020; Hoehl & Markova, 2018). Evidence suggests that the degree of neural synchrony between interaction partners is influenced by their shared pre-existing relationship. Namely, we tend to synchronize more easily with people we have a close relationship with. On the other hand, short interactions can facilitate synchronization and they both influence each other (Hoehl et al., 2021). Essentially, INS is sensitive to the affective and cooperative quality of interaction. Cooperative contexts, shared intentionality, and affectively rich exchanges are associated with increased INS (Zhao et al., 2024) whereas competitive or misaligned scenarios tend to diminish it (Lei et al., 2025). A recent meta-analysis reported consistently elevated INS across frontal,

temporal, and parietal cortices in close relationships such as parent-child and romantic dyads, suggesting that relational depth and familiarity can amplify neural coupling (Zhao et al., 2024). Couples with an established relationship history exhibit greater INS than strangers, which raises the question of whether affiliative social cues, such as spontaneous laughter, might similarly evoke heightened synchrony in newly formed dyads.

Testing these possibilities requires methods that capture reciprocal, naturalistic engagement. Hyperscanning techniques commonly used to assess INS include EEG, fMRI, and functional near-infrared spectroscopy (fNIRS), the latter of which offers particular advantages for the study of dynamic social behaviours such as laughter. Unlike magnetic resonance imaging, fNIRS allows for face-to-face interaction and supports auditory-vocal engagement to occur with minimal constraint. In addition, compared to other imaging methods, it is robust against motion artifacts and does not severely restrict participants (e.g., tolerates head and body movement) enabling natural interaction. fNIRS operates by transmitting near-infrared light in a banana-shaped curve through cortical tissue to detect oxygenated and deoxygenated haemoglobin concentrations change. A high temporal sampling rate makes it possible to detect even slight changes in neural activity during live interactions between people. Specifically, fNIRS permits capture of neural dynamics in regions critically implicated in social cognition and interaction. Therefore, fNIRS has the potential for continuous measurement of the prefrontal and temporoparietal cortex - central regions for social cognition and interpersonal alignment - in ecological valid communicative contexts (Moffat et al., 2024; Zhao et al., 2024). Conversational hyperscanning captures stable INS signatures (Kelsen et al., 2022), demonstrating the possibilities for this method to investigate laughter exchanges in a more naturalistic manner. Further, meta-analytical support indicates synchrony effects can generalize across cooperative and communicative tasks, brain regions, and participant population, structured problem-solving to spontaneous conversation (Czeszumski et al., 2022; Zhao et al., 2024), making hyperscanning a strong candidate for testing the notion that laughter could serve as an entrainment signal that impacts INS in a naturalistic real-time social interaction.

From Synchrony to Prosocial Intention

If laughter can induce neural alignment in regions implicated in social cognition, the question naturally arises: does such alignment translate into measurable prosocial outcomes? The overlap between laughter's recruitment of auditory-motor and reward systems and the regions implicated in social cognition suggests that its entrainment effects may directly engage the neural substrates most often linked to prosocial decision-making. A growing body of research indicates that interpersonal synchrony is positively associated with a range of prosocial outcomes, including cooperation, helping behaviour, rapport, and perceived closeness (Chetouani et al., 2017; Rabinowitch & Meltzoff, 2017). INS is associated with these outcomes across diverse contexts, extending to trust, empathy, and shared intentionality (Hu et al., 2017; Kinreich et al., 2017; Gvirts & Perlmutter, 2020). In controlled experimental settings, INS in prefrontal (including dorsolateral) and temporoparietal regions – areas implicated in mentalising and norm-based decision-making – has been found to mediate the relationship between behavioural synchrony and prosocial decisions via increased self-other overlap and perceived similarity (Feng et al., 2020; Hu et al., 2017; Wyss & Knoch, 2022). Yet, it remains unclear whether such synchrony plays a direct role in promoting prosocial decision-making in contexts devoid of coordinated task demands or strategic incentives. Addressing this gap, the present study examines whether INS elicited through spontaneous social laughter predicts generosity – an altruistic behaviour that reflects voluntary resource sharing. These abovementioned social-cognitive regions are therefore central candidates for linking laughter-induced alignment to generosity. Broader frameworks emphasise that prosocial behaviour is shaped by both dispositional traits (Thielmann et al., 2022) as well as context-dependent empathic and reward-processing mechanisms (Lamm & Forbes, 2023), underscoring the need to integrate neural, behavioural, and personality-level perspectives. However, the mechanisms by which synchrony translates into prosociality remain underdefined. It is unclear, for example, whether synchrony induces a shift in affective state, enhances predictive models of the partner's behaviour, or simply reinforces perceived group membership. This conceptual gap mirrors a broader tendency in prosociality research to focus on behavioural outcomes while neglecting the underlying cognitive and affective decision processes. Process-oriented accounts emphasise that moment-by-moment dynamics of attention, evidence accumulation, and affective engagement jointly shape prosocial decisions (Rahal & Fiedler, 2022), suggesting that

laughter-induced synchrony effects on generosity may be mediated by changes in both informational focus and affective valuation.

Prosocial generosity is conceptualized as a behavioural expression of altruistic motivation, often assessed via economic paradigms such as dictator games, in which individuals unilaterally choose whether and how much to share with another (Engel, 2011). Such tasks offer a relatively pure index of intention-based altruism, disentangled from reciprocity or strategic gain. Nevertheless, empirical evidence on laughter's direct impact on generosity is mixed.

For instance, the first to investigate on this matter were Dunbar et al. (2021), whose experiments revealed that, while laughter increased self-reported bonding, donations did not increase with laughter frequency or with activations of the endorphin system. participants were more generous toward friends than toward strangers, without distinguishing between themselves and a close friend. The disconnect between bonding mechanisms and prosocial behaviour indicates that the journey from shared laughter to prosocial behaviour may be mediated by additional mechanisms previously unexamined. These may include duration of interaction, reciprocal patterns of engagement, or pre-existing relational investment. The present study extends this work by examining whether INS, focuses on real-time coupling that can happen during interaction itself, and can offer a closer temporal proximity to prosocial decision-making. Synchronizing movements promotes cooperative behaviour among children toward their peers (Rabinowich and Meltzoff, 2017). A possible explanation for the decisive mechanisms underlying the synchrony effect may be also perceptual-cognitive or social-emotional in nature and not mutually exclusive.

This corresponds to the theoretical distinction between bonding mechanisms supported by neurochemical systems and strategic prosocial decisions. Laughter, with its emotionally charged and socially embedded nature, offers a naturalistic pathway by which interpersonal synchrony might lead to downstream affiliative outcomes. Thus, in theorizing the effects of laughter and INS, it is analytically useful to distinguish between affective-neurochemical outcomes (e.g., bonding, opioid release) and behavioural expressions (e.g. helping, donating). Only the latter qualify as *prosocial intention*, while the former contribute to broader prosocial outcomes, which may scaffold the motivational landscape from which such actions emerge (Marsh et al., 2021; Gvirts & Perlmutter, 2020). By capturing both neural alignment and behavioural generosity through hyperscanning, the current design seeks to link these traditionally separated levels of analysis.

The present research thus examines whether dyads exposed to spontaneous laughter exhibit heightened neural synchrony in social brain regions, and whether this synchrony predicts increased prosocial orientation toward the interaction partner. In doing so, it seeks to elucidate the neurocognitive mechanisms that bridge moment-to-moment alignment and the formation of affiliative intent, testing whether such alignment predicts generosity toward an interaction partner.

Present Study

This study specifically focuses on the inferior frontal gyrus and temporoparietal junction as regions of interest, given their established roles in action-perception coupling, mentalizing, and the dynamic modelling of others' behaviour during interaction. Accordingly, the following hypotheses were tested:

H1: INS will differ between the laughter condition and the neutral condition, with the laughter condition showing higher INS across the interaction compared to the controls.

H2: Higher levels of INS at the end of the interaction will positively predict prosocial intention scores, with the expectation that the effect may differ by experimental condition.

Methods

This study is part of an EU-funded research project called 'Laughing Together' (LT), conducted at the institute of Developmental Psychology at University of Vienna, Austria. LT aims to bring a new perspective on the significance of laughter in social interactions, combining social neuroscience and developmental psychology. LT has been authorized by the ethics committee of the University of Vienna. Participants filled out informed consent and were briefed about their right to cancel participation at any time. Upon completion, all participants were debriefed about the actual aim of the study.

Sample

The final sample comprised 40 dyads (n = 80; 42 female and 38 male) recruited using convenience sampling. 20 dyads the laughter condition and 20 in the neutral condition. Participants ranged from 18-25 years-old (*M_age* = 21,44 years; *SD*=2,01) and were divided into two subgroups in order that the difference did not exceed four years. A priori power analyses were conducted using G*Power (Faul et al., 2007) to determine the minimum required sample sizes for testing the planned hypotheses.

For Hypothesis 1, a medium effect size (Cohen's d = 0.51) was assumed. This estimate is based on comparable effects found by van Vugt et al. (2013) for laughter manipulations in social cooperation contexts and is in line with moderate condition effects reported in recent meta-analyses of dyadic INS (Zhao et al., 2024). Converting $d = 0.51$ to an ANOVA framework yields $f \approx 0.255$. With an alpha level of 0.05, desired power of 0.80, two groups (laughter vs. control), and two measurement intervals (post-manipulation and post-interaction), the required sample size was estimated to be approximately 98 dyads (49 per group).

