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# Laughter Responsiveness and Acoustic Alignment in Parent-Child and Adult-Adult Interaction

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## Abstract

While alignment in laughter production has been shown in adults, its presence in children remains understudied. We examined laughter responsiveness and acoustic alignment in middle childhood, comparing parent-child and parent-adult computer-mediated conversations. While no significant differences were found in laughter frequency, antiphonal laughter was less frequent in parent-child interactions, despite intra-dyadic balance. Acoustic analysis revealed an increase in low-frequency spectral modulations in antiphonal laughter. To test whether this was due to local alignment with the preceding laughter, we compared distances from genuine and pseudo-random initiating-antiphonal laughter pairs. In parent-adult interactions, genuine laughter pairs exhibited greater acoustic similarity than pseudo-random pairs, a pattern absent in parent-child interactions. Our study contributes to discussions on alignment theories and the role of laughter in pragmatic development.

**Index Terms:** antiphonal laughter, mimicry, alignment, middle-childhood, child-caregiver interaction, interlocutor effect, spectrotemporal modulation.

## 1. Introduction

Laughter is crucial in managing interactions at different levels [1, 2] and, cross-linguistically, it has been observed in approximately 35% of laughs produced in adult-adult conversation when shortly following an interlocutor's laugh [3, 4, 5]. [6] and [7] show adults align in their acoustic laughter production over the course of a conversation. Nevertheless, studies in early development (up to 36 months) have shown that laughter use evolves over time, and even the occurrence of antiphonal laughter is not purely an automatic display, but is informative about pragmatic development [8, 9]. The close relation between laughter behaviour and communicative skills is endorsed also by studies showing atypicalities in antiphonal laughter occurrence and acoustic features in populations where pragmatic skills are atypical or compromised, e.g., autism spectrum and schizophrenia [10, 11, 12, 13, 14]. Given the reviewed literature emphasising the relationship between what we refer to here as *antiphonal laughter* and communicative skills, it is plausible that laughter use is still evolving during middle childhood. However, research on this topic in spontaneous interactions during middle childhood is limited, making comparisons with adult conversations challenging.

## 2. Our study

We aim to compare antiphonal laughter in parent-child and parent-adult interactions within the same context of computer-mediated conversations. We employ a composite methodology,

combining distributional and acoustic analyses, to investigate whether child and adult behaviour would differ in terms of (1) probabilities of antiphonal laughter occurrences, (2) acoustic features of antiphonal laughter, (3) acoustic alignment to the partner's laughter production. We believe that this investigation not only offers insight to the nature of laughter itself and its interplay with conversational dynamics and development, but also contributes to discussions relating to current models of alignment in interaction.

## 3. Method

Our dataset is constituted by the ChiCo corpus [15]: 16 video-call conversations of participants engaged in a word-guessing game. Eight conversations involved a Child playing the game with a Parent (CP), and the other eight involved the same Parent playing with an Adult (AP). The age range of children was 6 - 11 years old ( $M=8.7$ ,  $SD=1.48$ ). Laughter audio-visual identification criteria followed the procedures outlined in [16] and [8] and were conducted using the software ELAN [17]. The inter-annotator agreement of laughter identification between two coders was assessed with the Staccato algorithm [18], leading to an overall degree of organisation of 0.74. After discussion, the two annotators adjudicated 573 laughter occurrences.

For this paper Antiphonal laughter is any laughter with an onset occurring within 1 second from the offset of the preceding laughter.<sup>1</sup> Any laughter not meeting these criteria was considered Non-Antiphonal (NA), while the NA preceding an Antiphonal laughter was considered Initiating. Transitional Probabilities (TP) of Antiphonal laughter were measured by calculating the probability of Antiphonal laughter occurring by one participant over the total number of laughs produced by their partner [16, 5].

To examine differences in spectrotemporal modulations across laughter types, the Modulation Power Spectrum (MPS) was calculated from each recording, where a two-dimensional Fourier transform was applied to its time-frequency representation (see [19, 20, 21]). For the current study, similar procedures described in [22] were used. Laughter recordings were first down-sampled to 16 kHz. Time-frequency representations were obtained using a filter bank summation method, whereupon Hilbert transforms were used to extract the analytical amplitudes. The *fft2* MATLAB function transformed the time-frequency representations into the modulation domain. This study analysed temporal modulations (TM) and spectral modulations (SM) ranging from 0 to 32 Hz and 0 to 4 cycles per octave (c/o), respectively.

