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# Differences between Mimicking and Non-Mimicking laughter in Child-Caregiver Conversation: A Distributional and Acoustic Analysis

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**Abstract**

Despite general agreement that laughter is crucial in social interactions and cognitive development, there is surprisingly little work looking at its use through childhood. Here we investigate laughter in middle childhood, using a corpus of online calls between child and parent and between the (same parent) and another adult. We focus on laughter mimicry, i.e., laughter shortly following laughter from the partner, and we compare mimicking and non-mimicking laughter in terms of distribution and acoustic properties using spectrotemporal modulation measures. Our results show, despite similar frequencies in laughter production, different laughter mimicry patterns between Parent-Child and Parent-Adult interactions. Overall, in comparison with previous work in infants and toddlers, our results show laughter mimicry is more balanced between parents and school-age children. At the acoustic level, we observe differences between mimicking and non-mimicking laughter in children, but not in adults. Moreover, we observe significant differences in laughter acoustics in parents depending on whether they interact with children or adults, which highlights a strong interlocutor effect on laughter mimicry.

**Keywords:** laughter; mimicry; adult-child conversation; multi-modal communication development; spectrotemporal modulation.

## Introduction

Laughter is a non-verbal vocalization pervading our conversations universally across cultures and languages (Trouvain & Truong, 2012; Bryant & Bainbridge, 2022). Its evolutionary roots are found in nonhuman play vocalizations (Ross, Owren, & Zimmermann, 2010), and in humans, it is most often associated with positive emotional feelings and humor appreciation (Winkler & Bryant, 2021). Nevertheless, in human adults, laughter functions span a much wider range: regulating turn-taking and topic changes, signaling problems of lexical retrieval or lexical imprecision, marking irony, disambiguating meaning, managing self-corrections, smoothing or softening difficult situations (e.g., a criticism, an embarassing moment, asking a favor, or manage trouble-telling), but also showing (dis)affiliations and marking group boundaries (Wessel-Tolvig & Paggio, 2017; Cosentino, Sessa, & Takanishi, 2016; Glenn & Holt, 2013; Petitjean & González-Martínez, 2015; Shaw, Hepburn, & Potter, 2013; Mazzocconi, Tian, & Ginzburg, 2020; Jefferson, 1984). It is a communicative signal to disclose emotional, attentional, and intentional mental states to our interlocutors (Hoicka & Gattis, 2008; Mazzocconi et al., 2020; Provine, 1993).

Despite the pragmatic complexity observed in adults (Mazzocconi et al., 2020), laughter emerges in infancy around three months of age (Nwokah, Hsu, Dobrowolska, & Fogel, 1994; Sroufe & Wunsch, 1972), a developmental stage when the same level of elaborated adult pragmatic reasoning (as briefly described above) cannot be expected. Growing evidence suggests that changes in laughter use correlates with the development of socio-cognitive skills of babies and children (Mazzocconi & Ginzburg, 2022b, 2022a; Mireault & Reddy, 2016; Martin, 2010). Even when considering exclusively its occurrence in relation to humorous stimuli, laughter can offer a precious, early window into the cognitive development of babies (Mireault & Reddy, 2016). Piaget (1945) proposed to consider laughter as a "sign of cognitive mastery": funniness residing especially in zones of proximal development (Vygotsky, 1980). For example, a simple peek-a-boo game may be extremely amusing and exciting for a baby who has just acquired the principle of object permanence, but may be extremely boring for an older child, or frightening for a baby that has not yet acquired such principle (Shultz, 1976; Parrott & Gleitman, 1989). Moreover, laughter can be informative about the child's cultural and social attunement to the environment (Mireault & Reddy, 2016). Humour appreciation is indeed often guided by social referencing (Mireault et al., 2014), and non-humour related laughter is tightly bound to cultural norms: what is considered to be embarrassing or face-threatening varies importantly across cultures (cfr. (Brown & Levinson, 1987; Brown, 2015)) and depends on the emergence of a sense of self (self-reputation) and awareness of others' mental states (Tomasello, 2009; Mazzocconi & Ginzburg, 2022a; Hoicka, 2014). Therefore the study of laughter development is interesting since it can offer insight into not only the underlying cognitive processes of laughter, but also into the socio-cognitive development of children.

