The Suppes Brain Lab
The Study of Language and Emotion
The Couple Therapy Dataset

A talk given by Michelle Nguyen Suppes and Colleen Crangle, September 2015

Center for the Study of Language and Information (CSLI), Stanford University

Background

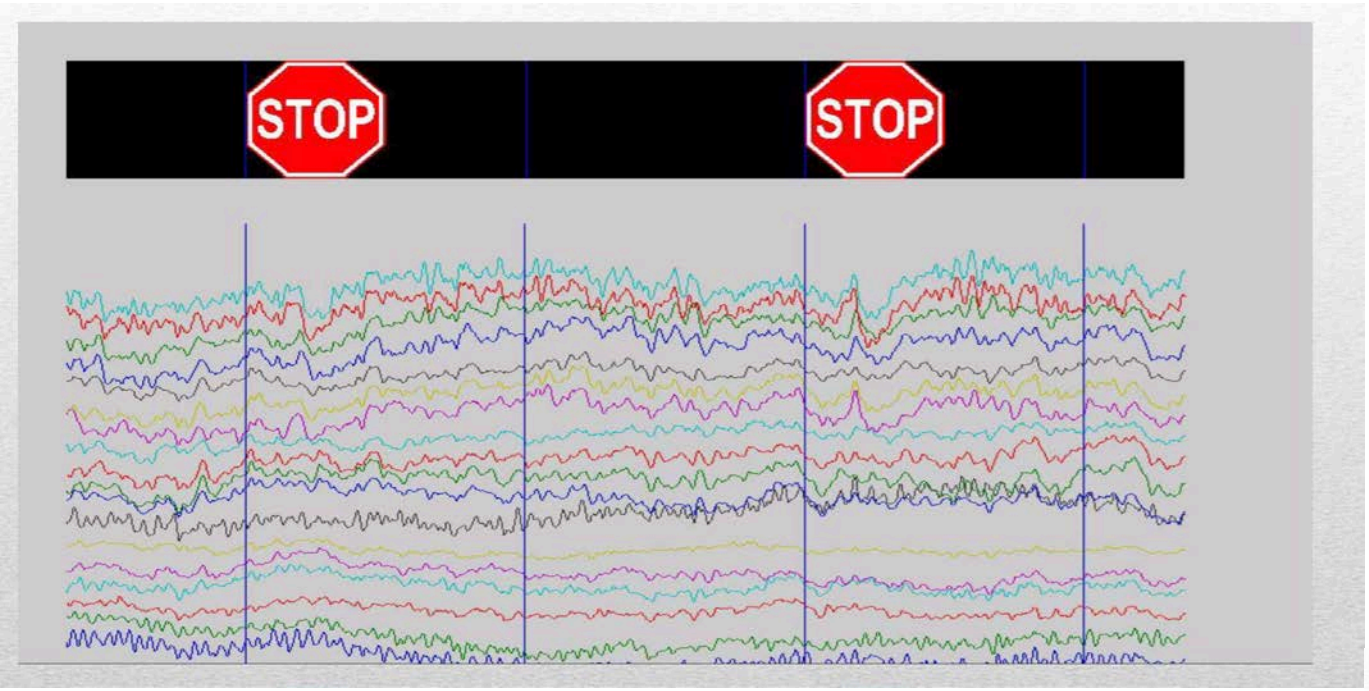
1. Study of Language

(Source: Suppes-brain-lab.stanford.edu)

- The Suppes Brain Lab prior studies applied machine-learning methods to EEG data to probe questions related to brain representations in the study of language in the brain. In these earlier studies, the focus was on ***human brain representations*** of stimuli (e.g. simple objects, (their colors, geometric shapes), words (phonemes and short sentences), or musical phrases).
- Address questions related to the representation of language, music, visual/auditory and imagine stimuli in the electromagnetic field generated by the human brain.
- This knowledge is of both theoretical importance (as it relates to fundamental neuro-cognitive and philosophical questions) and practical importance (as it relates to the design of brain-computer interfaces).