For Hypothesis 2, a medium effect size (*Cohen's d* = 0.60) was assumed. This estimate is supported by effect sizes for the association between INS and cooperative or prosocial outcomes reported in recent hyperscanning research, with Hedges' *g* values ranging from 0.5 to 0.8 (Zhao et al., 2024). Conservatively using $d = 0.60$ yields $f^2 \approx 0.10$ for multiple regression. Assuming an alpha level of 0.05, desired power of 0.80, and two predictors (INS and condition), the required sample size was estimated to be approximately 73 dyads. Effect size assumptions for both hypotheses are consistent with comparable published findings: van Vugt et al. (2013) for condition effects on prosocial outcomes, and Zhao et al. (2024) for INS-outcomes in naturalistic dyadic contexts. However, due to time and resource constraints, the planned sample sizes were not achieved. The results should therefore be interpreted with caution. Individuals with a history of psychological or neurological diagnoses were excluded from participation. Prospective participants completed psychiatric pre-screening that included assessments for depression, social anxiety, and autism spectrum traits, alongside sociodemographic questions. Only those whose results did not indicate any psychiatric conditions or clinically relevant symptoms were invited to take part in the study. Participants were recruited through flyer distribution across university campuses and other locations frequented by young adults. Online recruitment was also conducted via the University of Vienna's SONA system and the Vienna Cognitive Science Hub Study Participant Platform. In addition, flyers were shared through various Vienna-based social media platforms, including student and chat groups. This recruitment strategy constitutes a convenience sample. Most participants were university students, with a substantial portion studying psychology. As compensation for their participation, individuals received either 15 € or course credit.

Experimental Procedure

The study followed a between-subjects experimental design with participants randomly assigned to one of two conditions: a laughter condition or a neutral interaction condition, serving

as control. Each session lasted approximately 90 -120 minutes and took place in a controlled laboratory environment at the University of Vienna ("Tropical Lab").

Participants were scheduled in same-gender dyads, matched in a way that they did not know each other. This approach controlled possible confounding effects of gender and social familiarity on interpersonal synchrony. Upon arrival, dyads were greeted by experimenters and seated face-to-face at a table. Experimenters shortly introduced themselves and their respective roles: one person for the tech-part, managing the fNIRS measures and software and two for the front-part, setting up and giving out measurements as well as communicating with the dyad. After providing informed consent, the participants were fitted with mobile fNIRS caps and instructed to minimize head movements during the recording, in line with standard recommendations for naturalistic hyperscanning studies (Czeszumski et al., 2020). The experiment consisted of three main phases: first the manipulation phase, second the free interaction phase, and third outcome phase.

In the manipulation phase, participants completed two tasks designed to modulate affect. First, they played a cloze game based on a Mad Libs template, where one participant selected random words to complete a gap-fill (cloze) story, which was then read aloud by the other. The roles were reversed for a second round. In the laughter condition, the stories were humorous, often yielding absurd or unexpected narratives. The controls followed the same structure, but the texts were affectively neutral and coherent. Furthermore, experimenters modulated their behaviour to match the assigned condition: friendly and humorous in the laughter group, compared to formal and minimally expressive in the control group.

Next, participants jointly watched two short animal video compilations, selected during piloting to elicit either laughter or mild amusement and interest. Laughter videos included comedic editing and background laughter, a known social stimulus for promoting affective contagion and interpersonal alignment (Dunbar, 2012; Manninen et al., 2017). The neutral videos were devoid of exaggerated voiceovers and had less emotional content. After instructing participants to watch and rate the videos together the front part experimenters left the room.

Following the manipulation, participants entered a 10-minute free interaction phase, which formed the basis for INS assessment. Interbrain synchrony was assessed by excerpts (each lasting five minutes) from two points during the experiment: once following the manipulation phase and once following the free interaction. These intervals were chosen to capture both task-

induced and spontaneous synchronization. At this point, the tech-part experimenter left the room, under the pretext of fetching the belated front-part experimenters. No specific instructions were given, and participants were unaware that this phase was part of the study. They remained seated across from each other and were free to engage in spontaneous conversation. The ecological validity and minimal instruction in this phase are consistent with recommendations for studying real-time, reciprocal interaction in hyperscanning research (Schilbach et al., 2013; Redcay & Schilbach, 2019). After the interaction, participants completed a brief questionnaire battery including a custom-developed prosocial intention scale (see section Prosocial Intention Measure). Although participants additionally engaged in a cooperative block-stacking game afterwards, this task and its data are not considered in the present analysis. The session concluded with a full debriefing, during which the concealed nature of the interaction phase was disclosed and the aims of the study explained, namely the investigation of laughter and synchrony.

fNIRS Optode Placement

To enable simultaneous measurement of cortical activity in both participants, fNIRS data were recorded using a dual-device setup with two mobile NIRSport 8-8 systems (NIRx Medizintechnik GmbH, Berlin, Germany). The setup employed four 2 × 2 probe sets attached to EEG caps using the international 10–20 configuration. Probe sets were positioned to target the left and right IFG and TPJ. Specifically, optodes for the IFG were placed in the regions F7 and F8, and for the TPJ around CP5 and CP6. These placements are supported by standard 10–20 system mappings to cortical regions (Okamoto et al., 2004) and have been widely used in fNIRS studies investigating language, emotion, and social interaction (e.g., Jiang et al., 2012).

The IFG and TPJ were selected as regions of interest because they are well-established cortical sites for social-cognitive processes directly relevant to this study's hypotheses. The IFG has repeatedly been linked to action-perception coupling and mirroring mechanisms, supporting the processing of rhythmic, affective vocalizations such as laughter (Kilner et al., 2009; Gervais & Wilson, 2005). The TPJ plays a critical role in mentalizing, perspective-taking, and mutual prediction during real-time interaction, which are functions hypothesized to underpin interpersonal neural synchrony (Gvirts & Perlmutter, 2020; Moffat et al., 2024; Nguyen et al., 2021). Recent hyperscanning research has confirmed robust INS effects in these regions during dyadic cooperation and joint tasks, further supporting their inclusion in studies investigating naturalistic social signals like laughter. In combination, these regions provide a theoretically and empirically

grounded basis for testing whether laughter-driven neural synchrony predicts prosocial outcomes.

In each probe set, eight sources and eight detectors were arranged to yield sixteen measurement channels per participant, with an interoptode distance of 3 cm. Near-infrared light absorption was measured at 760 and 850 nm wavelengths, and the sampling frequency was 7.81 Hz. Standard electroencephalogram caps were prepared to fit the fNIRS optodes, which were inserted into predefined slots corresponding to the desired recording sites. Three cap sizes (54 cm, 56 cm, and 60 cm circumference) were available and selected based on each participant's head circumference, measured horizontally around the widest part of the skull. Caps were fitted and aligned using inion-nasion. Short-separation channels were not included in this configuration. After cap placement, any hair obstructing optode contact was gently moved aside. To minimize ambient light interference from the experimental environment, a second opaque cap was placed over the optode cap. The quality of all channels was checked using NIRStar software, and channels with insufficient signal quality were readjusted prior to recording.

fNIRS Preprocessing

fNIRS data were pre-processed in MATLAB (The MathWorks Inc., Natick, MA). Raw recordings were first converted from. fNIRX to .nirs format to ensure compatibility with the analysis pipeline. The signal was segmented by task phase, and only data from the free interaction phase were retained. To reduce potential artefacts from experimenter movement at the start and end of this phase, the first and last minute were excluded.

Preprocessing followed established procedures using functions from the Homer2 toolbox (Huppert et al., 2009). Raw light intensity signals were converted to optical density; movement artifacts were corrected using a combination of spline interpolation and wavelet filtering. Then, the signal was bandpass filtered between 0.01 and 0.5 Hz and hemodynamic changes were computed using the modified Beer-Lambert law. Channel quality was assessed visually, with criteria including a clearly visible cardiac component and minimal motion artefacts. Channels failing to meet these criteria were excluded. These criteria followed current best practices for fNIRS hyperscanning data as outlined in Nguyen et al. (2021). Following preprocessing, relevant measures were derived to test the study's hypotheses.

Measurements

Interpersonal Neural Synchrony

INS was operationalized as Wavelet Transform Coherence (WTC) between each pair of participants within a dyad. WTC estimates the time- and frequency-resolved coherence of hemodynamic signals, capturing dynamic brain-to-brain coupling during social interaction (Grinsted et al., 2004; Nguyen et al., 2021).

For each dyad, INS was computed at two time points. The first measurement captured neural coherence immediately following the manipulation phase, reflecting synchrony during structured interaction. The second measurement was derived from the free interaction phase, representing spontaneous neural alignment during unstructured social engagement. To minimize artefacts related to experimenter movement, the first and last minute of the interaction phase were excluded.

WTC was calculated between corresponding channels in the left and right IFG and TPJ. Coherence values were averaged over the full-time segment. The final INS metric consisted of one mean WTC value per region of interest (ROI), dyad and time point respectively. These region- and interval-specific INS estimates served as predictors in the linear mixed-effects models (LME) examining their association with dyad-level prosocial intention. Higher WTC values reflect stronger temporal alignment of cortical activity between interaction partners.

Prosocial Intention Measurement

To assess participants' prosocial intentions toward their interaction partner, four custom-developed items inspired by the public goods game paradigm, a well-established approach for quantifying prosocial intentions, were administered following the interaction phase (Engel, 2011). Therefore, internal consistency and validity estimates are not available. Participants indicated how much money they would be willing to spend on a birthday gift for their interaction partner (Q1) and for a close friend (Q2), and how likely they would be to help their interaction partner move (Q3) and a friend move (Q4). Monetary generosity items (Q1 and Q2) were answered on a continuous scale ranging from 0 to 30 Euros, while helping intentions (Q3 and Q4) were rated on a 4-point Likert-type scale (1 = "very unlikely" to 4 = "very likely").