### Laughter mimicry and its development

Due to its contagiousness, laughter can easily lead towards alignment, maybe more than other non-verbal behaviors (Palagi, Caruana, & de Waal, 2022; Scott, Cai, & Billing,



In M. Goldwater, F. K. Anggoro, B. K. Hayes, & D. C. Ong (Eds.), *Proceedings of the 45th Annual Conference of the Cognitive Science Society*. 

2022), i.e., laughter mimicry, commonly defined as the production of laughter within one second from the end of a previous laughter produced by an interactant. Laughter mimicry occurrence plays an important role for the unfolding of conversations (e.g., showing agreement and affiliation, jointly manage and shape meaning), as well as the establishment and maintenance of relationships (Smoski, 2004; Kurtz & Algoe, 2017), including non-human primates (Davila-Ross & Palagi, 2022). However, laughter mimicry is not a purely automatic response: it is influenced by context (Bryant, 2020), interactional partner (Smoski & Bachorowski, 2003), object of the laughter[1] (Jefferson, Sacks, & Schegloff, 1977), and by the developmental stage of the interactants. In mother-infant interactions, laughter mimicry is more frequent in caregivers than in children (Nwokah et al., 1994; Cohn & Tronick, 1987; Mazzocconi & Ginzburg, 2022b). In a longitudinal study from 12 to 36 months, a decrease in laughter mimicry produced by mothers was observed over time, which suggests a negative correlation between it and the communicative skills of children (Mazzocconi & Ginzburg, 2022b). The same study reported that at around 36 months, mother and child reach more balanced patterns in terms of laughter reciprocity, responding to each other approximately 20% of the time. While this percentage is close to what is expected in adult conversations (Mazzocconi et al., 2020; Smoski & Bachorowski, 2003), this comparison should be taken with reservation as the interactional contexts among infant (free play at home) and adult studies (mostly conversations in lab setting) are quite different. While a wealth of studies is available on laughter and its mimicry in adults and children from infancy to preschool, to the authors' knowledge, there is little investigating laughter mimicry in middle childhood (i.e., 6 to 12 years old), especially in spontaneous interactions. Few existing studies have been conducted exclusively in controlled settings (e.g., Helt, Fein, and Vargas (2019)).

## The acoustics of laughter

While studies in non-human primates have shown that Mimicking laughter is acoustically significantly different from initiating laughter (Davila-Ross, Allcock, Thomas, & Bard, 2011), Truong and Trouvain (2014) have shown that such distinction is absent in adult humans[2]. The latter has been interpreted as a consequence of the tendency of interlocutors to align with each other in their laughter production (Ludusan & Wagner, 2022). Nevertheless, in adult humans the acoustic features of laughter mimicry are influenced, and informative about, the relationships between interactants: mimicking laughter between friends are overall characterized by higher pitch and faster burst rates, features correlated with both heightened arousal and perception of spontaneity (Bryant & Aktipis, 2014; Oveis, Spectre, Smith, Liu, & Keltner, 2016). Furthermore, clinical data suggests that the acoustic analysis of laughter and its mimicry can be indicative of social-cognitive processing (Bryant, 2020; O'Nions et al., 2017; Reddy, Williams, & Vaughan, 2002; Lavelle, Howes, Healey, & McCabe, 2018; Kant, 1942; Helt et al., 2019; Hudenko, Stone, & Bachorowski, 2009). Little work though has compared laughter types across different developmental stages.

Numerous acoustic features have been used to describe the perceptual characteristics associated with laughter and its social functions (see Bachorowski and Owren (2002); A. Wood, Martin, and Niedenthal (2017)). These descriptors span both temporal and spectral dimensions. Bryant and Aktipis (2014) showed that by increasing laughter rate, listeners perceived laughs as more spontaneous. In a separate study, Bryant et al. (2018) showed that listeners associated irregular dynamics in pitch and loudness with friends laughing instead of strangers. Related research showed that adults from different cultures, and even 5-month old babies, are extremely good at telling apart co-laughter produced between strangers and between friends (Bryant et al., 2016; Vouloumanos & Bryant, 2019). This is quite remarkable, as the acoustic signals of laughter are oftentimes short in duration and embedded with dynamic changes across both temporal and spectral dimensions.