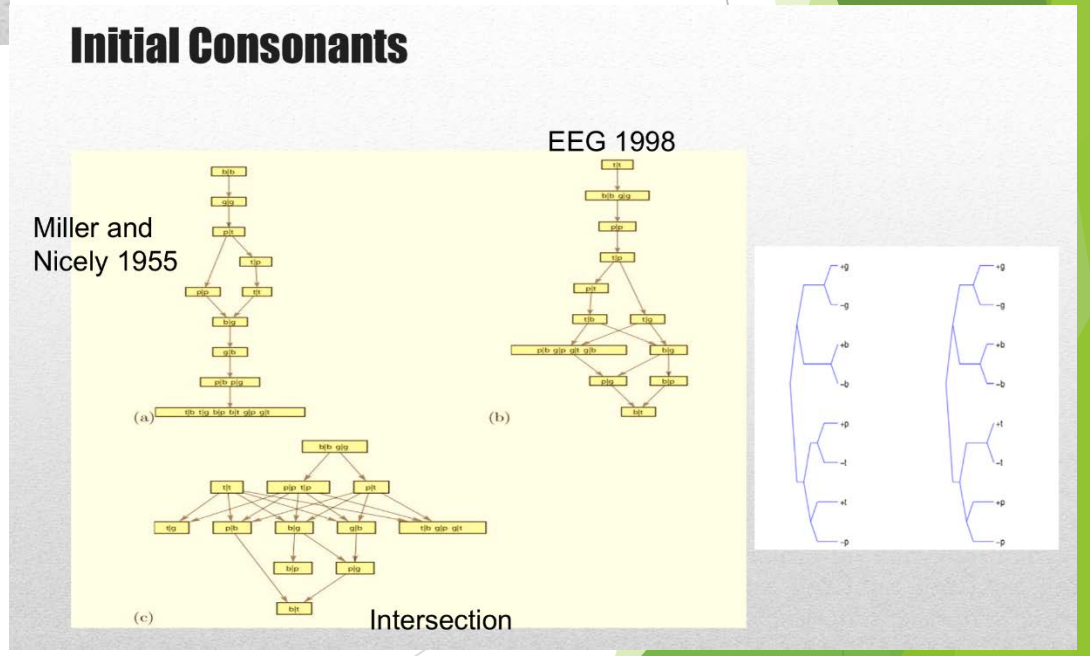
Early Years

- Patrick Suppes, Zhong-Lin Lu, and Bing Han. Brain-wave recognition of words. *Proceedings of the National Academy of Sciences*,**94**, 1997, pp. 14965-14969.
- Patrick Suppes, Bing Han, and Zhong-Lin Lu. Brain-wave recognition of sentences. *Proceedings of the National Academy of Sciences*, **95**, 1998, pp. 15861-15866.
- Patrick Suppes, Bing Han, Julie Epelboim, and Zhong-Lin Lu. Invariance between subjects of brain-wave representations of language.*Proceedings of the National Academy of Sciences USA*, **96**, 1999, pp. 14658-14663.
- Patrick Suppes, Bing Han, Julie Epelboim, and Zhong-Lin Lu. Invariance of brain-wave representations of simple visual images and their names. *Proceedings of the National Academy of Sciences USA*, **96**, 1999, pp. 14658-14663.
- Patrick Suppes and Bing Han. Brain-wave representation of words by superposition of a few sine waves. *Proceedings of the National Academy of Sciences*, **97**, 2000, pp. 8738-8743.
- Dik Kin Wong, Marcos Perreau Guimaraes, E. Timothy Uy, and Patrick Suppes. Classification of individual trials based on the best independent component of EEG-recorded sentences. *Neurocomputing*, **61**, 2004, pp. 479-484.
- Dik Kin Wong, Marcos Perreau Guimaraes, E. Timothy Uy, and Patrick Suppes. Tikhonov-based regularization of a global optimum approach of one-layer neural networks with fixed transfer function by convex optimization. M. Zhao and Z. Shi (Eds.), *Proceedings of the 2005 IEEE International Conference on Neural Networks and Brain,* **3**. Beijing: IEEE Press, 2005, pp. 1564-1567.
- Dik Kin Wong, Marcos Perreau Guimaraes, E. Timothy Uy, Logan Grosenick, and Patrick Suppes. Multichannel classifications of single EEG trials with independent component analysis. J. Wang, et al. (Eds.), *Advances in Neural Networks-ISNN 2006*. Berlin: Springer, **150**, 2006, pp. 354-359.
- Dik Kin Wong, E. Timothy Uy, Marcos Perreau Guimaraes, W. Yang, and Patrick Suppes. Interpretation of perceptron weights as constructed time series for EEG classification. *Neurocomputing*, **70**, 2006, pp. 373-383.
- Marcos Perreau Guimaraes, Dik Kin Wong, E. Timothy Uy, Logan Grosenick, and Patrick Suppes. Single-trial classification of MEG recordings. *IEEE Transactions on Biomedical Engineering*, **54**, 2007, pp. 436-443.
- Patrick Suppes and J. Acacio de Barros. Quantum mechanics and the brain. *Quantum Interaction: Papers from the AAAI Spring Symposium, Technical Report SS-07-08*. Menlo Park, CA: AAAI Press, 2007, pp. 75-82.
- Dik Kin Wong, Logan Grosenick, E. Timothy Uy, Marcos Perreau Guimaraes, Claudio G. Carvalhaes, Peter Desain, and Patrick Suppes. Quantifying inter-subject agreement in brain-imaging analyses. *NeuroImage*, **39**, 2008, pp. 1051-1063.



Classification rate. Visual and auditory stimulus impact on EEG. Experiments used mainly for developing method for classification of brain waves (of shapes, colors, phonemes).

Theoretical work beyond classification. Language is not that simple. There are grammatical, syntactic and semantic rules to consider.

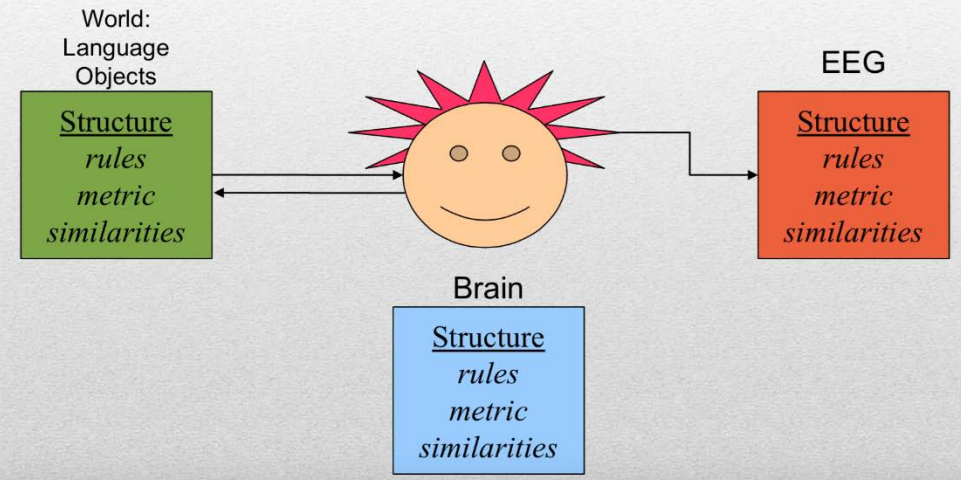


Source

Marcos Perreau-Guimares, "Language and the Brain: 15 years of the Suppes Brain Lab", on occasion of Patrick

Partial orders of similarity differences invariant between EEG-recorded brain and perceptual representations of language.

