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# Prosodic Speech Entrainment in Romantic Relationships

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## Abstract

In the current study, we investigated prosodic entrainment between romantic partners. We extracted a set of acoustic-prosodic features from the conversations of twenty-six couples in order to examine (1) the degree to which romantic partners prosodically entrain their speech and (2) whether relationship factors predict romantic partners' level of entrainment. Using observational ratings and self-report data from the Couples Communication Project corpus, comprised of recordings of couples discussing relationship conflicts and agreements, we investigated whether speech entrainment is associated with (a) couples' exhibited behavior during the discussions or (b) factors about their relationship. Couples exhibited overall speech entrainment for features of pitch, intensity, voice quality and speech rate. Moreover, entrainment varied with the content of the conversation: couples who entrained during a conflict discussion were less likely to resolve the conflict; conversely, couples who entrained during an agreement discussion were rated as healthier and better collaborators.

**Index Terms**: entrainment, dialogue, relationships, acoustics

## 1. Introduction

Interlocutors tend to match each other's speech patterns, a phenomenon known as accommodation, convergence, or entrainment. The latter term comes from dynamical systems theory, where it describes phase-locking between two yoked systems; however, in the current paper, following [1] we adopt the term *prosodic entrainment* to describe the more general tendency of two speakers to demonstrate similarity in aspects of their speech over the course of a conversation.

### 1.1. Speech entrainment and social success

The extent to which conversational partners entrain on acoustic-prosodic features can predict the success of their social interactions [2,3], as evidenced by associations between entrainment and social success when speakers are talking on the phone [2] or in person [4], playing verbal communication computer games [1], and collaborating during problem solving [5,6]: In a prisoner's dilemma game, participants whose dialogue converged on a similar speech rate were more likely to cooperate [3]; prosodic entrainment on pitch and voice quality predicted perceived rapport between students working in pairs to solve mathematical problems [6]; an analysis of entrainment and social variables using the Columbia Games Corpus indicated that greater prosodic entrainment was associated with higher ratings of "giving encouragement" and "trying to be liked". [7]. Finally, higher levels of entrainment predicted self-reported closeness of previously unacquainted college roommates over a 5-month period [8]. These studies suggest that social factors may predict the extent to which partners entrain their speech. However, the studies described so far have focused almost exclusively on interactions between strangers; the focus of the current study was on entrainment between romantic partners.

### 1.2. Speech entrainment in romantic relationships

Effective communication is central to the satisfaction of romantic partners [9,10]. Indeed, non-prosodic entrainment has been shown to be predictive of relationship success: In a study of 4-minute first dates, the level of lexical entrainment (i.e., the extent to which partners produced similar words) predicted whether participants wanted to meet again; lexical entrainment of subsequent messages between the pairs predicted whether they were still dating after 3 months [11].

Investigations of entrainment during conversations of established couples explored the association between prosodic entrainment and emotional tone using the Couples Therapy Corpus, a dataset of chronically-distressed married couples receiving therapy [12, 13]: Results demonstrated that level of entrainment could predict positive or negative affect 63% of time, and that higher levels of speech entrainment were associated with more positive affect. In addition, acoustic features of the partners' speech could better predict a couple's marital outcome than behavioral features [13].

These studies demonstrate that speech entrainment occurs between romantic partners, and that it can be associated with positive interactions. However, the causal chain is not clear; specifically, are positive relationship outcomes the result of entrainment, or does entrainment predict positive outcomes? Moreover, research thus far has predominantly examined speech entrainment within specific romantic situations: relatively new romantic exchanges (i.e., first dates) and relatively troubled romantic relationships (i.e., chronically distressed married couples). Finally, studies on entrainment between strangers and between romantic partners have not effectively explored what relationship factors might predict the degree of partners' entrainment.

### 1.3. Current Study

The goals of the current study were to (1) explore prosodic speech entrainment within romantic relationships and (2) investigate what relationship factors affect the degree to which romantic partners entrain their speech.

We carried out an acoustic-prosodic analysis of recordings of couples engaged in two conversations, one about a topic of conflict within their relationship (*conflict discussion*), and one about a topic of agreement (*recovery discussion*). Using survey data and observational ratings, we investigated whether couples' entrainment is associated with (1) the length of their relationship, (2) their behavior during the discussions, and (3) the quality of their relationship.