These changes can be measured by transferring the time-frequency representations of acoustic signals into the *spectrotemporal modulation* domain (hereafter STM), i.e., fluctuations across the temporal and frequency domains. STM measures have been widely used by researchers in speech production and perception studies to characterise the acoustic signals (Chi, Gao, Guyton, Ru, & Shamma, 1999). Temporal modulations have been shown to reflect broad linguistic categories, specifically prosody (1-2 Hz), rhythmic and syllabic patterns (4-8 Hz), and articulatory gestures (16-32 Hz) (Flinker, Doyle, Mehta, Devinsky, & Poeppel, 2019; Giraud & Poeppel, 2012). Spectral modulations have been shown to correspond with F0 fluctuations, harmonics, and formant patterns (Giraud & Poeppel, 2012; Rosen, Carlyon, Darwin, & Russell, 1992) with perceptual limits around 3 cycles per octave (hereafter, c/o) (Dusan, 2007; Liu & Eddins, 2008) and a critical region of 0.8-1.3 c/o (Flinker et al., 2019). Numerous studies focused on unpacking the modulation representation of speech signals in the context of assessing speech intelligibility (Elhilali, Chi, & Shamma, 2003; Elliott & Theunissen, 2009; Flinker et al., 2019) and voice pathologies (Moro-Velázquez, Gómez-García, Godino Llorente, & Andrade-Miranda, 2015; Marczyk, O'Brien, Tremblay, Woisard, & Ghio, 2022). There have been but a handful of studies that use STM metrics to analyze anything other than speech. For example, scream production was shown to have significantly increased temporal modulations (compared to speech) in the 30-150 Hz range (Arnal, Flinker, Kleinschmidt, Giraud, & Poeppel, 2015). The authors showed that this upper band of temporal modula-

[1] For example, in the context of patient-doctor interaction, laughter related to trouble-telling should not be reciprocated by the doctor.

[2] We need to highlight that the classifications used in these studies are slightly different: (Truong & Trouvain, 2014) compared specifically initiating and responding laughs which showed overlap, while in (Davila-Ross et al., 2011), as we will in the current work, the comparison is between all the laughs not shortly following another laughter and all the mimicking laughs, regardless of their overlap.

tions corresponds to both the perception of "roughness" and engages subcortical structures critical to assessing danger.

Recent work by Ludusan and Wagner (2020b, 2020a) showed that modulations of the amplitude envelope and F0 could be used to distinguish speech, laughter, and speech-laughter. Nevertheless, no study investigated whether such measures can discriminate between laughter types and be influenced by interlocutors.

### The current study

The current work aims at filling several gaps in the literature reviewed above. Our focus on middle childhood allows us to bridge research on laughter-mimicking patterns in infants and toddlers to research on adult behavior. The use of a similar interaction context enables us to directly compare adult-adult and child-adult laughter responsiveness dynamics. Further, our study introduces state-of-art acoustic analysis techniques as a tool to provide a more precise investigation of mimicking versus non-mimicking laughter behavior in development. More precisely, our study investigates two main questions:

- Do distributional patterns of laughter mimicry differ between children, caregivers, and adults?
- Are there intra- and inter- participant (children, caregivers, and adults) differences between mimicking and non-mimicking laughter in terms of acoustics?

## Methods

### Dataset

The ChiCo corpus (Bodur, Nikolaus, Kassim, Prévot, & Fourtassi, 2021) contains 16 video-call conversations of participants engaged in a simple word-guessing game. Eight of these conversations involved a child playing the game with a parent and the other eight involved the same parent playing the same game with an adult. The age range of children was between 6 and 11 years old (M=8.7, SD=1.48). We chose to use this dataset as it allows us to investigate not only laughter mimicry in children interacting with caregivers, but also possible differences between parent-child and adult-adult dynamics, using the same conversational context.