Patrick Suppes, Marcos Perreau-Guimaraes, and Dik Kin Wong.
***Neural Computation.* 21, 2009, pp.3228-3269.**



Isomorphism between the words of the stimulus and what we see in the EEG. (Using Pat's previous work on the theory of measurement and partial orders)

Sentences Experiment

	# trials	LDC	LDC regularized	LIBSVM linear	LIBSVM radial
III+IV	1020	32.10%	36.00%	34.00%	30.20%
II Aud	2040	10.60%	11.70%	14.50%	14.90%
II Vis	4590	15.00%	15.40%	18.60%	18.10%

1) The capital of italy is paris
2) London is not the capital of poland
3) The largest city of france is not berlin
4) Warsaw is not the largest city of russia
5) Moscow is east of warsaw
6) Rome is north of london
7) Paris is not west of berlin
8) Rome is not south of moscow
9) The capital of germany is warsaw
10) Moscow is not the capital of russia
11) The largest city of italy is not rome
12) London is not the largest city of france
13) Paris is east of berlin
14) Moscow is north of paris
15) Warsaw is not west of london
16) Berlin is not south of rome
17) The capital of italy is not berlin
18) Warsaw is the capital of france
19) The largest city of germany is berlin
20) London is the largest city of russia
21) Moscow is not east of paris
22) Rome is not north of warsaw
23) London is west of moscow
24) Paris is south of rome

Exp II Vis LDC	france 1	paris 1	london 1	berlin 1	warsaw 1	moscow 1	france 2	paris 2	london 2	berlin 2	warsaw 2	moscow 2	North	South	East	West	poland	russia	germany
france 1	14.2	1.5	3.1	0.1	3.5	3.4	3.5	5.7	3.9	4.5	9.2	7.5	6.6	7.3	5	4.3	2.9	8.5	6.2
paris 1	1.3	20.3	10.6	2.7	8.6	11.5	3	3.2	2.9	4.2	4.1	2.3	6.1	3.7	3.2	3.2	1.2	3.8	4
london 1	1	9.4	19.1	2.9	10.5	10.5	2.8	3.3	2.9	4.1	3.9	3.1	3.6	6.1	3.4	3.6	1.8	3.4	4.5
berlin 1	1.2	10	6.2	8.7	9.9	11.8	3.3	4.3	2.6	3.9	4.4	3.7	5.9	6.1	3.2	3.5	2	3.3	5.9
warsaw 1	2	9	10.5	2.7	17	9.5	2.8	3	3.8	4.2	3.8	3.1	6	5.6	3.1	3.1	1.5	4	5.2
moscow 1	1.4	9.4	9.7	3.9	9.2	17.5	2.3	3.9	3.4	4.3	4.1	2.6	5.1	5	3.4	3.7	1.7	3.9	5.6
france 2	0.6	1.6	2.9	0	1.3	3.4	15.2	9.7	5	10.4	8.3	5.1	4.5	7.5	5.4	4.1	5.1	7.6	2.3
paris 2	1.4	1.5	1.2	0.2	1.5	3.8	9.6	15	4.8	8.4	9.9	8.6	3.8	6.9	5.9	3.9	5.5	6.5	1.8
london 2	1.3	1.4	2.6	0.4	2.4	7.3	6.2	6.4	11.4	9.6	4.9	4.3	8.2	7.6	4.9	4.9	2.8	8.6	4.6
berlin 2	1.7	1.5	2.2	0.1	1.9	4.3	6.2	6.7	5.1	17	7.3	4.9	6.8	6.8	6.4	5.1	4	9.7	2.4
warsaw 2	1.5	1.6	1.9	0.2	1.7	4	6.2	10.7	4.6	9.1	12.6	12.6	4.2	6.4	5.3	4	4.4	6.7	2.2
moscow 2	1.4	1.5	2.5	0.1	1.7	4.3	6	10	3	6.9	16.7	12.9	3.6	6.3	5.5	5.7	3	6.4	2.6
North	1.7	3.7	4.1	0.5	4.5	4.5	3.4	4.5	6.9	8	5.4	3.4	15.3	6.6	6	7.3	2.3	5.1	6.9
South	1.4	1.7	4.2	0.5	3.2	4.5	4.5	3.8	3.7	6.8	3.2	3	6.9	19.2	8.8	10.8	1.9	3	8.9
East	2.1	2.1	3	0.3	3	4.1	5.2	5.6	3.7	10.5	4.5	4.8	7.5	8.6	13.7	9.1	2.5	5.4	4.3
West	2.3	2.2	3.5	0.3	2.5	2.6	6.1	4.5	3.9	7.7	5.1	4.6	8	11	9.6	12.9	2	4.1	7.2
poland	2.2	0.5	2.1	0	0.9	3	8.8	13	4.3	8.6	7.3	4.4	5.2	8.9	5.4	2.8	10.2	10.2	2.2
russia	1.6	2.2	1.9	0.1	1.6	4.3	8.2	6.6	5.4	14.7	5.9	3.4	5.8	4.5	5.8	5.1	5	15.2	2.4
germany	2.7	4.2	4.6	0.7	3.3	6.1	2.6	3.7	3.8	5.7	2.8	3.3	8.5	9.1	4.8	6.5	2.3	2.4	22.8

Acquisition of a dual-channel EEG with 128-sensor net each. (2009)

Psychotherapy sessions available (source from Duc Nguyen, Suppes Brain Lab):

- 6 couples, 8 individuals
- 211 total sessions recorded (93 couples sessions/118 individuals)
- 185 sessions synced wuth EEG recording (69 sessions from couples, 116 individuals).
- 15 sessions fully transcribed
- 16 sessions partially transcribed
- 21 sessions with emotion coding