Responses were z-standardized at the individual level for each question. To isolate prosocial intentions specifically directed toward the interaction partner, two relative scores were computed for each participant by subtracting the friend baseline from the partner response (Q1 minus Q2; Q3 minus Q4). The final dyad-level prosocial intention index was then derived by averaging

these relative scores across both dyad members. Higher composite values indicate stronger pro-social intentions toward the interaction partner relative to a close friend. These measures served as primary predictors and outcome variables in the subsequent statistical models.

Other Measures

More data were collected within this study but have not been used for this project. These measures include video and audio, as well as various questionnaires and finally a cooperative task.

Results

All statistical analyses were conducted in R version 4.4.0 (R Core Team, 2024) using the following packages: lme4 (Bates et al., 2015) and lmerTest (Kuznetsova et al., 2017) for LME modelling. For all models, random intercepts for dyads were included to control for the non-independence of observations within pairs. Further used were performance (Lüdecke et al., 2021), model diagnostics and effect size estimation, boot (Canty & Ripley, 2021) for bootstrap procedures, and ggplot2 (Wickham, 2016) for data visualization. The significance level was set at $\alpha = 0.05$ for all analyses. Model assumptions were assessed through systematic diagnostic procedures for each fitted model. Normality of residuals was evaluated using Quantile-Quantile plots (Supplementary Figures D2, D4). Homoscedasticity was assessed via residuals versus fitted values plots (Supplementary Figures D1, D4). Independence assumptions were verified through examination of residuals across dyads and time intervals.

Bootstrap confidence intervals (95%) were computed for key model parameters to provide robust estimates of parameter uncertainty. Following established guidelines for bootstrap inference with mixed-effects models (Thai et al., 2013), bootstrap analysis was restricted to ROIs meeting pre-specified data quality criteria: (1) minimum 30 complete observations per ROI, and (2) less than 40% missing data to ensure stable confidence interval estimation (Supplementary Tables C7; Figure D5). Bootstrap samples (n = 500 iterations) resampled dyads with replacement while preserving the nested data structure. Percentile confidence intervals were calculated using the 2.5th and 97.5th percentiles of the bootstrap distribution. Models failing to converge in >10% of bootstrap samples were excluded from bootstrap analysis.

Fixed effects results for all models are reported in Table 1 for H1 and 2 for H2. For Hypothesis 1, region- and interval-specific INS served as the dependent variable. Fixed effects included Group (laughter vs. control), Time Interval (post-manipulation vs. post-interaction), and their interaction. Separate models were fitted for each of the four ROIs. This approach allowed testing whether the experimental manipulation influenced INS over time, and whether this effect differed by ROI.

For Hypothesis 2, dyad-level prosocial intention scores were modelled as a function of ROI-specific INS values, condition, and dyad random intercepts. Only INS values from the end of the interaction phase were included to capture synchrony emerging during unstructured social

engagement. Separate models were again estimated for each ROI to examine whether region-specific INS predicted prosocial intentions toward the interaction partner.

All continuous predictors were z-standardized prior to modelling to facilitate the interpretation of main effects and interactions. Model fit and assumptions were checked using residual diagnostics and plots of fitted values. Significant effects were followed up with estimated marginal means and simple slopes analyses where appropriate. All p-values are two-tailed, and the alpha level was set at 0.05. Effect sizes and 95% confidence intervals were computed for all relevant estimates.

Missing data were present in the INS measures due to artifacts in the fNIRS measurement and varied across ROIs (Supplementary Figure D5). Specifically, for the IFGr, 33 out of 80 possible observations were missing; 6 values were missing for IFGl; 31 for TPJl, and 21 for TPJr. Analyses were conducted on the available data per ROI using listwise deletion, resulting in different sample sizes across models.

Hypothesis 1

To test whether INS differed between experimental groups and across the course of the interaction, we estimated LMEs separately for four regions of interest: the IFG and TPJ, each in left and right hemispheres. For each ROI, INS was entered as the dependent variable, with Group (laughter vs. interaction), Time Interval (Start vs. End), and their interaction as fixed effects, while Pair was entered as a random intercept. The same model structure was used across ROIs, and results are reported separately below.

Prior to analysis, the dataset was screened for completeness and model assumptions. Visual inspection of residual plots for each linear mixed-effects model indicated approximate normality and homoscedasticity, satisfying assumptions for mixed-model estimation. Random intercepts for dyads were included to account for the non-independence of observations due to repeated measures within participant pairs. For descriptive information of the data see Supplementary Table C1.

IFGl

The model for the IFGl revealed no significant main effect of Group, $b = 0.021$, $SE = 0.024$, $t(53.92) = 0.90$, $p = .371$. However, there was a significant main effect of Time Interval, $b = 0.061$, $SE = 0.025$, $t(53.30) = 2.50$, $p = .016$, indicating that INS increased from the beginning to the end of the interaction across both groups. In addition, the Group × Time interaction was significant, $b = -0.069$, $SE = 0.033$, $t(52.60) = -2.07$, $p = .043$. This interaction effect ran counter to theoretical predictions: while control dyads demonstrated the expected increase in synchrony over time, laughter dyads showed a significantly attenuated increase, suggesting that any initial synchrony enhancement from the laughter manipulation may have dissipated during subsequent unstructured interaction.

IFGr

The model for the IFGr revealed no significant main effect of Group, $b = 0.013$, $SE = 0.030$, $t(35.26) = 0.44$, $p = .666$. The main effect of Time Interval was also not significant, $b = -0.038$, $SE = 0.035$, $t(30.69) = -1.09$, $p = .285$, suggesting that INS in this region did not reliably change from the beginning to the end of the interaction. Similarly, the Group × Time interaction was not significant, $b = -0.029$, $SE = 0.045$, $t(30.75) = -0.65$, $p = .519$, indicating that the laughter manipulation did not moderate temporal changes in IFGr synchrony.

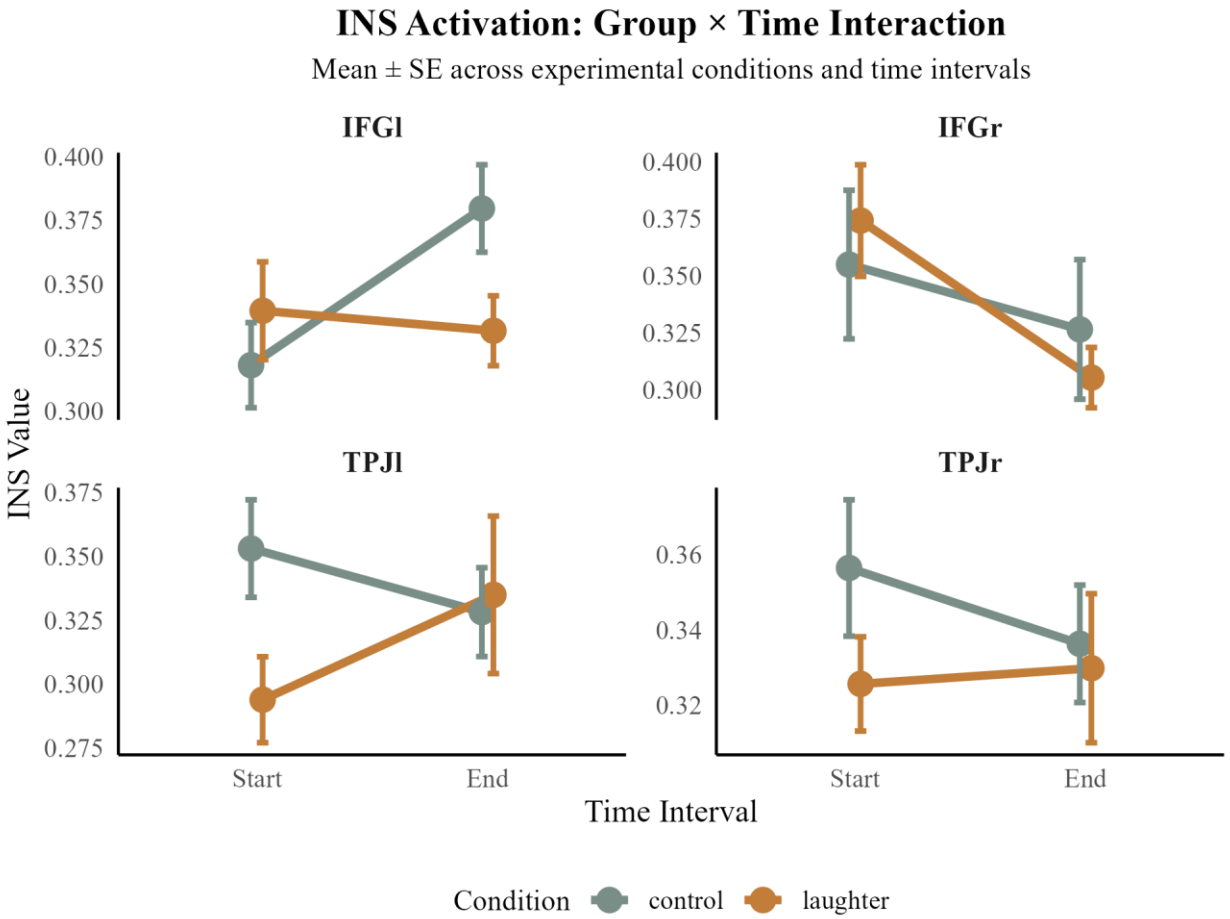
TPJl

The model for the TPJl revealed no significant main effect of Group, b = -0.057, SE = 0.029, t(38.33) = -1.93, p = .061, although this effect approached significance, suggesting a trend toward lower INS in the laughter condition compared to controls. The main effect of Time Interval was not significant, b = -0.025, SE = 0.029, t(31.47) = -0.85, p = .404, indicating no systematic change in INS across time. Similarly, the Group × Time interaction was not significant, b = 0.066, SE = 0.041, t(31.87) = 1.61, p = .118.