### Annotation and Models

**Laughter Annotation** The whole dataset was annotated independently by two of the authors using the software ELAN (Brugman & Russel, 2004). The laughter audio-visual identification criteria followed the procedures outlined in El Haddad, Chakravarthula, and Kennedy (2019); Mazzocconi and Ginzburg (2022b). The inter-annotator agreement score was calculated, both for laughter identification and segmentation (start-time and end-time boundaries). For laughter identification, we obtained an overall Cohen's kappa of $\kappa = 0.76$. Segmentation was assessed with the Staccato algorithm implemented in ELAN (Lücking, Ptock, & Bergmann, 2011), leading to an average degree of organization of 0.71.[3]

[3]This value was obtained by running 1000 Monte Carlo simulations, using an annotation length granularity of 10, and $\alpha = 0.05$.

**Mimicry calculation** For laugh B to mimic laugh A, B must occur after A's start and can have its onset anytime until A's stop within a margin $\Delta T$. In order to avoid duplication, B should stop before the next A starts. So, to count a laughter as mimicry the following must apply:

(1) $T_{start}(A_i) < T_{start}(B_i)$

(2) $T_{start}(B_i) < min\{T_{stop}(A_i) + \Delta T, T_{start}(A_{(i+1)})\}$

Where $B_i$ and $A_i$ are the $i^{th}$ laugh in a conversation and $T_{start}$ and $T_{stop}$ are the starting and stopping times of a laugh, respectively. $\Delta T$ was set to 1 second. Henceforth, "Mimicking" laugh refers to any laugh shortly following a preceding laugh, while a "Non-Mimicking" laugh refers to a laugh not shortly following a preceding laugh. Given the variability in laughter occurrences among participants, it was important to establish a laughter mimicry metric that accounted for the number of laughs produced by the interlocutors. Following a similar procedure used by El Haddad et al. (2019) and Smoski and Bachorowski (2003), the Transitional Probability (TP) was measured by calculating the probability of laughter mimicry occurring in one participant over the total number of laughs produced by their partner. This metric offered a likelihood value that one participant moved from a "non-laughing" state to a "laughing state", given the laughter produced by their partner. Equation 1 describes the TP of participant $X$, where $M$ is the total number of laughter mimicry produced by $X$ and $L$ is the total number of laughs produced by their partner $Y$.

$$\text{TP}(X) = \frac{\sum_{m=1}^{M} X_m}{\sum_{l=1}^{L} Y_l} \quad (1)$$

**Spectrotemporal modulation** The energy distribution across the spectrotemporal modulation domain can be characterized in terms of the measure of Modulation Power Spectrum (MPS). Previous work (Elliott & Theunissen, 2009; Singh & Theunissen, 2003; Thoret, Caramiaux, Depalle, & Mcadams, 2021) has defined MPS as a two-dimensional Fourier transform of the time-frequency representation of an audio signal. Equation 2 below provides the formal definition of the MPS, where $s$ and $r$ are spectral and temporal modulations, respectively, and $Y(t, f)$ is the amplitude extracted from the Fourier transform:

$$\text{MPS}(s,r) = \int\int |Y(t,f)| e^{-2\pi i s f} e^{-2\pi i r t} df dt \quad (2)$$

We adopted scripts developed in MATLAB 2016b (MathWorks Inc, USA) by (Flinker et al., 2019) to obtain the MPS of laughs in our dataset. Laughter recordings were first downsampled to 16 kHz, which is a sufficient resolution to analyse laughter events. Time-frequency representations were obtained using a gammatone filter bank summation method (128 full-width half-maximum Gaussians with center frequencies logarithmically spanning the frequency domain). Hilbert transforms were then used to extract the analytical amplitudes

Table 1: Occurrences of Mimicking and Non-Mimicking laughter according to Participant (C: Child, PwC: Parent interacting with Child, PwA: Parent interacting with Adult, and A: Adult) and Dyad.

| Participant | Total | Non-Mimicking | Mimicking |
|---|---|---|---|
| C | 110 | 85 | 25 |
| PwC | 133 | 103 | 30 |
| PwA | 168 | 130 | 38 |
| A | 169 | 123 | 46 |
| Total | 580 | 441 | 139 |