2. Study of Emotion

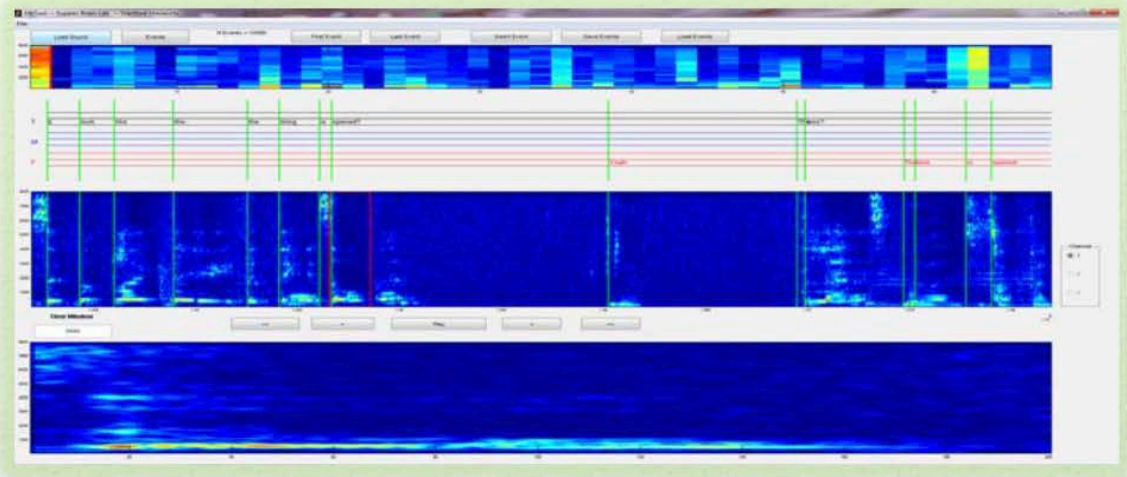
- Acquisition of new and as yet not widely tested, EEG equipment to record simultaneously two participants, as in the studies of expression of emotion in psychotherapy, music experiments, and neural economic games.
- Attempts to look at the expression of emotion, and the reception of it, as the most prominent phenomena in the interactions of couples.
- Simultaneously making video recordings of couples psychotherapy sessions, for which speech and brain recording are also made.
- Study the couples' behaviors, as recorded in video, in detail, to understand how emotion is expressed in language. The rich context of psychotherapy sessions allows for a deeper understanding of the emotional features expressed in the speech.
- Emotions recognition and classification using speech signals and EEG data.
- Brain data from these psychotherapy experiments can provide a bridge to connect psychotherapy and neuroscience.

Experimental design

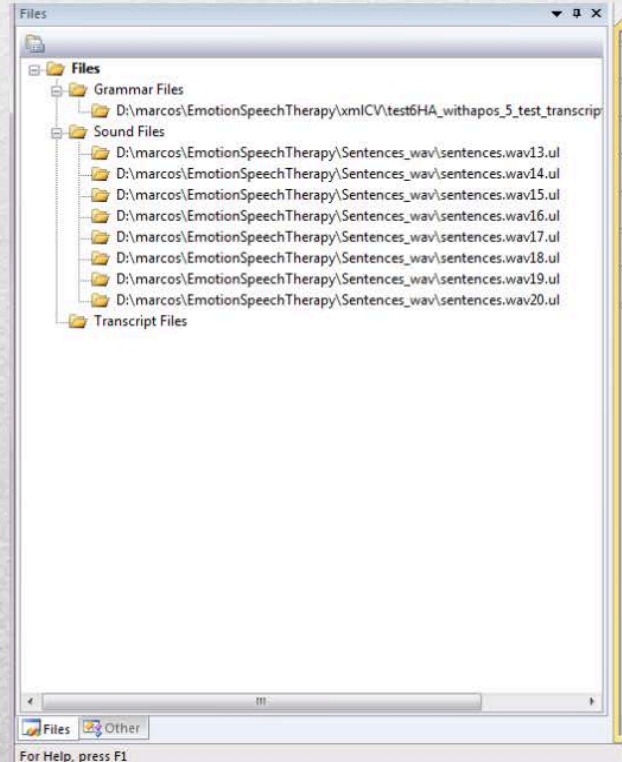
(Excerpts from Internal Review Board (IRB) Protocol, Human Subjects Research)

- Video, audio and EEG data are collected from an individual or a couple simultaneously in the following possible settings:
  - A) Two individuals working with a therapist (in therapeutic setting)
  - B) Two individuals listening to music together in the presence of an experimenter (not a therapist)
  - C) Two individuals in the environment of an experimental game in the sense of economics, now often called neuroeconomics.
- Participants recruited by psychotherapists in the study.
- During the experiment period, a geodesic net of EEG sensors is placed on each participant's head.
- The study lasts from 30 minutes to 60 minutes.
- An individual participant is asked to attend to various simple perceptual stimuli.
- A couple participate in psychotherapy involving relationship or marital issues.
- Therapy is focused on the expression of emotion (EFT), to elicit real-time emotional responses from the couple.

