

# Dynamical Systems Modeling of Acoustic and Physiological Arousal in Young Couples

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## Abstract

Well-being and mental health are directly associated with relationship status particularly in the context of relatedness and support. A key factor in relationship functioning is emotional arousal. We examine the interplay between emotional arousal manifested through acoustic and physiological cues and its association to relationship satisfaction. We propose a dynamical systems model to infer the within- and across-modality as well as the between-partner relations. Our results suggest that increased emotional regulation is negatively associated with relationship satisfaction and indicate that the proposed system consists a viable framework for analyzing such multi-modal interrelations within romantic partners.

## Introduction

Physical and psychological well-being have been extensively associated with relationship status (Coombs, 1991; Lillard and Waite, 1995; Dush and Amato, 2005). Similarly, committed romantic relationships of young couples providing companionship and aid are related to reduced mental and physical health problems (Braithwaite, Delevi, and Fincham, 2010).

Emotional arousal has been studied in the context of family conflict, as it is associated with degraded quality of family life (Katz, Kramer, and Gottman, 1992; Gottman et al., 1995; Baucom et al., 2012b) and negative child outcomes (Gottman and Katz, 1989; Baucom et al., 2012a). However, little research has examined emotional arousal in early family environments, as well as momentary fluctuations of multiple indicators of arousal. The goal of this study is to model moment-to-moment changes of acoustic and physiological indices during conflict discussions between young couples and investigate whether their potential associations can be related to relationship outcomes.

## Dynamical Systems Modeling

Dynamical systems, and particularly linear oscillators, can capture the coevolution between signals and have been previously used for studying interaction Felmler and Greenberg (1999); Ferrer and Helm (2013); Reed, Barnard, and Butler (2015). Their benefit compared to statistical data

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(surface) models lies in their capability to accurately describe the underlying generative behavior of various human-derived signals. We demonstrate how a coupled linear oscillator with appropriate input can jointly model the coevolution of acoustic and physiological arousal patterns of a person, while at the same time integrate the influence of his/her partner on these measures. For this purpose, we can write the general model as follows:

$$\frac{d}{dt} \begin{bmatrix} A_x \\ P_x \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} A_x - A_x^* \\ P_x - P_x^* \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} (A_y - A_y^*) \quad (1)$$

or else

$$\begin{aligned} \frac{dA_x}{dt} &= a_{11}(A_x - A_x^*) + a_{12}(P_x - P_x^*) + b_1(A_y - A_y^*) \\ \frac{dP_x}{dt} &= a_{12}(A_x - A_x^*) + a_{22}(P_x - P_x^*) + b_2(A_y - A_y^*) \end{aligned} \quad (2)$$

where  $A_x$ ,  $P_x$  represent the acoustic and physiological arousal measures of a person,  $A_y$  the acoustic arousal index of his/her partner, and  $A_x^*$ ,  $P_x^*$ ,  $A_y^*$  the corresponding variables at equilibrium state. Parameters  $a_{11}$  and  $a_{22}$  capture the amount of change within the acoustic and physiological modality, while  $a_{12}$  and  $a_{21}$  represent the cross-modal influence within a person. The amount of interconnection between partners is expressed by  $b_1$  and  $b_2$ , which capture the effect of one's acoustic features to the other's acoustic and physiological patterns. Negative values of the aforementioned parameters indicate instantaneous fluctuations towards the equilibrium, while positive terms reflect the opposite - as similarly described in (Ferrer and Helm, 2013). This suggests that the degree of self-regulation in the acoustic and physiological domain and cross-regulation between the two modalities is reflected by negative values of  $(a_{11}, a_{22})$  and  $(a_{12}, a_{21})$ , respectively. Similarly, negative values of  $b_1$  and  $b_2$  suggest opposite patterns between one's acoustic and physiological indices compared to his/her partner's vocal arousal.

## Data Description

Our data was collected as part of an ongoing study of 26 young dating couples (ages 18-25 years) engaging in a 10-minute "change discussion", during which they had to talk

Table 1: Pearson’s correlation values between relationship satisfaction scores and dynamical system parameters.

		Female	Male
Within-modality	$a_{11}$	-0.48 (0.16)	0.66 (0.05)
	$a_{22}$	-0.04 (0.90)	-0.57 (0.09)
Across-modalities	$a_{12}$	-0.55 (0.1)	-0.18 (0.62)
	$a_{21}$	-0.21 (0.56)	0.24 (0.51)
Across-partners	$b_1$	-0.68 (0.05)	-0.58 (0.08)
	$b_2$	0.33 (0.35)	0.13 (0.72)

Parentheses denote p-values.

to each other about things in their relationship that could be different. One of the partners from ten of these couples participates in a multi-wave longitudinal study, during which he/she had also visited the laboratory approximately five years before as a youth. Participants completed the Relationship Satisfaction Questionnaire (adapted from the Quality of Marriage Index; (Norton, 1983)) concerning the degree of satisfaction in various areas of the relationship.

Each conflict discussion was manually segmented in talk turns, each bounded by consecutive speaker transitions. For vocal arousal, we used a combination of pitch (F0), voice intensity and the ratio of high-to-low frequency energy (HF500), the latter serving as a voice quality index (Bone, Lee, and Narayanan, 2014). The physiological arousal measure included the frequency of skin conductance responses (SCR), because of its relation to various psychophysiological constructs (Dawson, Schell, and Filion, 2007). Mean SCR frequency was computed over the starting points of two consecutive talk turns.

## Results

Our results (Table 1) indicate that relationship satisfaction is negatively associated with vocal self-regulation ( $a_{11}$ ) and physiological-to-vocal cross-regulation ( $a_{12}$ ) in females, and physiological self-regulation ( $a_{22}$ ) in males. Couples with higher relationship satisfaction tend to depict opposite patterns of vocal arousal ( $b_1$ ), e.g. one shows reduced vocal arousal after his/her partner’s highly-aroused turn. These are consistent with previous findings concerning the interconnection between negative emotions and high arousal (Baucom et al., 2012a) and suggest the usefulness of the proposed framework for modeling and interpreting the coevolution of multiple modalities within a person and their association with the interacting partner.

## Conclusions

In this study, we proposed a dynamical systems model to quantify the interplay between acoustic and physiological arousal in young couples. We further examined the validity of our approach, which indicates that decreased self-regulation within and across modalities is present in couples with low relationship satisfaction. The consistency of this finding to the existing literature suggests the usefulness of the proposed model for analyzing relations of various emotional indices within and across partners.

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