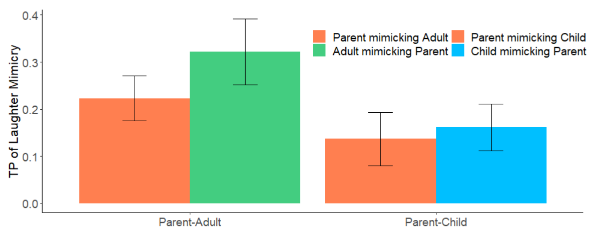


Figure 1: Overall TP of laughter mimicry in Parent-Adult and Parent-Child conversations

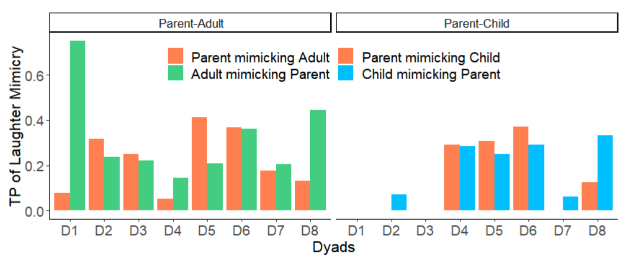


Figure 2: TP of laughter mimicry within each dyad.

from these filter outputs. The *fft2* MATLAB function transformed the time-frequency representations into the modulation domain. Previous work reported that the speech signal is embedded with temporal and spectral modulations ranging from 0 to 32 Hz and 0 to 4 c/o, respectively. We used these same ranges to compare the STM profiles associated with Mimicking and Non-Mimicking laughter.

**Statistics for acoustic analysis** Generalized additive mixed models (GAMMs) (S. Wood, 2006) were used to evaluate the effects of laughter type and interlocutor on time-normalised temporal modulations (TM) and spectral modulations (SM). GAMMs were selected for statistical analysis as they can handle time-varying data with non-linear relationships and have been shown to be effective at evaluating amplitude and F0 modulations (Ludusan & Wagner, 2020b). Although this method differs from traditional statistical analyses of laughter acoustics, GAMMs afford precision in identifying specific modulation regions. Following the procedures suggested by (Wieling, 2018; Ludusan & Wagner, 2020b) the R-package *mgcv* was used. Thin plate regression *splines* were used as smoothing functions to model the non-linear variation present in the data (s in Formula 3). The R-package *itsadug* (van Rij, Wieling, Baayen, & van Rijn, 2015) was used to estimate an AR-1 correlation parameter $\rho$ and pairwise differences between the non-linear smooths of the factor levels.

Formula 3 describes the general GAMM used in the current study. Amplitudes $A$ (in dB) corresponding to modulations $v$ (the unit for $v$ is Hz for TM and c/o for SM) were used as dependent variables. The term $T$ represents the interaction between laughter type $l$ (mimicking vs. non-mimicking) and dyadic role (C: Child, A: Adult, PwC: Parent interacting with child, PwA: Parent interacting with adult). It was entered as fixed factors (leading to 8 levels). A non-linear random factor of participant $p$ was added to the models. The $\rho$-value described in formula 3 was estimated from the data and included to control for auto-correlation in the time series ($\rho_{TM}$ = 0.82; $\rho_{SM}$ = 0.95). As proposed in (Ludusan & Wagner, 2020b), each model was first tested against a base model not containing the fixed factor via the *compareML* function.

$$\mathrm{bam}(A \sim T + \mathrm{s}(v, \mathrm{by} = T) + \mathrm{s}(v, p, \mathrm{by} = l, \mathrm{bs} = \text{“fs”}), rho = \rho) \quad (3)$$

## Results

Our study is based on the identification of 580 laughter events: 243 in the Parent-Child (PC) interactions (110 C: 14 $\pm$ 14; 133 P: 17 $\pm$ 8) and 337 in the Parent-Adult (PA) interactions (per participant: 21 $\pm$ 12). Wilcoxon-tests of laughter frequency per minute between PC and PA conversations and between parent and child were not statistically significant. No significant difference in duration were observed neither according to participant neither according to laughter type.