Transcription



- Manual transcription with ~5ms accuracy for the onset of words
- ~100h to transcribe 1h
- Software Development



acoustic_score="92.1339"
confidence="0.543" >but</arc>
acoustic_score="122.588"
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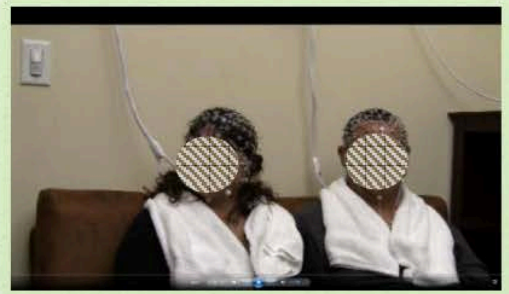
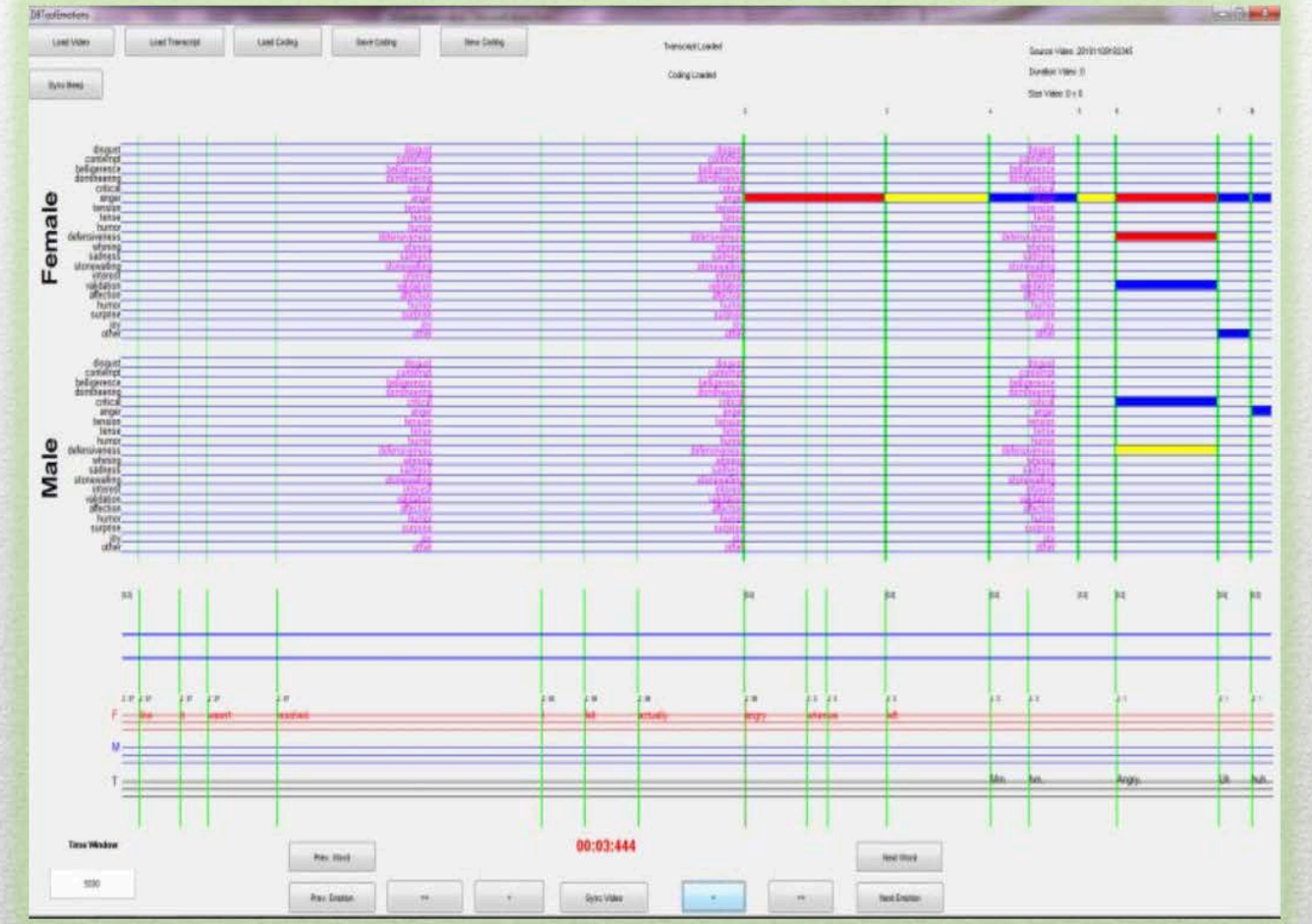
- Automatic Transcription
- Hard problem
  - 3 speakers
  - Conversational
  - Disfluent
- Software Development