TPJr

The model for the TPJr revealed no significant main effect of Group, $b = -0.030$, $SE = 0.023$, $t(46.66) = -1.29$, $p = .203$. The main effect of Time Interval was also not significant, $b = -0.020$, $SE = 0.023$, $t(40.10) = -0.86$, $p = .393$, suggesting no reliable change in INS from the beginning to the end of the interaction. The Group × Time interaction was likewise non-significant, $b = 0.023$, $SE = 0.032$, $t(40.48) = 0.71$, $p = .483$.

Figure 1.



Note. Error bars represent standard error(s). Each panel shows a different brain region of interest. Lines connect group means across time intervals to illustrate Group × Time interactions.

Across the four ROIs, LMEs revealed predominantly null effects for the hypothesized laughter enhancement of INS. The most theoretically significant finding emerged in the IFGl, where a significant main effect of Time Interval (p = .016) indicated overall increases in synchrony across the interaction period. However, this effect was qualified by a significant Group × Time interaction (p = .043) that contradicted theoretical predictions: rather than showing enhanced synchrony development, laughter dyads exhibited significantly less temporal increase in neural alignment compared to controls. This pattern suggests that laughter's affiliative effects may operate through different temporal dynamics than anticipated, potentially creating initial synchrony that fails to sustain during unstructured social engagement. For the remaining regions,

no significant effects of Group, Time Interval, or their interaction were observed, with the exception of a marginal trend toward reduced synchrony in the laughter condition for TPJl (p = .061). These findings collectively challenge the hypothesis that shared laughter reliably enhances interpersonal neural synchrony in the examined brain regions.

Table 1

Fixed effects from LMEs predicting INS in all four ROIs from Group, Time Interval, and interaction (H1)

Predictor	b	SE	df	t	p	95% CI
IFGl – Group	0.021	0.024	53.92	0.90	.371	[-0.025, 0.067]
– Interval	0.061	0.025	53.30	2.50	.016*	[0.013, 0.110]
– Group × Interval	-0.069	0.033	52.60	-2.07	.043*	[-0.135, -0.004]
IFGr – Group	0.013	0.030	35.26	0.44	.666	[-0.046, 0.073]
– Interval	-0.038	0.035	30.69	-1.09	.285	[-0.107, 0.031]
– Group × Interval	-0.029	0.045	30.75	-0.65	.519	[-0.117, 0.059]
TPJl – Group	-0.057	0.029	38.33	-1.93	.061**	[-0.114, 0.001]
– Interval	-0.025	0.029	31.47	-0.85	.404	[-0.082, 0.033]
– Group × Interval	0.066	0.041	31.87	1.61	.118	[-0.016, 0.148]
TPJr – Group	-0.030	0.023	46.66	-1.29	.203	[-0.076, 0.016]
– Interval	-0.020	0.023	40.10	-0.86	.393	[-0.064, 0.025]
– Group × Interval	0.023	0.032	40.48	0.71	.483	[-0.040, 0.085]

Note. Estimates (b) are unstandardized fixed effects. Random intercepts for dyads were included in all models. Confidence intervals (95%) are based on Wald approximations. **p < .10, *p < .05.

Hypothesis 2

To test whether INS at the end of the interaction predicted prosocial behaviour, we fitted separate LMEs for each of the two ROIs in both the left and right hemispheres. For each ROI,

prosocial intention scores were entered as the dependent variable, with INS and Group as fixed effects, and Pair as a random intercept. Prior to analysis, the dataset was screened for missing values and model assumptions, and the final sample sizes varied across models due to listwise deletion of cases with missing ROI values. Visual inspection of residual plots indicated that assumptions of normality and homoscedasticity were met.

IFGl

The model for the IFGl revealed no significant main effect of INS, b = -0.035, SE = 1.741, t(27.55) = -0.02, p = .984, suggesting that neural synchrony in this region at the end of the interaction did not predict prosocial behaviour. There was also no significant main effect of Group, b = -0.117, SE = 0.225, t(18.98) = -0.52, p = .608.

IFGr

The model for the IFGr revealed no significant main effect of INS on prosocial behaviour, b = -0.465, SE = 1.406, t(23.27) = -0.33, p = .748. Group also did not significantly predict prosocial behaviour, b = -0.086, SE = 0.227, t(18.94) = -0.38, p = .707

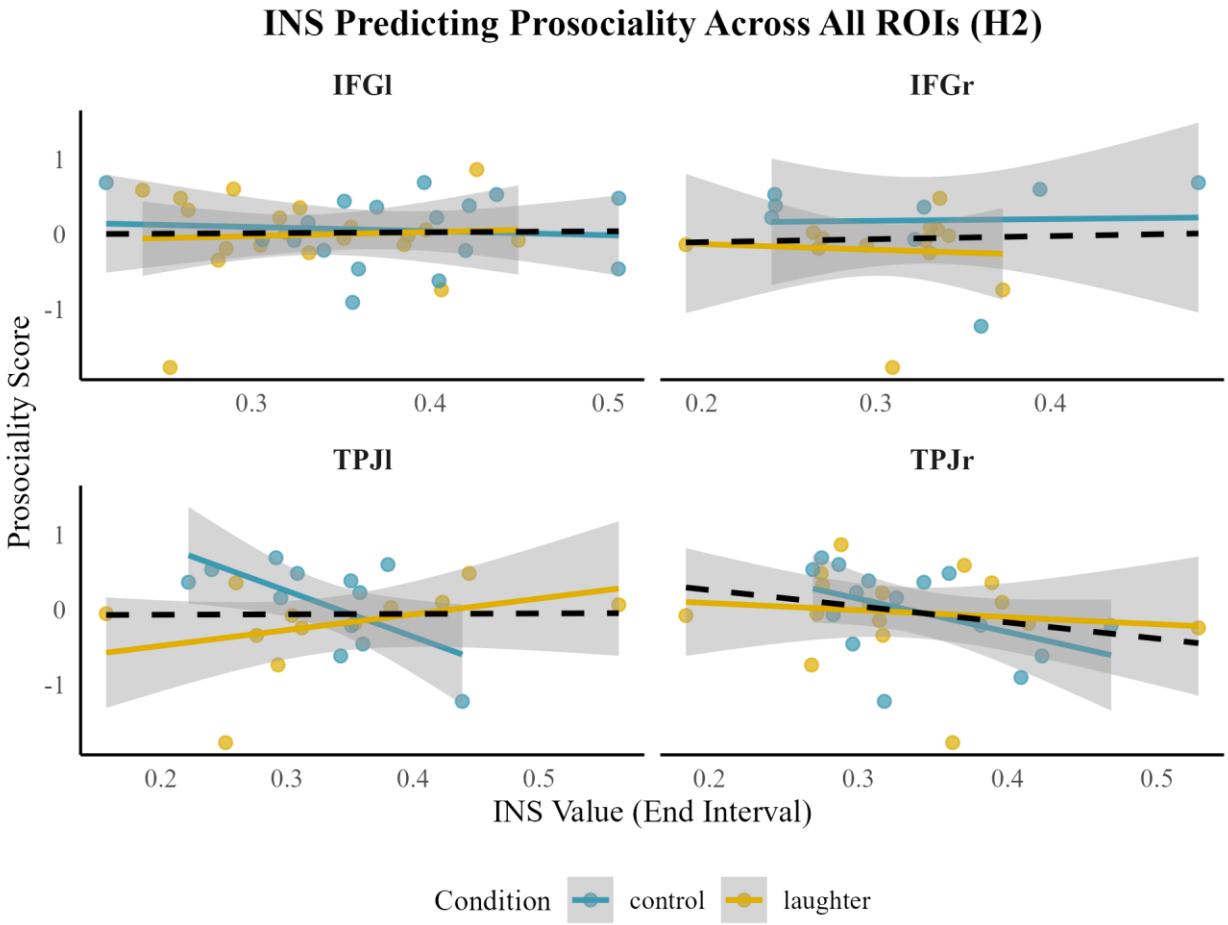
TPJl

The model for the TPJl revealed no significant main effect of INS, b = 0.125, SE = 1.479, t(21) = 0.09, p = .933. The main effect of Group was likewise non-significant, b = −0.277, SE = 0.246, t(21) = −1.13, p = .272.

TPJr

Similarly, the model for the TPJr revealed no significant main effect of INS, b = −2.175, SE = 1.538, t(28) = −1.42, p = .168. The main effect of Group was also not significant, b = −0.032, SE = 0.211, t(28) = −0.15, p = .881.

Figure 2.



Note. Coloured lines show group-specific regression lines with 95% confidence intervals. Dashed black line shows overall trend.

Across all four regions of interest, LMEs revealed no significant effects of INS at the end of the interaction on prosocial behaviour. Similarly, no significant effects of Group emerged in any model. These results suggest that, in this sample, INS in the examined ROIs did not serve as a robust predictor of subsequent prosocial intention.