### Laughter Mimicry

Table 1 shows the distribution of laughter types across Participants. Overall 55 Mimicking laughs were identified in PC interactions and 84 in PA interactions. Figure 1 illustrates the TP of laughter mimicry per participant type (C, PwC, PwA, A), while Figure 2 shows TP of laughter mimicry at the participant level. Occurrences of laughter mimicry are overall significantly more frequent in PA than in PC interactions ($\chi^2$ 39.82, p<.001). The same pattern is found when considering TP of laughter mimicry, which is larger in Parent-Adult interactions (mean TP = 0.27 $\pm$ 0.17) compared to Parent-Child interactions, with mean TP = 0.14 $\pm$ 0.14 (W=103, p=0.03). We found no differences in laughter mimicry within dyads, i.e., between PwC and C and between PwA and A. Regarding individual patterns (Fig. 2) laughter mimicry was consistently present in all PA dyads, however, much higher variability was observed in PC interactions.

### Spectrotemporal modulation

**Temporal modulations** Fig. 3 (top) illustrates the results for the TM GAMM model (adjusted $r^2$ = 0.69) for the **intra-participant** effects of laughter types. Although no significant differences were observed between Mimicking and Non-Mimicking laughter produced by adults and parents, they

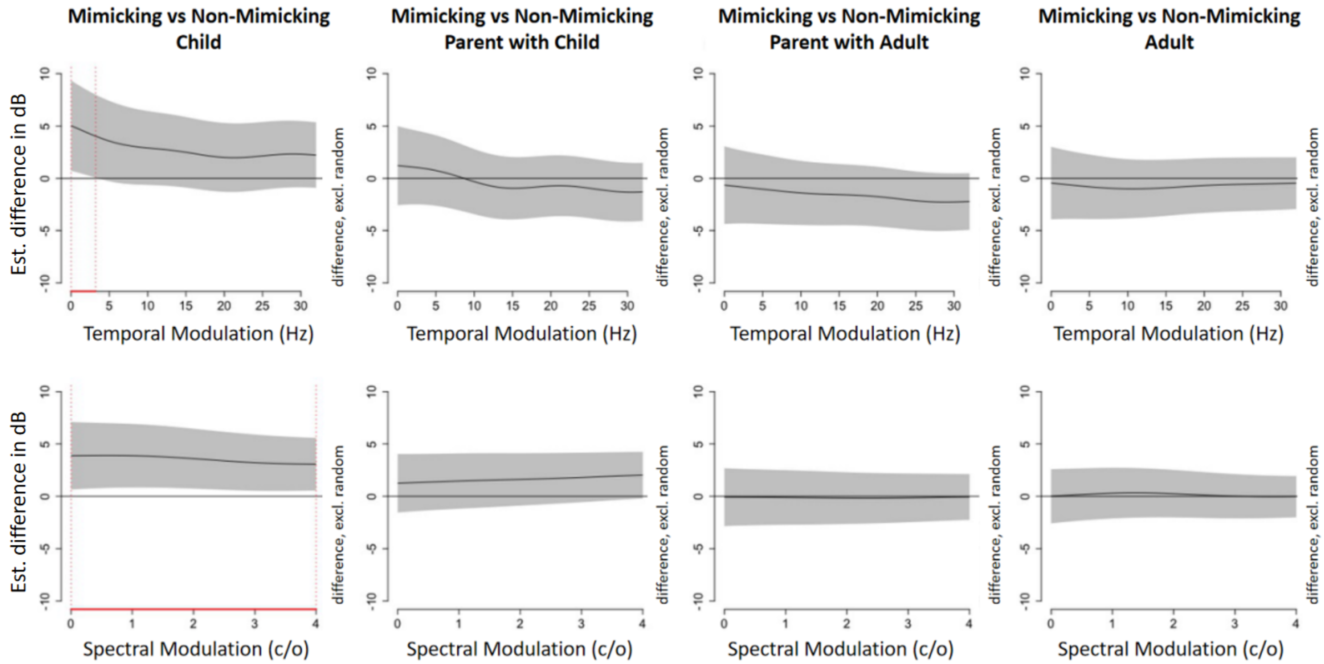


Figure 3: Differences between the fitted class models for temporal modulations (Top row) and spectral modulations (Bottom row) across laughter types and dyadic roles. The red interval on the horizontal axis represents the range of modulations for which the two models differ significantly.