Consistent with past research on speech entrainment between conversational partners, we predicted that romantic partners would entrain their speech during both conversations.

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In addition, we tested three predictions about the effects of relationship factors on entrainment. In line with previous research demonstrating that romantic partners become more similar to one another over time in their emotional responses [14], life values [15], and social activities [16], we predicted that romantic partners who have been in a relationship for longer would demonstrate a higher degree of speech entrainment. In accordance with research suggesting that romantic partners exhibit more speech entrainment during interactions characterized by positive affect [12] we predicted that couples who more effectively resolved their conflict would exhibit higher entrainment. Finally, we predicted that couples in healthier relationships would exhibit higher levels of speech entrainment.

# 2. Method

## 2.1. Participants

The current study used data (audio recordings and behavioral measurements) from 26 couples (52 total participants; 18 heterosexual couples, five same-sex or genderqueer couples) drawn from the Couples Communication Project corpus [17]. All Project participants were at least 18 years of age and had been in their relationship for at least one year. The 52 participants ranged in age from 19 to 43-years-old ($M$ = 26.1 SD = 4.9) and were in relationships that ranged in length from one to 6.5 years ($M$ = 2.7, $SD$ = 1.8).

## 2.2. Materials

The Couples Communication Project Corpus [17] is an existing dataset of one hundred couples who participated in (1) an online survey of demographic information and family relationship history, (2) an interview session in which they answered questions about their relationship history, and (3) a discussion task in which they conversed about mutual disagreements and agreements within their relationship.

The current study focused on measures of *relationship length, interview collaboration, conflict resolution,* and *overall quality*. Relationship length (in months) was reported by each couple in the on-line survey. The three other measures were rated independently by two trained research assistants, naïve to the hypotheses of the current study. Inter-rater reliability was computed with one-way random intraclass correlation (ICC) and established on 23% of the sample for all three scales. *Interview collaboration* (rated on a 1-5 scale) indicated how much the couple collaborated during the interview session. Couples who received higher scores on collaboration worked together to tell their relationship history, built off of one another's stories, and viewed the relationship similarly. Couples who received lower scores did not work together when telling their relationship history, and disagreed with each other's stories. Coders exhibited high inter-rater reliability for collaboration (ICC = .87).

The discussion task was comprised of the Markman-Cox Procedure [18], consisting of a conflict section and recovery section. During the *conflict section* (10 minutes) partners tried to resolve a topic of disagreement in their relationship. During the *recovery section* (4 to 5 minutes), partners discussed topics or parts of their relationship that they mutually agreed on. *Conflict resolution* (rated on a 1-7 scale) indicated how well the couple worked together to resolve their disagreement during the conflict. Couples received higher scores if they worked towards a common goal cooperatively, and if they appeared mutually satisfied with the process. Couples received lower scores if they were insensitive to each other's feelings, or if only one partner appeared satisfied with the resolution. Coders exhibited high inter-rater reliability of conflict resolution (ICC = .90). *Overall quality* (rated on a 1-7 scale) indicated both partners' general sense of relationship quality. Couples received higher scores if they demonstrated mutual caring, trust, emotional closeness, and sensitivity and enjoyment of one another, while couples who received lower scores appeared to lack these qualities. Coders exhibited high inter-rater reliability of overall quality (ICC = .94).

## 2.3. Procedure

The audio track of each couples' discussion task (conflict and recovery sections) were exported from the video recordings at a sampling frequency of 48kHz as stereo wav files and imported into Praat [19]. Both partners' speech was contained on a single track. Acoustic-prosodic measures were extracted from non-overlapping parts of the audio track as follows:

### *2.1.1. Identifying inter-pausal units*

In order to measure acoustic-prosodic speech entrainment, we compared inter-pausal units (IPUs): the last segment of a speaker's turn or the first segment of his/her partner's turn. Identifying IPUs began with hand-marking *speaker backchannels*, *speaker overlap*, and *speaker turns*. Speaker backchannels were defined as speech lacking conversational content (e.g. "okay," "mm-hmm,"). Speaker overlap was defined as simultaneous speech by both partners. Speaker turns were defined as continuous speech by a single speaker, interrupted only by overlap or backchannels lasting less than 400 ms.