Table 2

Fixed effects from LMEs predicting prosociality from INS per ROI and Interval H2

Predictor	b	SE	df	T	P	95% CI
IFGl – INS	-0.030	1.370	34	-0.02	.980	[-2.810, 2.750]
– Group	-0.062	0.188	34	-0.33	.740	[-0.444, 0.320]
IFGr – INS	-0.104	2.083	18	-0.05	.960	[-4.480, 4.270]
– Group	-0.399	0.268	18	-1.49	.150	[-0.960, 0.160]
TPJl – INS	0.125	1.480	21	0.09	.930	[-2.950, 3.200]
– Group	-0.278	0.246	21	-1.13	.270	[-0.790, 0.230]
TPJr– INS	-2.175	1.538	28	-1.42	.170	[-5.320, 0.970]
– Group	-0.032	0.211	28	-0.15	.880	[-0.460, 0.400]

Note. Estimates (b) and standard errors (SE) are unstandardized. Degrees of freedom use Satterthwaite's method. 95% confidence intervals were computed as Wald intervals. Group is coded 'laughter' vs. control. IFGl model showed singular fits (random intercept variance for Pair estimated ≈ 0), so results are effectively equivalent to fixed-effects models.

Discussion

The present study investigated the influence of shared laughter on interpersonal neural synchrony during dyadic interaction, and whether such synchrony predicted subsequent prosocial behaviour. Using fNIRS hyperscanning and linear mixed-effects modelling, we examined group (laughter vs. control) and time interval effects on INS across four ROIs and the predictive relationship between ROI-specific INS and prosocial intentions.

Contrary to expectations, shared laughter did not produce reliably increases in INS or prosocial intent. However, the pattern of findings proved more nuanced than simple null effects. In the left inferior frontal gyrus, a significant Group × Time interaction ($p = .043$) revealed that while control dyads demonstrated progressive neural synchronization throughout the interaction, laughter dyads showed significantly attenuated synchrony development over time. This finding directly contradicts theoretical predictions and suggests that laughter's neural effects may operate through different temporal mechanisms than hypothesized. In other words, dyads in the laughter condition showed no significant INS advantage over controls, nor did higher INS predict greater

willingness to help the partner. While both groups showed numerical increases in neural synchrony over time, this increase was significantly less pronounced in the laughter condition compared to controls. This suggests that laughter may have led to an initial increase in synchrony during the manipulation phase, with subsequent decline during free interaction, whereas control dyads demonstrated more sustained or progressive synchronization. Overall, these results run counter to our hypotheses and suggest that, under the present conditions, laughter was insufficient to align neural activity measurably or to generate prosocial intent. It is important to note that a null finding does not prove the absence of any effect. It simply indicates no reliable difference was detected given our sample and measures. Our findings diverge from reports that affiliative cues, including laughter, enhance synchrony (Zhao et al., 2024; Feng et al., 2020). They also challenge the proposed theoretical link between affiliation and synchrony (Feldman, 2017). At the same time, they align with studies showing that laughter's social benefits do not always translate into overt prosocial action.

The significant interaction effect in IFGl warrants careful theoretical consideration. Rather than sustaining or enhancing neural alignment, shared laughter appears to have created initial synchrony that subsequently dissipated during unstructured interaction. This pattern suggests that laughter's affiliative effects may be temporally constrained, producing immediate but transient neural coupling that fails to generalize to subsequent social engagement. Control dyads, by contrast, demonstrated the capacity for progressive synchrony development through sustained conversational reciprocity. This finding aligns with theoretical accounts distinguishing between stimulus-driven synchrony and interaction-dependent alignment, suggesting that genuine interpersonal neural coupling may require sustained mutual engagement rather than shared emotional activation. The IFGl's role in action-perception coupling and rhythmic processing (Kilner et al., 2009) may render it particularly sensitive to the immediate effects of shared laughter, while its inability to sustain this synchrony points to the limitations of stimulus-based approaches to fostering interpersonal neural alignment.

No predictive relationship between INS during interaction and prosocial intentions was discovered. Dunbar et al. (2021) similarly found that while laughter increased endorphin release as measured by pain threshold elevation and self-reported bonding, it did not reliably increase

generosity toward others. It is interesting to note that an affective prosocial outcome appears distinct from altruistic decision-making. Our results suggest that the bonding effect of laughter and the behavioural expression of helping may operate through different mechanisms or timescales.

Despite strong theoretical grounds for expecting laughter to foster neural alignment, no reliable INS increase was observed. There are several possible explanations for this outcome. One plausible interpretation is that laughter's affiliative effects may operate mainly through affective neurochemical pathways, such as endorphin-mediated bonding. Such processes may not involve moment-to-moment neural coupling of social-cognitive brain regions detectable with fNIRS (Dunbar et al., 2012; Feldman, 2012). The biobehavioural synchrony and multi-level synchrony framework posits that social bonds emerge from coordinated rhythms across neural, behavioural, and hormonal systems (Feldman, 2012; Hoehl et al., 2021). Shared laughter, as a rhythmic, affectively rich signal, was expected to engage this mechanism. Yet neural synchrony is only one observable channel; laughter might have enhanced subjective closeness without producing INS. This distinction echoes interactive neuroscience accounts separating affective bonding from synchronized cognitive-motor processes (Dunbar et al., 2021; Kinreich et al., 2017; Redcay & Schilbach, 2019).

Another explanation concerns laughter itself. While potent as a social cue, laughter may not be sufficient on its own to generate detectable INS, especially under the conditions of the present study. Genuine, spontaneous laughter is often brief and episodic (Bryant & Aktipis, 2014), producing only transient concurrent activations within social-cognitive brain regions. Moreover, the acoustic characteristics, frequency, and type of laughter were not systematically examined here, leaving open the possibility that only certain laughter, or certain interactional context in which it arises, elicit robust INS. Gvirts and Perlmutter (2020), for example, argue that stronger and more engaging interactions, such as tasks requiring continuous coordination or empathy, produce more robust INS. In our study, the laughter induction did not require sustained reciprocal engagement at a cognitive level. It might indicate that laughter alone did not impose enough shared attention or joint action to drive neural alignment in a dyad of unacquainted individuals.

It is also worth considering the relational context: As Hoehl et al. (2021) emphasise, INS is shaped not only by interactional signals but also by the depth and history of the relationship. Higher synchrony is typically observed in close friends, romantic couples, parent-child pairs

compared to strangers (Kinreich et al., 2017; Zhao et al., 2024). In the present study, all participants were strangers. Laughter may have signalled affiliation and enhanced mood yet lacked the relational grounding to elicit the neural coupling detectable by fNIRS. The WTC method alone, used in the present study may have lacked sensitivity to such synchrony. This corresponds with social bonding theories, which propose that while laughter can initiate affiliative processes, the emergence of INS may require either an extended shared history or more structured cooperative engagement.

Previous hyperscanning studies confirm that cooperative interaction and shared affective experience can elicit increased INS, particularly in frontal, temporal, and parietal cortices (Hu et al., 2017; Zhao et al., 2024). Such effects are typically strongest in structured joint tasks and close relationships and can be amplified by emotionally engaging contexts (Hu et al., 2022). In Li et al. (2022), for instance, the participant's shared emotion was immediately followed by a synchronous cooperation task, which may have reinforced neural coupling. In contrast, our design assessed INS during an unstructured post-laughter interaction, and prosocial intentions were measured with a self-report questionnaire rather than an online cooperative performance. It is possible that without an explicit joint task any transient alignment from laughing together dissipated quickly.

Additionally, some hyperscanning research indicates that physical or contextual factors can influence results. For example, face-to-face contact and mutual gaze reliably enhance neural synchrony (Czeszumski et al., 2020). Our laughter manipulation was partly stimulus-driven (watching a funny video and humorous text), the resulting INS might owe more to each individual's response to the stimulus than to interactive neural coupling.

In summary, while the literature demonstrates that cooperative and affective entrainment can result in increased INS, the absence of evidence in our case suggests the type and depth of engagement were insufficient to produce the same effect. This underscores the idea that INS appears to be a sensitive measure of interactive alignment: it emerges clearly under certain social and emotional conditions but may be minimal when those conditions are not fully met (Czeszumski et al., 2020).

Certain limitations could have influenced the results obtained. The temporal dynamics observed in IFGl highlight the importance of measurement timing in hyperscanning research. Our assessment periods may have captured synchrony decay rather than sustained alignment,

suggesting that future studies should examine longer interaction periods or employ continuous measurement approaches to fully characterize laughter's neural effects. A major source of unreliability lies in our sample size and statistical power: With 40 dyads, our sample was underpowered relative to the a priori target (~98 dyads) to detect medium effects. Low power increases the risk of false negatives; hence a subtle INS effect of laughter might have gone undetected. The effect sizes reported in the literature on INS and prosocial outcomes vary from small to moderate (Zhao et al., 2024) to large (Czeszumski et al., 2022), which makes this limitation important.

Another limitation of the current study is that laughter was induced in a laboratory setting, which raises concern about ecological validity. Informal participant feedback also suggested that the humour stimuli might not have been uniformly engaging, as some participants did not find the animal videos amusing. This variability in humour perception may have weakened the experimental manipulation, and consequently the INS effect. Moreover, without systematic coding of laughter, such as counting laugh bouts, rating laugh type and intensity, it is uncertain whether all dyads experienced similar mirth. Therefore, it remains unclear whether the laughter was uniformly affiliative, socially contagious or polite, each of which may differentially affect INS. In addition, debriefing conversations with several participants indicated they could not suspend disbelief in the deception that preceded INS measurements. If participants are conscious of being measured, and hence are unable to act naturally, it is probable that both their responsivity and spontaneity are reduced, thus affecting the authenticity of the social exchange.