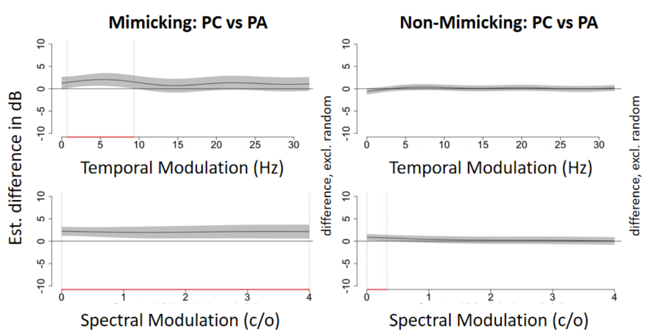


Figure 4: Differences between the fitted class models for temporal modulations and spectral modulations between laughter types across interactions with children and adults. The red interval on the horizontal axis represents the range of modulations for which two models differed significantly.

were present in children: When producing Mimicking laughter, children showed an increase (≈ -4 dB) of temporal modulations in the 0-3.23 Hz range in comparison to parents. The **inter-participant** analysis revealed no significant differences in Non-Mimicking laughter, however, they were found in Mimicking laughter, as parents who interacted with children exhibited an increase (≈ -2 dB) in the 0.65-9.38 Hz range in comparison to interactions with other adults (Fig. 4, top).

**Spectral modulations** Figure 3 (bottom) illustrates the results for the SM GAMM model (adjusted $r^2$ = 0.65) for the **intra-participant** effects of laughter types. Similar to the TM model, no significant differences between laughter types were observed in adults and parents, however, they were present in children. When producing mimicking laughter, children exhibited an increase (≈ -4 dB) in spectral modulations in the 0-4 c/o range in comparison to non-mimicking laughter. The **inter-participant** analysis showed several significant differences. When comparing Mimicking laughter, parents interacting with children had an increase (≈ -3 dB) in the 0-4 c/o range in comparison to interactions with other adults (Figure 4, bottom). When producing Non-Mimicking laughs (figure not shown), parents showed an increase (≈ -3 dB) in spectral modulations in the 0-0.81 c/o range in comparison to children. When producing Non-Mimicking laughs, parents interacting with children also increased (≈ -2 dB) spectral modulations in the 0-0.32 c/o in comparison to interactions with adults.

## Discussion

This study investigated laughter use and mimicry in middle childhood in terms of both their distribution in naturalistic conversations and acoustic properties. Despite comparable overall laughter distributions among participants, we found laughter mimicry to be more present in Parent-Adult (PA) compared to Parent-Child (PC) interactions when both groups of dyads conversed in a similar context and played the same (word-guessing) game. The spectrotemporal modulation analysis showed clear differences between Mimicking and Non-Mimicking laughter in children, whereas no such differences were observed in adults. As for inter-personal results, we found acoustic differences between laughter produced by parents conversing with children in comparison to their laughter when conversing with other adults.

When looking at patterns across participants, the overall lower TP of laughter mimicry in PC interaction is mainly driven by the high variability observed among PC dyads. Indeed, we observe laughter mimicry only in 6 children out of 8 dyads and only in 4 parents when interacting with their children. In contrast, laughter mimicry was present in all PA dyads from both interlocutors. That said, the variability observed in PC dyads is not random: Either mimicry is present or it (almost) never occurs for both interactants. The fact that PC mimicry is rather balanced suggests an important change from earlier developmental stages, where asymmetrical patterns (namely, that caregivers produce much more laughter mimicry than children do) are dominant (Nwokah et al., 1994; Mazzocconi & Ginzburg, 2022b). Mazzocconi and Ginzburg (2022b) report balanced child-parent laughter mimicry only at 36 months in the context of free play at home, averaging the behaviour of 4 child-parent dyads.