Coding of Emotions



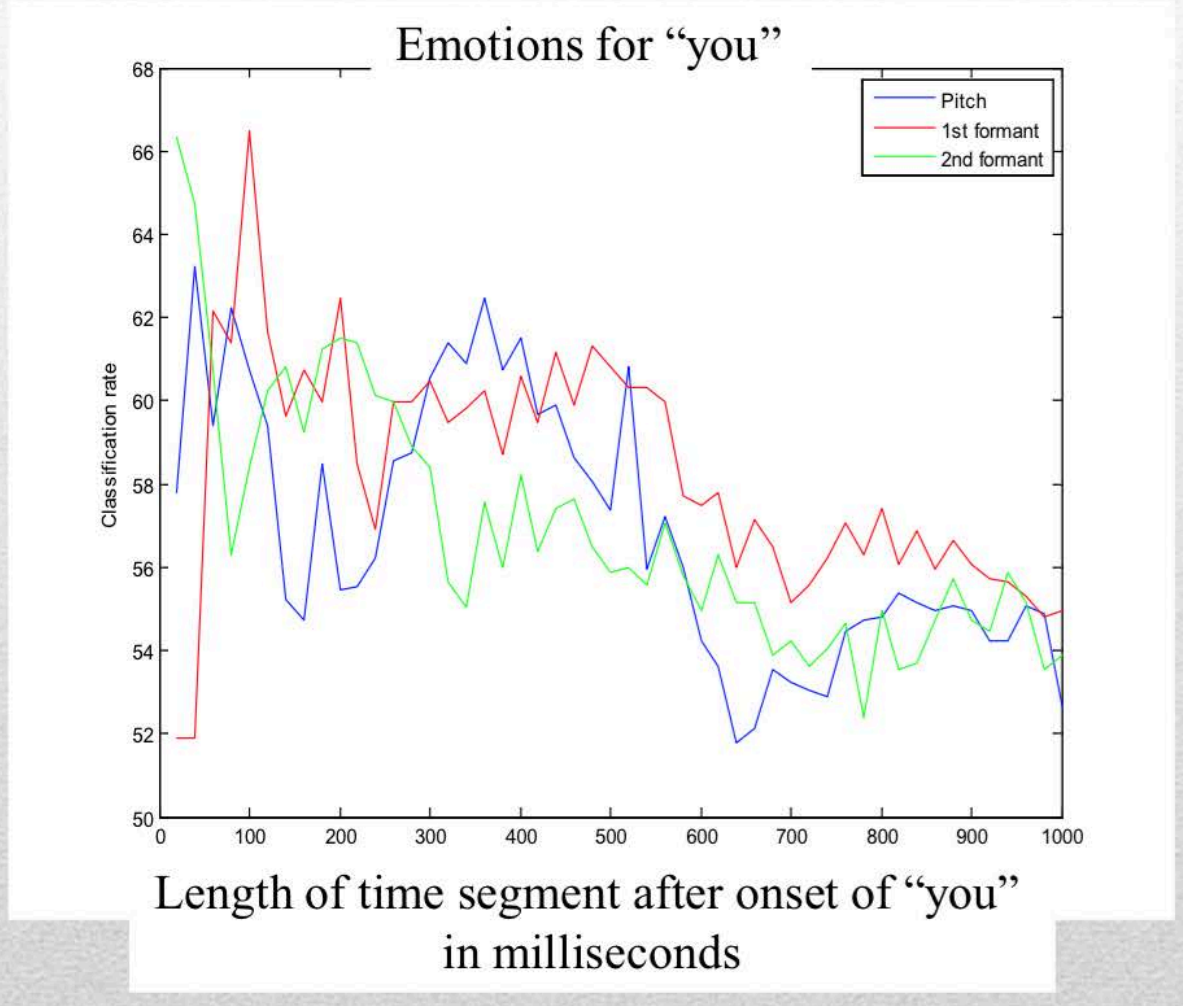


- 4 to 19 emotions
- Verbal and non verbal
- Levels of
  - Intensity
  - Confidence
- Direction
- Insight
- ~30h to code 1h

- ***Emotionally focused therapy (EFT)***
- An empirically supported humanistic treatment[4].
- Arosed out of the theoretical integration of research on psychotherapy with ideas from constructivist psychology, emotion theory, and attachment theory.
- Views emotions as centrally important in the experience of self and others, in both adaptive and maladaptive functioning, and in therapeutic change.
- Change occurs by means of emotional awareness and arousal, regulation of emotion, reflection on emotion, and transformation of emotion taking place within the context of an empathetically attuned relationship.

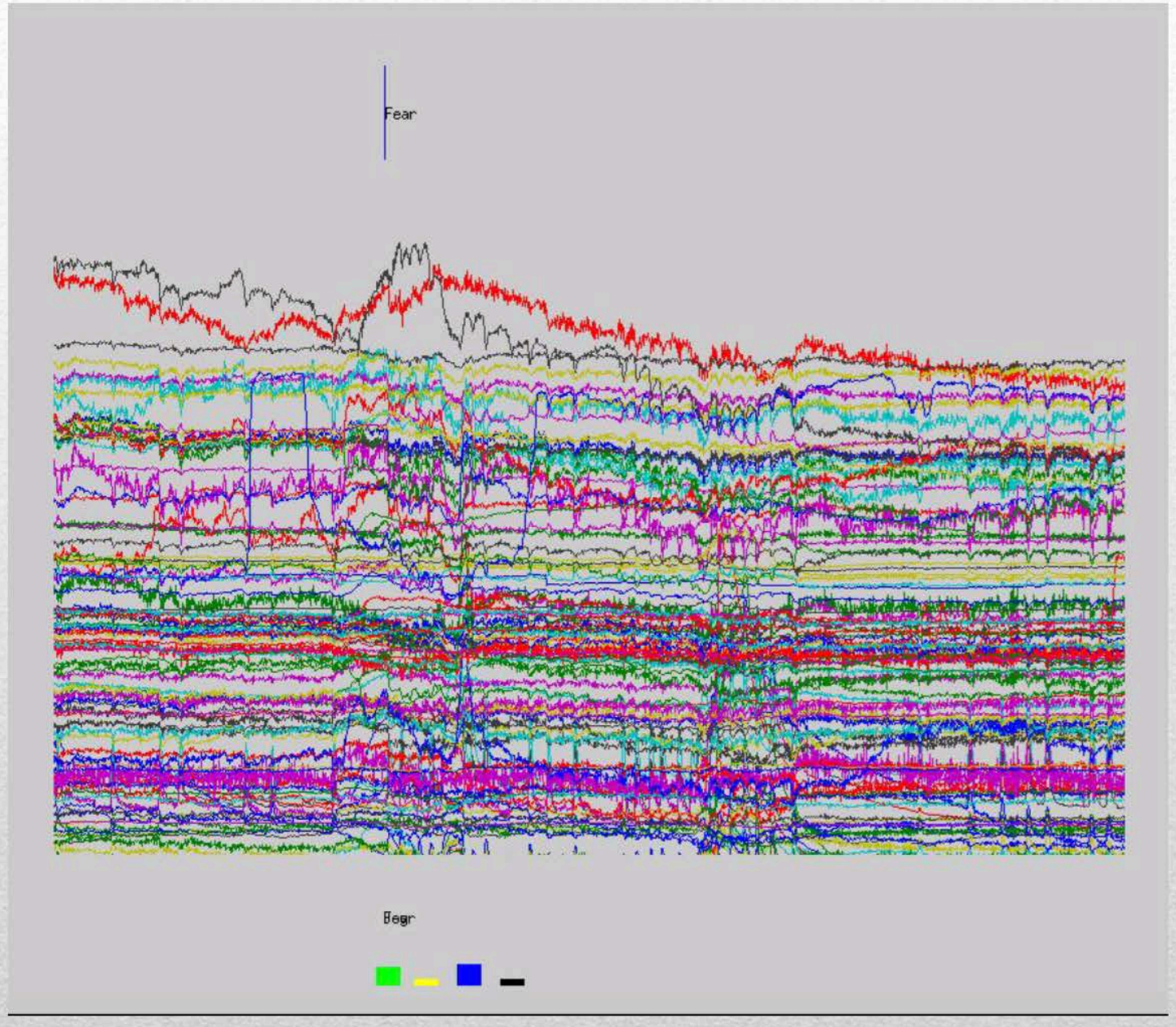
Problem to solve: Colleen Crangle's talk.