IPUs were identified and hand-marked as pause-free segments of speech from a single speaker that were (a) separated from one another by at least 50ms (as defined by [4]), and (b) not interrupted by instances of backchannels or overlap. In the atypical absence of a silence or interruption during a speaker's turn, IPUs were also marked at clear sentence or phrase boundaries, indicated by characteristic pitch movement or lengthening. This process identified IPUs that were too long to reliably exhibit local entrainment. IPUs < 50 ms long were excluded from analysis. Additionally, IPUs that were one or two syllables were only included if they were more than 90 ms long, so as to accurately measure speech rate. Only initial and final IPUs of each speaker's turn were used for analysis. In the case that a turn contained only one IPU, that IPU was marked as both initial and final.

We compared the prosodic characteristics of adjacent final and initial IPU's from alternating speakers. In the example below, initial IPUs are bolded and final IPUs are underlined. The acoustic characteristics of Speaker One's final IPU would be compared with those of Speaker Two's initial IPU:

*Speaker 1*: **"This morning I woke up early** [pause] <u>but when I looked outside I decided to go back to sleep"</u>
*Speaker 2:* **"That sounds like my morning too** [pause] except for [pause] <u>well I decided to make breakfast"</u>
*Speaker 1:* **"Well I think you made a good choice**. [clear sentence boundary] <u>What time you will get home tonight?"</u>
*Speaker 2:* <u>**"Not before nine o' clock"**</u>

#### 2.1.2. Extracting Acoustic Measures

Using Praat's scripting tools, we extracted the following acoustic measures of pitch, intensity, voice quality, and speech rate from the first and last IPUs in each speaker turn:

- Mean fundamental frequency (F0)
- Maximum F0
- Mean intensity
- Maximum intensity
- Jitter
- Shimmer
- Mean noise-to-harmonics ratio (NHR)
- Mean harmonics-to-noise ratio (HNR)
- Speech rate

Jitter indicates variation in fundamental frequency, calculated as the average absolute difference between the frequencies of consecutive periods, divided by the average period. Shimmer indicates variation in intensity, calculated as the average absolute difference between the amplitudes of consecutive periods, divided by the average amplitude. Noise-to-harmonics ratio and harmonics-to-noise ratio indicate the proportion of the speech that is harmonic and aperiodic, respectively. Speech rate indicates the number of syllables per second; syllable boundaries were annotated automatically whenever the speaker's intensity changed by ≥40 dB. All acoustic features were z-score normalized by speaker.

#### 2.1.3. Measurements of Acoustic-Prosodic Entrainment

Using the definitions in [4], we implemented three measures of entrainment: *Proximity* describes the similarity of partners' speech at turn exchanges; *synchrony* describes the extent to which speakers exhibit relative similarity across turn exchanges; *convergence* quantifies the tendency of partners' speech to become more similar over the course of the conversation.

For each acoustic feature, proximity was measured by calculating the absolute value of the difference between the value for a speaker's target IPU and her/his partner's adjacent IPU's (*partner distance*) (1), and comparing that value to the absolute value of the difference between the value for a speaker's target IPU and five other random non-adjacent IPU's (*other distance*) (2). Couples exhibited proximity entrainment if partner distances were significantly less than other distances, as determined by a paired-samples t-test, meaning that negative values indicate more entrainment. A single proximity score for each couple was computed by averaging the absolute value of the differences between partner distance and other distance across the conversation.

Convergence was calculated by computing the correlation between the absolute value of prosodic differences of adjacent IPU's and the IPU number (used as a measurement of time). Couples exhibited convergence if this correlation was significant. The value of the correlation coefficient represented a single couple's convergence score.