Inevitably, some limitations pertain to ecological validity. Whereas social laughter often occurs in comfortable and familiar contexts, our participants were fitted with fNIRS caps, aware of continuous video observation and monitored by multiple experimenters. These conditions may have weakened laughter's affiliative impact. Additionally, fNIRS caps, when worn for a prolonged time, can cause physical discomfort, due to pressure sensation. These reasons may influence participants' emotional states and, subsequently, their dyadic interaction. All things considered, it is likely the study's setup may have captured laughter out of context, limiting participants' ability to bond. However, even if these limitations are endemic to many neuroimaging setups and difficult to sidestep, it is still important examining them, especially considering the push for naturalistic settings (De Felice et al., 2025). Importantly, this also applies to laughter as a research subject: Both in the laboratory and in naturalistic settings, it remains technically challenging to capture its social and expressive nature (Caruana et al., 2022).

Finally, our measure of prosocial intention may not have captured the full effect. Participants were asked to self-report their intent to help their partner, but it is possible that the effects of laughter on generosity are subtle or indirect, emerging in naturalistic interaction, possible over time, rather than as immediate survey response. For example, Dunbar et al.'s (2021) participants expressed an increase in bonded feelings after laughter, but not in one shot donations. Our null result on prosocial intention could similarly indicate that while participants enjoyed laughing together, it may be that bonding and prosocial intention are mediated by partially distinct neurobiological systems and motivational architectures. It seems possible that endorphin-based bonding processes indeed fosters affiliative alignment, rather than directly activating altruistic acts. Also, as Dunbar et al. describe, prosocial intent may be less contingent on transient affiliative signals like laughter and more on the intensity and duration of previously forged bonds, reinforcing the idea of relational contexts to consider. As such, this consideration provides many opportunities for further research on laughter, INS, and prosocial outcomes.

Only a handful of studies have tackled the challenge of systematically breaking down the acoustic, temporal, and contextual properties of laughter in hyperscanning paradigms. In future studies, researchers should consider incorporating systematic behavioural coding of laughter (e.g., frequency, spontaneous vs. intentional, acoustic profile) to distinguish different types of laughter (Bryant & Aktipis, 2014; Vettin & Todt, 2004). Preselection and calibration of humour stimuli appropriate to the target group would ensure consistent levels of emotional relevance and in turn, consistent engagement. The broader theoretical implications that arise from this study also need to be considered. The present study did not assess individual-level factors such as personality traits. Future studies could utilize validated measures of personality to investigate how differences in personality affect the neural and behavioural responses to laughter (Scott et al., 2014). In addition, it is currently unknown if laughter-induced INS requires simultaneous behavioural synchrony (e.g., gaze alignment, coordinated movement) to increase prosocial outcomes; this is critical to develop a link between momentary synchrony and more lasting social consequences. Design adjustments also seem reasonable. Repeated interaction designs could incorporate both relationship type and long-term bonding trajectories to test whether laughter cumulatively facilitates synchrony and affiliation across multiple interactions.

This approach would integrate relational history with real-time affective cues (Kinreich et al., 2017; Redcay & Schilbach, 2019). Longitudinal data would also allow researchers to assess

if any laughter-induced INS or prosocial outcomes persist beyond the current interaction, and how such outcomes get influenced by interaction frequency, duration, or mode (Nummenmaa et al., 2021). This would be key in understanding long-term dynamics, as well as evaluating the stability and generalizability of synchrony effects at both neural and behavioural levels. Future research should also adopt a mechanistic focus. Incorporating physiological synchrony measures, such as heart rate variability or skin conductance, would allow explicit testing of multi-level synchrony models (Feldman, 2017; Nummenmaa et al., 2021). Experimental designs could also disentangle bonding from prosocial decision-making by using subjective closeness ratings, and behavioural generosity tasks, across time, to clarify whether laughter's prosocial effects operate via shared emotional states, cognitive alignment, or both.

In conclusion predominantly null findings were obtained for reassessment of laughter's associated relationship to interpersonal neural synchrony. Clear reporting of these null findings is critical for building cumulative science. Drawing on findings from social neuroscience and through continual improvements of experimental designs, future research can better determine the nuanced role of shared laughter in synchronizing dyads or groups of interaction partners. Though laughter undoubtedly fosters subjective bonding, its impact on neural synchrony and overt prosocial behaviour appears more complex than anticipated, depending on the quality of the interaction, relational context, and methodological precision. Continued interdisciplinary work will help clarify how, and when, this phenomenon aligns our minds and supports us in social interaction.

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List of Abbreviations

CI	Confidence Interval
fNIRS	Functional Near-Infrared Spectroscopy
H1 / H2	Hypothesis 1 / Hypothesis 2
IFG	Inferior Frontal Gyrus
IFGl	Left Inferior Frontal Gyrus
IFGr	Right Inferior Frontal Gyrus
INS	Interpersonal Neural Synchrony
LME	Linear Mixed-Effects Models
LT	Laughing Together
ROI	Region Of Interest
SE	Standard Error
TPJ	Temporoparietal Junction
TPJl	Left Temporoparietal Junction
TPJr	Right Temporoparietal Junction
WTC	Wavelet Transform Coherence

Appendix

A. Abstract

This thesis investigated whether shared laughter enhances interpersonal neural synchrony (INS) between previously unacquainted individuals and whether increased INS subsequently promotes prosocial behaviour. Grounded in relational neuroscience, laughter was hypothesized to function as a rhythmic and emotionally contagious signal facilitating neural alignment, particularly in the inferior frontal gyrus (IFG) and temporoparietal junction (TPJ). A between-subjects experimental design compared laughter and control conditions in 40 dyads (80 participants; age: 18-25 years). INS was assessed using functional near-infrared spectroscopy hyperscanning during unstructured interaction phases. Prosociality was measured through participants' willingness to provide financial gifts and helping behaviours toward their interaction partner relative to close friends. Contrary to expectations, results revealed no significant main effects of laughter on INS across the four regions of interest. However, a significant Group × Time interaction emerged in the left IFG, where control dyads demonstrated progressive neural synchronization while laughter dyads showed attenuated synchrony development over time. No significant relationships were observed between INS and prosocial intentions across any brain region. These results suggest that neural synchrony induced by laughter may not translate into INS or immediate prosocial behaviour within brief interactions between strangers. The findings highlight the relevance of the relational context, as well as the duration and type of interaction, in synchrony research. For future research, methodological adaptations are therefore recommended that address the temporal dynamics and context of the social-cognitive effects of laughter.

Keywords: *laughter, interpersonal neural synchrony, fNIRS hyperscanning, prosocial behaviour, inferior frontal gyrus, temporoparietal junction*

B. Summary

Diese Arbeit untersuchte, ob gemeinsames Lachen die interpersonelle neurale Synchronizität (INS) zwischen Fremden fördert und ob eine erhöhte INS anschließend prosoziales Verhalten fördert. Basierend auf Erkenntnissen der sozialen Neurowissenschaft wurde die Hypothese aufgestellt, dass Lachen als rhythmisches und emotional ansteckendes Signal fungiert, das die neurale Synchronizität erleichtert, insbesondere im inferioren Frontallappen (IFG) und im temporo-parietalen Übergang (TPJ). In einem experimentellen Design wurden Lach- und Kontrollbedingungen bei 40 Paaren (80 Teilnehmenden; Alter: 18–25 Jahre) verglichen. Die INS wurde mittels funktionellem Nahinfrarotspektroskopie-Hyperscannings während unstrukturierter Interaktion gemessen. Prosozialität wurde anhand der Bereitschaft der Teilnehmenden gemessen, den Interaktionspartner:innen im Vergleich zu engen Freund:innen finanzielle Geschenke zu machen und ihnen zu helfen.

Entgegen den Erwartungen zeigten die Ergebnisse keine signifikanten Haupteffekte des Lachens auf die INS in den vier untersuchten Hirnarealen. Allerdings zeigte sich eine signifikante Wechselwirkung zwischen Gruppe × Zeit im linken IFG. Die Kontrollgruppe wies eine fortschreitende neurale Synchronisation auf, während die Paare in der Lachbedingung im Laufe der Zeit eine abgeschwächte Synchronisation zeigten. In keinem der untersuchten Hirnareale wurden signifikanten Zusammenhänge zwischen INS und prosozialen Absichten beobachtet.

Diese Ergebnisse deuten darauf hin, dass neurale Synchronizität, die durch Lachen hervorgerufen wird, sich möglicherweise nicht in INS oder unmittelbarem prosozialem Verhalten innerhalb kurzer Interaktionen zwischen Fremden niederschlägt. Die Ergebnisse heben die Relevanz des Beziehungskontexts, sowie der Dauer und Art der Interaktion in der Synchronizitätsforschung hervor. Für zukünftige Forschungen werden daher methodische Adaptionen empfohlen, die sich der zeitlichen Dynamik und dem Kontext der sozial-kognitiven Effekte des Lachens widmen.