Analysis of the Speech



- Control for words
- Non linear classification (SVM) of Sadness versus Anxiety using Frequency features (Pitch, Formants), Energy in auditory bands and Dynamics of the speech envelope

Analysis of the EEG



- Male EEG when The Female express emotions
- 4 Emotions : Joy, Sadness, Anxiety and Anger.

- Scalp, face and jaw muscle artifacts
- Too little data yet but promising first results

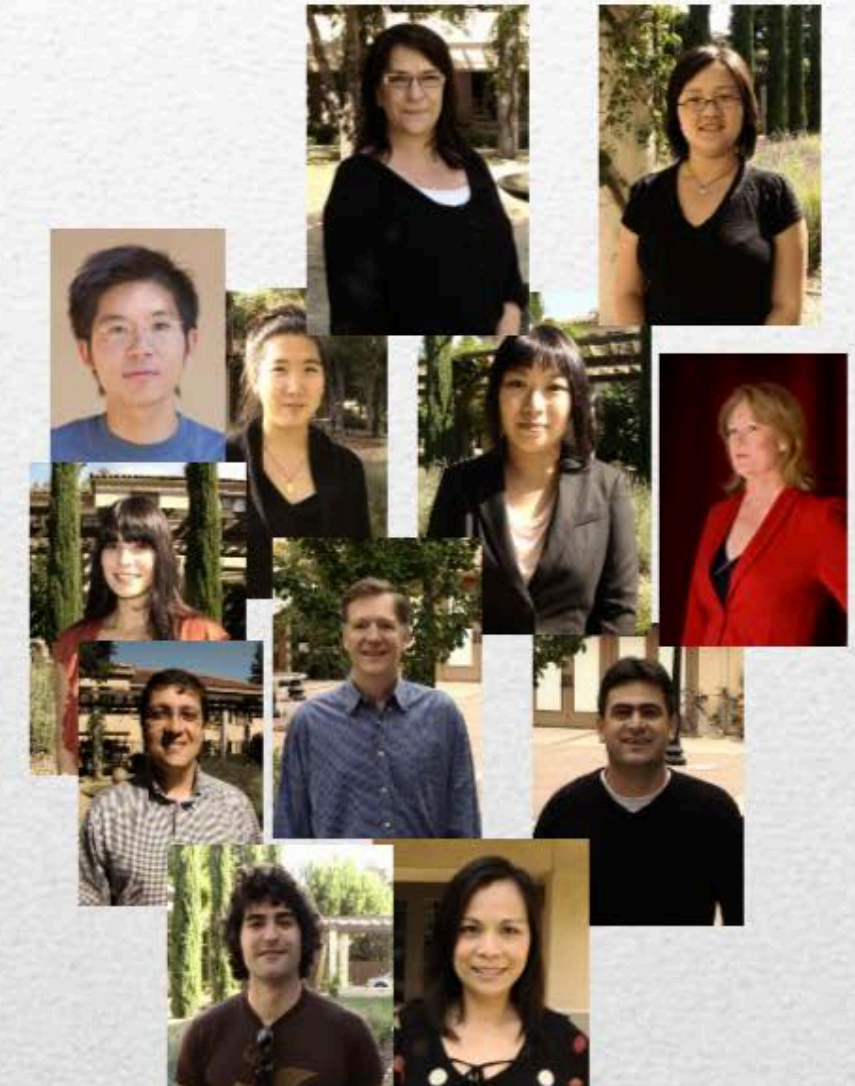
3. Weakly coupled phase oscillators

(Source: Summary from Leonardo Paulo Guimaraes De Assis, Suppes Brain Lab)