Synchrony was calculated by computing the correlation between the value of each acoustic feature at speakers' adjacent IPUs across the conversation. Couples exhibited significant synchrony if this correlation was significant. The value of the correlation coefficient represented a single couple's synchrony score.

$$partner\ distance = |IPU(target) - IPU(partner)| \quad (1)$$

$$other\ distance = \frac{\sum_{i=1}^{5} |IPU(target) - IPU(i)|}{5} \quad (2)$$

## 3. Results

### 3.1. Entrainment Results

We observed significant proximity and synchrony entrainment across most of the measured acoustic features during both the conflict and recovery discussions (Table 1). We observed significant proximity entrainment during the conflict discussion for mean pitch, mean and max intensity, shimmer, mean NHR, mean HNR, and rate. We observed significant proximity entrainment during the recovery discussion for mean and max intensity, jitter, and mean NHR. We observed significant synchrony entrainment during the conflict discussion for mean and max intensity, shimmer, mean NHR, mean HNR, and rate. We observed significant synchrony entrainment during the recovery discussion for mean and max intensity, jitter, mean NHR, and mean HNR. We only observed significant convergence entrainment on speech rate during the conflict discussion.

### 3.2. Entrainment and Social Factors

In order to investigate the relationship between entrainment and social factors, we conducted a series of principal component analyses (PCAs) on the nine acoustic features in Table 1. Because we hypothesized that entrainment might differ across the conflict and recovery discussions, we conducted separate PCAs for each measure of entrainment (proximity, convergence, and synchrony) and for each discussion (conflict, recovery), resulting in a total of six PCAs. The input to each PCA was a single entrainment score for each couple for each feature (as described above). In all but one case, a one-component solution provided the best account of the data, as determined by inspection of the eigenvalues and

| Acoustic feature | Proximity (*t*) | | Convergence (*r*) | | Synchrony (*r*) | |
|---|---|---|---|---|---|---|
| | Conflict | Recovery | Conflict | Recovery | Conflict | Recovery |
| Mean Pitch | -2.69* | n.s. | n.s. | n.s. | 1.84^ | 1.69^ |
| Max Pitch | n.s. | n.s. | n.s. | n.s. | n.s. | 1.84^ |
| Mean Intensity | -7.21** | -5.23** | n.s. | n.s. | 9.20** | 7.36** |
| Max Intensity | -5.15** | -3.22** | n.s. | n.s. | 8.05** | 5.93** |
| Jitter | n.s. | -2.28* | n.s. | n.s. | n.s. | 2.60** |
| Shimmer | -2.98** | n.s. | n.s. | n.s. | 4.28** | 1.75^ |
| Mean NHR | -2.64* | -2.24* | n.s. | n.s. | 3.04** | 2.64** |
| Mean HNR | -2.73* | n.s. | n.s. | n.s. | 3.42** | 1.99* |
| Speech rate | -2.86** | n.s. | 2.11* | 1.69^ | 2.27* | n.s. |

Table 1: *Acoustic features assessing three measures of entrainment for conflict and recovery discussions. Proximity is measured using a paired t-test; convergence and synchrony are measured by Pearson's correlation coefficient in a two-tailed t-test. n.s. = nonsignificant, ^ = marginal significance, * = significance at the .05 level; ** = significance at the .01 level.*

| Acoustic Feature | Proximity | | Convergence | | Synchrony | | |
|---|---|---|---|---|---|---|---|
| | Conflict | Recovery | Conflict | Recovery | Conflict PCA1 | Conflict PCA2 | Recovery |
| MeanPitch | 0.489 | 0.226 | **0.647** | 0.587 | 0.064 | **0.726** | -0.026 |
| MaxPitch | 0.020 | 0.306 | 0.017 | 0.289 | 0.113 | 0.214 | 0.168 |
| MeanInten | **0.745** | **0.777** | **0.704** | **0.778** | 0.415 | **0.757** | 0.572 |
| MaxInten | 0.486 | **0.761** | 0.409 | 0.186 | 0.280 | **0.847** | **0.671** |
| Jitter | **0.713** | -0.036 | **0.739** | 0.406 | **0.723** | -0.200 | 0.441 |
| Shimmer | **0.743** | **0.641** | **0.733** | 0.489 | **0.800** | 0.086 | **0.677** |
| MeanNHR | **0.921** | **0.680** | **0.858** | **0.785** | **0.952** | -0.162 | **0.773** |
| MeanHNR | **0.728** | **0.828** | **0.898** | **0.886** | **0.930** | -0.145 | **0.903** |
| Rate | 0.151 | 0.255 | 0.335 | 0.366 | 0.510 | -0.504 | 0.090 |

Table 2: *Factor loadings for principal components analysis for each feature and each conversation. Bolded factor loadings were retained in the final analysis.*

scree plots. Components were derived by retaining features that loaded above 0.6 and did not cross-load on other factors above 0.4 [20] (Table 2).