One of the more striking results from our acoustic analysis was that, while in general, no significant differences were observed between Mimicking and Non-Mimicking laughter produced by parents and adults, these emerged in children across both temporal modulation (0-3.23 Hz) and spectral modulation (0-4 c/o) dimensions. Although the main result we report is that there is an acoustic difference in children, but not in adults, one can still speculate on what this difference means. The lack of difference between Mimicking and Non-Mimicking laughter in adults corroborates with findings reported in (Truong & Trouvain, 2014), which associated it with the tendency of interlocutors to align with each other in their laughter production (Ludusan & Wagner, 2022). Previous work has linked temporal modulations in the 1-2 Hz range with prosody (Flinker et al., 2019; Giraud & Poeppel, 2012) and spectral modulations to variations in F0 (Elliott & Theunissen, 2009). These properties (especially variability in F0) tend to correlate with arousal in humans (Bryant & Aktipis, 2014; Oveis et al., 2016; Smoski & Bachorowski, 2003) and in non-human animals (Schwartz, Sanchez, & Gouzoules, 2022; Pisanski, Cartei, McGettigan, Raine, & Reby, 2016). This suggests that child laughter mimicry is associated with heightened arousal. The origin of this is still to be investigated, but could be due to developmental factors related to laughter coordination in interaction, or to the fact that joining the parent's laughter is particularly emotionally rewarding.

When conducting inter-individual comparisons for specific laughter types, we observed an important interlocutor effect in parents: When interacting with children, parents produced Mimicking laughter with increased spectral modulations in comparison to interactions with adults. Here again, the increased spectral modulations are likely associated with heightened arousal. It is, for example, possible that parent laughter mimicry serves the function of specifically inducing positive affect in their child, encouraging them when making a mistake (e.g., failing to guess the word), and therefore being particularly salient from a socio-emotional perspective. On the other hand, it is also possible, that Parents align to Children in the production of Mimicking laughter with higher spectrotemporal modulations. Such interpretation would be in line with previous work showing the tendency of adults to align to the others' laughter productions (Truong & Trouvain, 2014; Ludusan & Wagner, 2022).

## Conclusion, Limitations, and Future work

Our study contributes to the developmental literature on laughter and its mimicry, investigating for the first time, to the best of our knowledge, their *naturalist* dynamics in middle childhood in terms of distribution and acoustics features.

We can conclude that at a dyadic level, by middle-childhood a form of balanced alignment and synergic coordination (Fusaroli, Raczaszek-Leonardi, & Tylén, 2014) for what concerns laughter mimicry is at place in parent-child loosely-structured conversation. Interestingly, unlike Parent-Adult dyads, certain Child-Parent dyads did not exhibit laughter mimicry. Further research should investigate this result by studying Parent-Child laughter mimicry across various contexts, to explore whether the lack of mimicry is influenced more by individual differences, parenting style, or by the conversational context, and task.

The most striking result regarding the acoustic analysis is that while in children we observe a significant difference between Mimicking and Non-Mimicking laughter, they do not differ in adults. Although the precise meaning of these differences remains to be explained, it is relevant to mention that in previous work (Truong & Trouvain, 2014) the lack of difference between initiating and Mimicking laughter among adults has been interpreted as the result of alignment in laughter production between interlocutors.

Finally, corroborating previous literature (e.g., Paxton, Dale, and Richardson (2016); Chartrand and Lakin (2013)), the Parent-Adult and Parent-Child comparisons showed how laughter mimicry is not a reflex-like behaviour, but it is importantly influenced by the interlocutor both in its distribution and acoustics. Further work is needed to disentangle the possible explanatory factors leading to our results: social role, attachment, social motivation, approach to the task, etc.

One limitation of our study is that it relies on computer-mediated conversations. While the study of laughter dynamics in this communicative medium is – in and of itself – an important, impactful research pursuit (especially in light of the recent increase in children's use of video calls for various social and educational activities), the conclusions we draw from this study about communicative development need to be further corroborated with similar data in direct face-to-face conversations. That said, there is evidence that suggests computer-mediated mimicry generalizes to direct mimicry, at least in adults (Gironzetti, 2022). For example, the values we report in the current study about TP of laughter mimicry in adult dyads are comparable to what has been reported previously in adult direct face-to-face interactions (Mazzocconi et al., 2020; Smoski & Bachorowski, 2003).

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