Generalised Additive Mixed Models (GAMM) [23] were used to statistically evaluate differences between Antiphonal

<sup>1</sup>Some studies refer to Antiphonal laughter as Mimicry, e.g., [16].

and Non-Antiphonal laughter. Following [24, 25] the R-package *mgcv* was used. Formula 1 describes the GAMM design used to evaluate the effects of laughter type across interlocutors. Amplitude  $A$  (in dB) corresponding to modulation  $v$  was set as the dependent variable, where the unit for  $v$  is Hz for TM and c/o for SM.  $T$  represents the interaction between laughter  $l$  and interlocutor type (8 levels). Interlocutor  $p$  was entered as a non-linear random factor.  $\rho$  was estimated from the data and included to control for auto-correlation in the time series ( $\rho_{TM}=0.92$ ;  $\rho_{SM}=0.92$ ).

$$\text{bam}(A \sim T+s(v, \text{by} = T)+s(v, p, \text{by} = l, \text{bs} = \text{"fs"}), \text{rho} = \rho) \quad (1)$$

In order to test local acoustic alignment between each antiphonal laugh and its preceding laugh, we adapted procedures proposed in [6] to TM and SM metrics. For each interlocutor, we identified Antiphonal laughs and the preceding Initiating laughs produced by their partner (Genuine pairs). We then calculated separate temporal and spectral modulation Euclidean distances based on corresponding amplitudes. The Genuine pair distances were then compared against an equal number of Pseudo-random pairs. Pseudo pairs were constructed from the binomial coefficients of  $\binom{N}{2}$ , where  $N$  is the number of Genuine laughter pairs. After removing all Genuine laughter pairs from the set, the median<sup>2</sup> distance was selected followed by the closest  $N-1$  distances. One-sided Wilcoxon signed-rank tests were then applied Genuine and Pseudo distances (8 total).

## 4. Results

Our analysis is based on 573 instances of laughter: 337 within Adult-Parent (AP) interactions (Parents:  $N = 169$ ,  $21 \pm 15$ ; Adults:  $N = 168$ ,  $21 \pm 11$ ) and 236 within Child-Parent (CP) interactions (Parents:  $N = 127$ ,  $16 \pm 8$ ; Children:  $N = 109$ ,  $14 \pm 14$ ). Wilcoxon tests comparing laughter frequency per minute between AP and CP conversations ( $W=168$ ,  $p=0.14$ ) and between parents and children ( $W=28$ ,  $p=0.72$ ) yielded no significant differences. The average duration of laughter is  $2.08 \pm 1.6$  seconds. Using a linear mixed effects model with Participant as a random factor, no significant difference in duration was observed ( $F_{3,26} = 1.0$ ,  $p=0.41$ ).

89 Antiphonal laughs were identified in AP and 55 in CP interactions. We observe no significant difference in the amount of antiphonal laughter produced in AP and CP interactions overall ( $\chi^2_{1,573}=0.7$ ,  $p=0.4$ ). When considering the TP of Antiphonal laughter by subject, we observe overall a significant difference ( $W=184.5$ ,  $p=0.017$ ) between CP interactions (mean TP= $0.15 \pm 0.15$ ) and AP interactions (mean TP =  $0.28 \pm 0.18$ , Fig.1). Contrarily, we found no differences in Antiphonal laughter within dyads between the participants involved. Antiphonal laughter was consistently present in all AP dyads. Greater variability was observed in CP interactions, as it was absent in 2 out of 8 children and in 4 out of 8 parents interacting with children.

Both temporal modulation (TM) and spectral modulation (SM) GAMMs fit well to the data (TM: adjusted  $r^2=0.64$ ; deviance explained: 63.8%; SM: adjusted  $r^2=0.88$ ; deviance explained: 83.3%). TM fitted class models revealed no significant differences between Antiphonal and Non-Antiphonal neither in Adults nor in Parents,  $p > 0.05$ . Contrarily, for Children we observe  $\approx 5$  dB increase in temporal modulations in the 0-5.82 Hz range when producing Antiphonal laughter. Unlike

<sup>2</sup>The selection of median distances differs from [6], which, after judging minimum distances as too small, selected mean distances.