Schlagwörter: *Lachen, Interpersonelle Neurale Synchronizität, fNIRS Hyperscanning, Prosoziales Verhalten, Gyrus frontalis inferior, temporo-parietaler Übergang*

C. Supplementary Tables

Table C1

Descriptive statistics for INS by ROI, group, and time interval (H1)

ROI × Interval	Group	N	Means	SD	Std. Error
IFGl – Time Point 1 (Start)	control	17	0.318	0.069	0.017
	laughter	20	0.339	0.086	0.019
	Total	37	0.329	0.078	0.013
IFGl – Time Point 2 (End)	control	17	0.379	0.071	0.017
	laughter	20	0.331	0.061	0.014
	Total	37	0.353	0.069	0.011
IFGr – Time Point 1 (Start)	control	11	0.355	0.108	0.033
	laughter	15	0.374	0.095	0.024
	Total	26	0.366	0.099	0.019
IFGr – Time Point 2 (End)	control	8	0.326	0.087	0.031
	laughter	13	0.305	0.048	0.013
	Total	21	0.313	0.064	0.014
TPJl – Time Point 1 (Start)	control	12	0.353	0.066	0.019
	laughter	13	0.293	0.061	0.017
	Total	25	0.322	0.069	0.014
TPJl – Time Point 2 (End)	control	12	0.328	0.060	0.017
	laughter	12	0.335	0.107	0.031
	Total	24	0.331	0.085	0.017
TPJr – Time Point 1 (Start)	control	14	0.356	0.068	0.018
	laughter	14	0.325	0.047	0.013
	Total	28	0.341	0.059	0.011
TPJr – Time Point 2 (End)	control	15	0.336	0.060	0.016
	laughter	16	0.329	0.079	0.020
	Total	31	0.333	0.070	0.013

Table C2.

Descriptive statistics for INS by ROI, group, and time interval (H2)

			INS		Prosociality		
ROI		**n**	**M**	**SD**	**M**	**SD**	**r**
IFGl	Control	17	0.380	0.071	0.055	0.482	-0.081
	Laughter	20	0.332	0.061	-0.005	0.561	0.060
IFGr	Control	8	0.327	0.087	0.188	0.619	0.033
	Laughter	13	0.305	0.048	-0.209	0.543	-0.066
TPJl	Control	12	0.328	0.060	0.076	0.587	-0.627
	Laughter	12	0.335	0.107	-0.201	0.590	0.382
TPJr	Control	15	0.336	0.060	-0.019	0.581	-0.462
	Laughter	16	0.330	0.079	-0.036	0.609	-0.123

Note. INS operationalized as Wavelet Transform Coherence between each pair of participants within a dyad measured after the free interaction. Prosocial behavior scores represent standardized composite measures of helping, sharing, and cooperative behaviors assessed in post-scanning behavioral tasks. r = Pearson correlation coefficient between neural activity and prosocial behavior within each condition.

Table C3.

Random Effects Variance Components LMEs Testing (H1)

ROI	Random Effect	Variance	SD	Observations	Groups
IFGl	Pair (Intercept)	0.000108	0.0104	74	20
	Residual	0.005150	0.0718	—	—
IFGr	Pair (Intercept)	0.002030	0.0451	47	18
	Residual	0.005350	0.0732	—	—
TPJl	Pair (Intercept)	0.000538	0.0232	49	17
	Residual	0.005197	0.0721	—	—
TPJr	Pair (Intercept)	0.000522	0.0229	59	19
	Residual	0.003711	0.0609	—	—

Note. SD = standard deviation. Random intercepts for participant pairs account for between-dyad variability in baseline neural activity. Residual variance represents within-participant variability

across experimental conditions and time intervals. All models converged successfully without boundary (singular) fit warnings.

Table C4

Random Effects Variance Components for LMEs (H2)

ROI	Random Effect	Variance	SD	Observations	Groups	Convergence
IFGl	Pair (Intercept)	0.000	0.000	37	20	Singular fit
	Residual	1.060	1.030	—	—	—
IFGr	Pair (Intercept)	0.000	0.000	21	15	Singular fit
	Residual	0.987	0.994	—	—	—
TPJl	Pair (Intercept)	0.000	0.000	24	16	Singular fit
	Residual	1.030	1.020	—	—	—
TPJr	Pair (Intercept)	0.000	0.000	31	19	Singular fit
	Residual	1.000	1.000	—	—	—

Note. Results from standardized models predicting prosocial behaviour scores. All models exhibited boundary (singular) fit warnings with random effect variance estimates of zero, indicating insufficient between-participant clustering to support the specified random effect structure. Residual variance represents total unexplained variability.

Table C5.

Bootstrap Analysis

ROI	Original Estimate	Mean	SE	Lower CI	Upper CI	Successful boots
IFGl	0,021392	0,022813	0,025490	-0,027589	0,073850	500
TPJr	-0,030299	-0,030533	0,021491	-0,069144	0,013600	500

Table C6.

Model Fit Indices for linear mixed-effects models by region of interest (H1)

ROI	AIC	BIC	logLik	deviance	R2_marginal	R2_conditional
IFGl	-145.08572	-131.26133	78.54286	-157.08572	0.08571674	0.1045508
IFGr	-70.05088	-58.95000	41.02544	-82.05088	0.09958251	0.3474489
TPJl	-82.93757	-71.58665	47.46879	-94.93757	0.07311164	0.1600911
TPJr	-122.60507	-110.13985	67.30254	-134.60507	0.03134015	0.1508701

Note. AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; logLik = log-likelihood. R^2 Marginal reflects variance explained by fixed effects; R^2 Conditional reflects variance explained by both fixed and random effects. Models were specified with random intercepts for dyads.

Table C7.

Model Fit Indices for linear mixed-effects models predicting prosociality from INS (H2)

ROI	AIC	BIC	logLik	R^2_marginal	R^2_conditional	Singular Fit
IFGl	67.74	75.80	-28.87	0.003	NA	Yes
IFGr	44.07	49.29	-17.03	0.102	NA	Yes
TPJl	51.48	57.37	-20.74	0.052	NA	Yes
TPJr	63.07	70.24	-26.53	0.063	NA	Yes

Note. AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; logLik = log-likelihood; REMLcrit = restricted maximum likelihood criterion; R^2m = marginal R^2 (variance explained by fixed effects); R^2c = conditional R^2 (variance explained by fixed and random effects). All H2 models showed singular fits (random intercept variance for Pair estimated ≈ 0), making conditional R^2 not estimable. Results are effectively equivalent to linear regressions with fixed effects only.

Table C8.

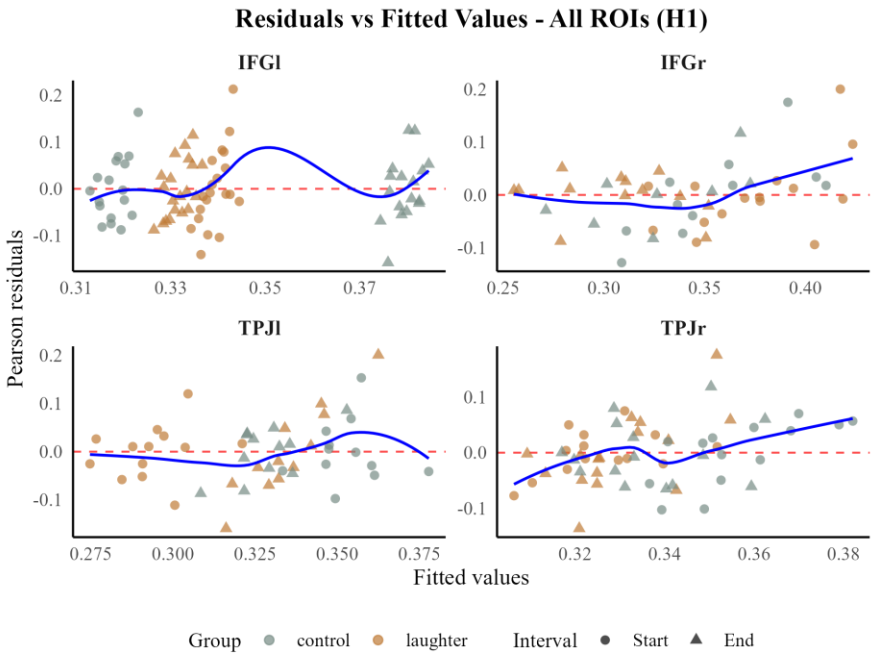
Missing values in INS by ROI and hemispheres

ROI	Interval	Total	Available	Absolute Missing	Completion Rate (%)
IFGl	1	40	37	3	92.5
	2	40	37	3	92.5
		80	74	6	92.5
IFGr	1	40	26	14	65.0
	2	40	21	19	52.5
		80	47	33	58.8
TPJl	1	40	25	15	62.5
	2	40	24	16	60.0
		80	49	31	61.3
TPJr	1	40	28	12	70.0
	2	40	31	9	77.5
		80	59	21	73.8

Note. Missing data patterns reflect participant-specific motion artifacts, signal dropout, or anatomical coverage limitations during fNIRS acquisition.