To determine whether relationship factors affected any of the three measures of entrainment, we regressed the four relationship values of interest—*relationship length*, *interview collaboration*, *conflict resolution*, and *observed quality*—against the PCA components in Table 2. We observed no significant relationship between proximity and synchrony entrainment factors and the relationship factors; however, convergence entrainment was modulated by relationship factors: couples who demonstrated higher convergence during the recovery discussion scored higher on interview collaboration and observed quality. Conversely, couples who demonstrated lower convergence during the conflict discussion scored higher on conflict resolution (Table 3).

| Relationship measure | Principal component | b | SE | t | p |
|---|---|---|---|---|---|
| Length of relationship | Conflict | 0.87 | 0.65 | 1.33 | 0.20 |
| | Recovery | 0.58 | 0.45 | 1.29 | 0.21 |
| Interview collaboration | Conflict | 0.15 | 0.34 | 0.45 | 0.66 |
| | Recovery | 1.17 | 0.42 | 2.78 | 0.01* |
| Conflict resolution | Conflict | -0.67 | 0.35 | -1.90 | 0.07^ |
| | Recovery | 0.48 | 0.53 | 0.89 | 0.38 |
| Observed quality | Conflict | -0.53 | 0.39 | -1.36 | 0.19 |
| | Recovery | 1.16 | 0.53 | 2.22 | 0.04* |

Table 3: *Linear regression models of convergence factors*

## 4. Discussion

The current study was designed to explore factors that affect prosodic entrainment in romantic couples' speech. We investigated three methods of operationalizing entrainment: Proximity, convergence, and synchrony. In addition, we explored whether any of three relationship factors (length of relationship, interview collaboration, and observed quality) affected couples' entrainment during two conversations, a discussion about a relationship conflict, and a recovery discussion about an agreed-upon topic.

We observed overall entrainment for most of the examined acoustic features as measured by proximity and synchrony, particularly for intensity and mean NHR. These results are consistent with previous research on acoustic-prosodic speech entrainment between conversational partners [3,4,6] and indicate that romantic partners tend to match their prosodic features during turn exchanges.

In contrast with the proximity and synchrony results, we observed overall convergence entrainment only for speech rate. This finding is inconsistent with prior studies that have reported convergence entrainment for other acoustic features [4]. However, the PCA results suggest that partners' convergence entrainment is related to both the strength of their relationship and their behavior during the discussion. Specifically, entrainment during conflict was (marginally) associated with poorer conflict resolution, while entrainment during recovery was associated with higher overall quality, and better collaboration during a subsequent non-conflict task. This pattern suggests that acoustic-prosodic entrainment may be maladaptive during conflict discussions but adaptive during positive discussions.

In contrast to our hypothesis, our results did not reveal an effect of relationship length on entrainment. Previous studies have demonstrated that strangers entrain over short time-scales [11] and couples in the current study had been together for at least a year, suggesting that entrainment is a fast process. In order to investigate the effect of relationship length on entrainment, future work should focus on romantic couples in the beginning stages of their relationship.

Finally, we observed no effects of relationship factors on proximity or synchrony. It may be the case that entrainment fluctuates with moment-to-moment conversation patterns and that these measures are too coarse to reveal local entrainment effects. Future work will investigate this possibility by adopting the method of annotating the emotional tone of each phrase to determine whether entrainment varies accordingly [12].

## 5. Conclusion

The results of the current study demonstrate that romantic couples entrain their speech on pitch, intensity, voice quality, and rate measures during discussions about agreements and disagreements. Furthermore, convergence entrainment varied with couples' behavior and their relationship quality. These early findings demonstrate that the Couples Communication Project corpus is a valuable resource with which to explore how individual and couple-level factors affect prosodic entrainment.

## 6. Acknowledgements

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