TM fitted class models, all interlocutors exhibit significantly increased spectral modulations ( $\approx 3$  dB) when producing Antiphonal laughter in comparison to Non-Antiphonal laughter, however, across different ranges: A: 0-0.48 c/o; PwA: 0-1.01 c/o; PwC: 0-0.28 c/o; C: 0-2.51 c/o.

We observe significant differences between Genuine and Pseudo-random Initiating-Antiphonal laughter pairs produced by AP dyads, but not CP dyads. In AP conversations Genuine pairs are significantly more similar, i.e., smaller distances, than Pseudo pairs: for adults (TM:  $z = -3.39$ ,  $W = 751$ ; SM:  $z = -3.57$ ,  $W = 218$ ) and parents (TM:  $z = -2.98$ ,  $W = 730$ ; SM:  $z = -3.32$ ,  $W = 425$ ),  $p < 0.001$ . However, in CP conversations no significant differences were observed for neither parents (TM:  $z = -1.41$ ,  $W = 382$ ; SM:  $z = -1.73$ ,  $W = 356$ ) nor children (TM:  $z = -0.84$ ,  $W = 231$ ; SM:  $z = -1.06$ ,  $W = 218$ ),  $p > 0.05$ .

## 5. Discussion

Lower probabilities of Antiphonal laughter were observed in CP rather than AP interactions despite similar frequencies of laughter occurrences. Nevertheless, probabilities of Antiphonal laughter within dyads were balanced, which mark a significant change in comparison to earlier developmental stages, where probabilities of Antiphonal laughter are significantly higher for the caregiver [8, 26]. However, the interlocutor effect observed in Parents (higher probabilities of Antiphonal laughter when interacting with an Adult rather than with a Child) requires further investigation in order to explore the factors at play, e.g., task-effect, engagement in an activity cognitively demanding for the child, affiliative relation.

With regards to our acoustic analysis, we observed Antiphonal laughter exhibited an increase in low frequency spectral modulations in comparison to Non-Antiphonal laughter for all participants. We tested the hypothesis that this was related to local alignment to the shortly preceding laugh produced by the partner. The hypothesis was validated for the AP dyads, supporting relative observations by [6], but not for the CP dyads. As laughter acoustic local alignment was not present in neither Parent nor Child suggests an adult interlocutor effect (as compared to the patterns observed in interaction with another adult). Different hypotheses could be put forward to explain the lack of alignment in the Child-Parent dyads [27]: pragmatic competencies of the child, (lack of) motivation to affiliate [28], conceptual misalignment [29], parents' adaptation to the lack of alignment from the child or vice-versa, or task-related cognitive load [30]. Our study shows that in middle-childhood some aspects of laughter production approach adult conversational use, i.e., frequency and balance of antiphonal laughter. However, in interactions involving parents and children some aspects remain different from those observed in adult-adult interactions, i.e., overall probability of antiphonal laughter and acoustic alignment. These results, taken together with the interlocutor effect observed in adults, suggest antiphonal laughter, far from being a purely automatic reflex, plays a role in development and interactional dynamics.

We are currently investigating whether some of the patterns observed might be linked to the level of arousal displayed by the laughter, since arousal is known to affect both spectral and temporal aspects of vocal production [31, 32]. Further studies will be able to validate and disentangle the interpretative hypotheses put forward. In particular, it would be interesting to compare patterns of child laughter alignment when interacting with peers while engaged in different kinds of conversation.

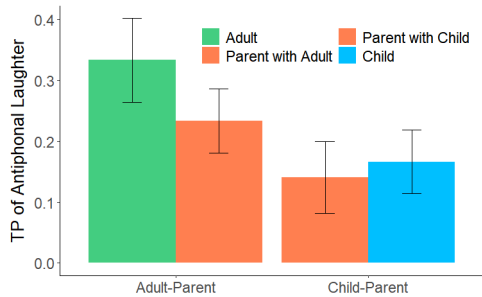


Figure 1: TP of Antiphonal laughter in Child-Parent and Adult-Parent interaction: means and SDs.

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