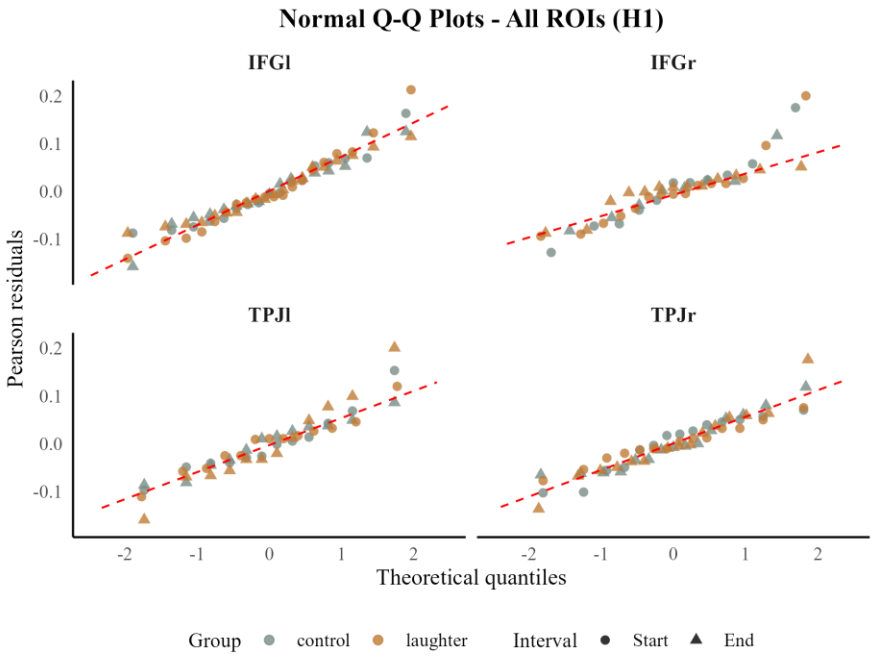
D. Supplementary Figures

Figure D1



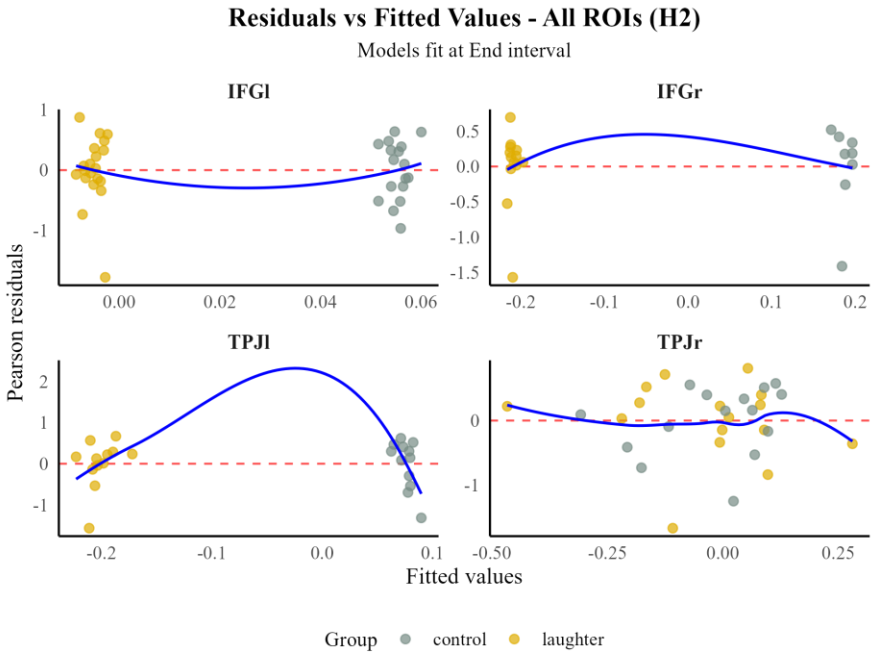
Note. Blue line shows LOESS smooth.

Figure D2



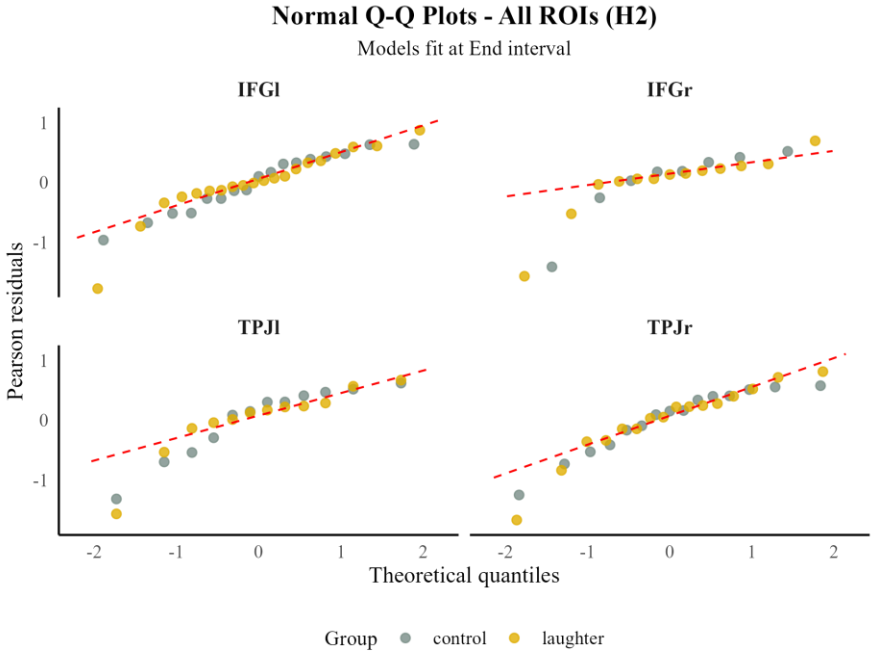
Note. Points near the red dashed line indicate approximate normality of residuals.

Figure D3



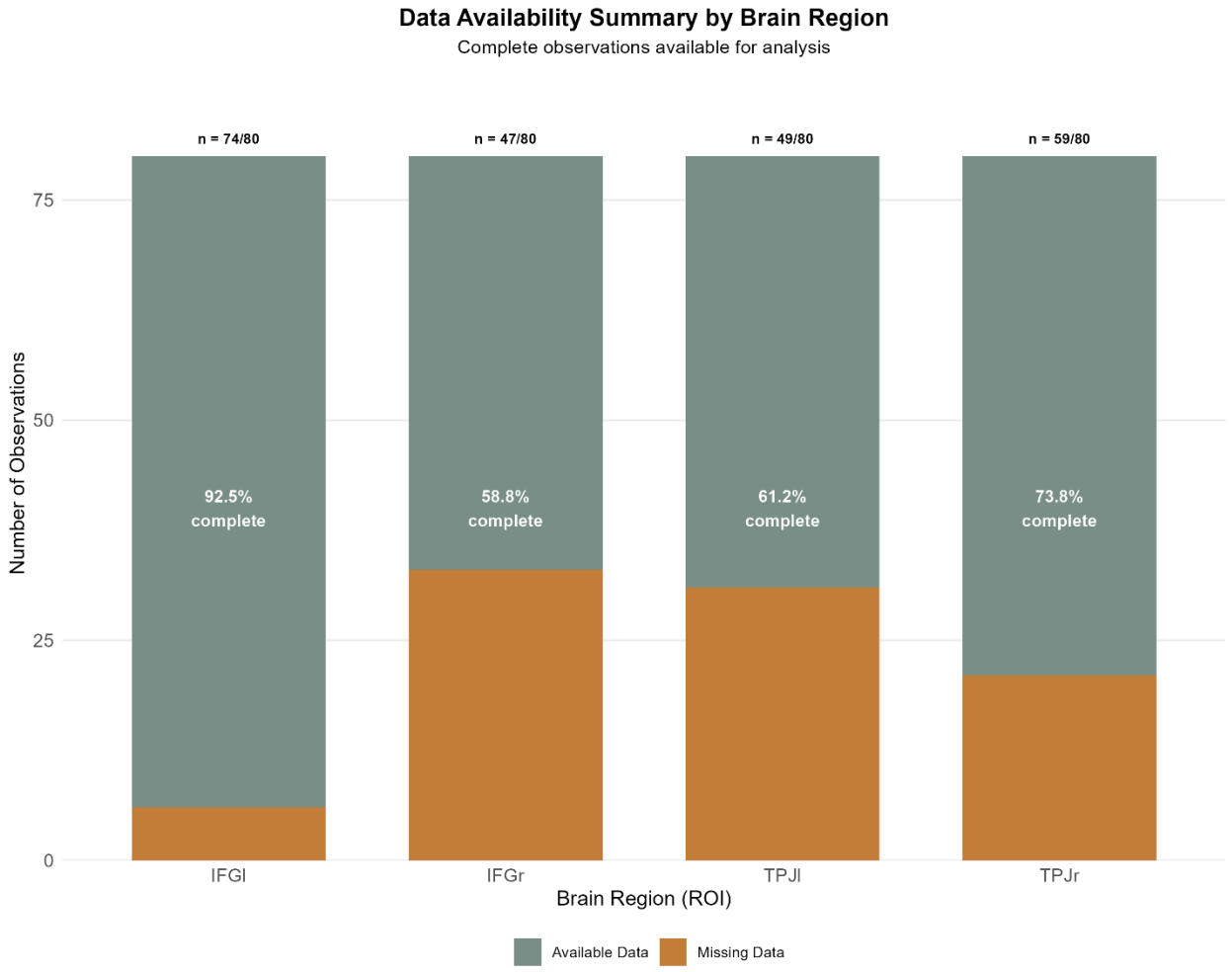
Note. Models estimated at End interval; blue line shows LOESS smooth.

Figure D4



Note. Points near the red dashed line indicate approximate normality of residuals.

Figure D5



Note. Stacked bars show complete (available) versus missing observations. Percentages indicate data completeness rates.

E. Prosocial Intention Questionnaire in English

How much money would you spend on a birthday present for the other participant?

○ ○

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

How much money would you spend on a birthday present for your friends?

○ ○

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

How likely is it that you will help the other participant move?

○	○	○	○
very unlikely	unlikely	likely	very likely

How likely is it that you will help a friend move?

○	○	○	○
very unlikely	unlikely	likely	very likely