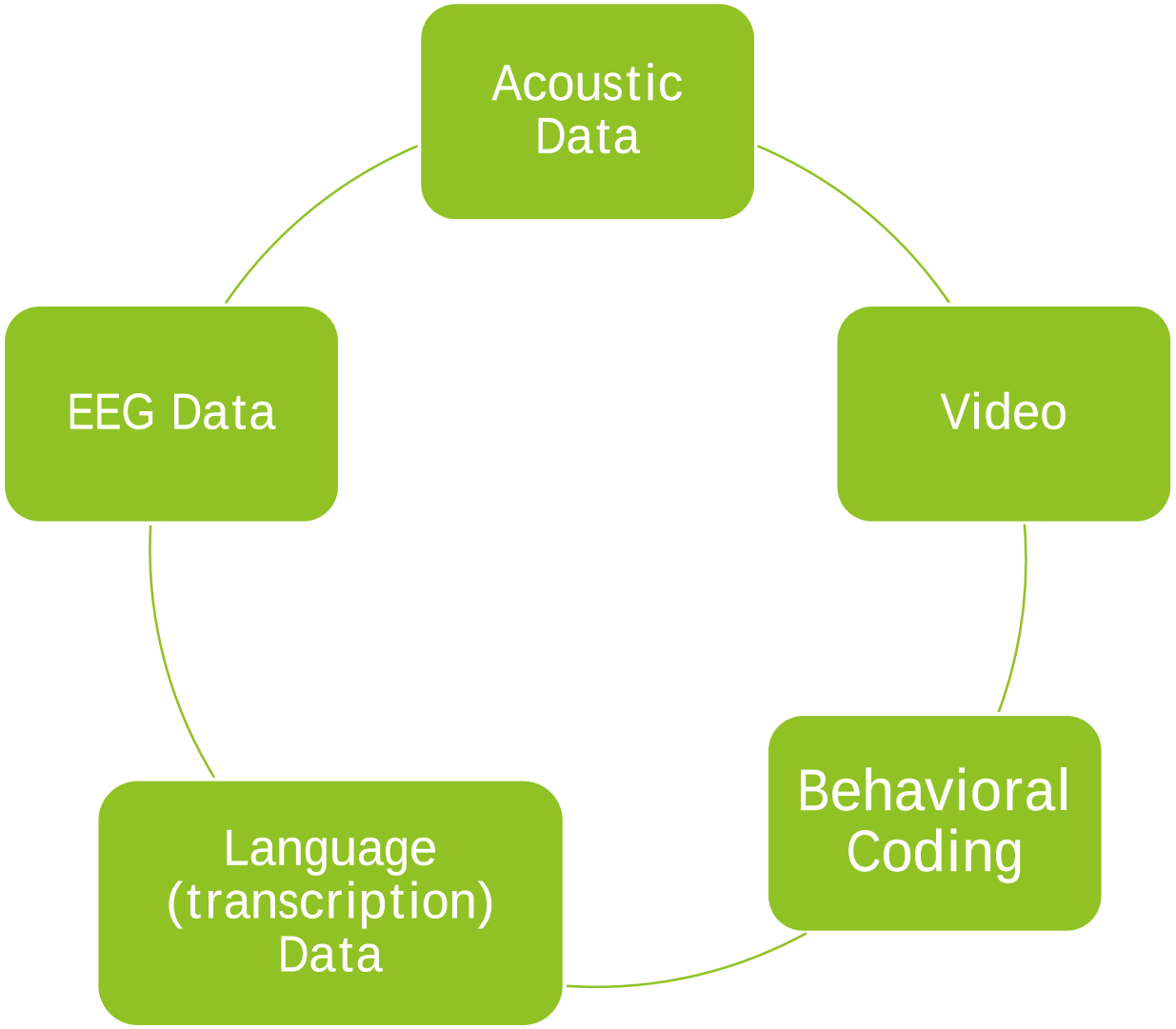
- Build a neural oscillator model to describe the main cognitive processes, pattern recognition, language processing, inference and emotion in the brain, from the point of view of physics.
- Brain can process information very fast so need to identify mechanisms that the neural phase oscillators model must have to enable this fast computing.
- Pat's lectures (May 23, 2011, Stanford University):
  - *What physical mechanisms of computation does the brain use?*
  - *Using phase to recognize phonemes in the brain (paper with collaborators Claudio Carvalhaes and Rui Wang).*

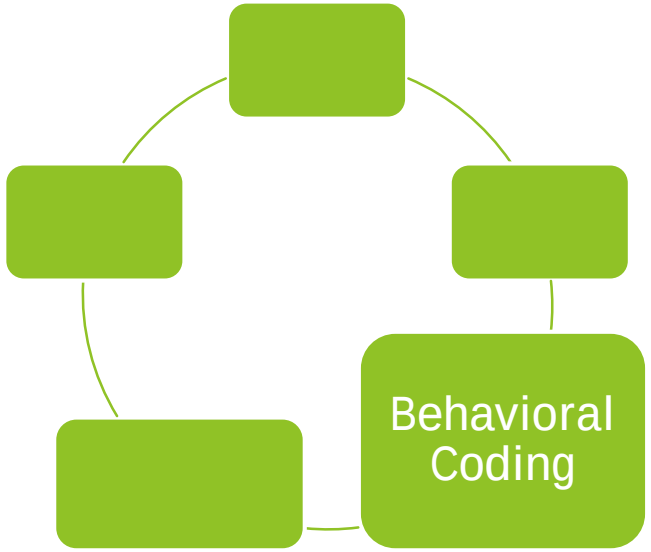
- Problems to solve:
  - **Binding.** In visual perception, how the brain can temporally combines features like color and shape to create coherent mental representation of an object., spreading activation, probabilistic model for emotion transitions.
  - **Spreading activation.** Refers to the chain of activations of different associations in the brain after an initial activation started from one perceptual stimulus.
  - Probabilistic model for emotion transitions. Proposed models describing the transition of emotions.
  - **Forced oscillator model.** Another oscillator model to understand how an external stimulus can affect the dynamics of the electrical activity of the brain.

Pat Suppes' Lab



The Circle of Data in the Study of Emotion





The expression of emotion by couples in psychotherapy sessions: testing hypotheses

Colleen E. Crangle, Michelle U. Nguyen, Marcos Perreau-Guimaraes, Duc T. Nguyen, Margot Tuckner, Patrick Suppes

Four emotions Tension (T), Anger (A), Joy (J) and Sadness (S). Each transcribed word in a session had two emotions identified with it: the emotion expressed by the male and the emotion expressed by the female. Each word was also tagged by who was speaking it (male, female or therapist).

I am not happy with you. Male Speaking, Female Listening

A A A A A A -- Emotion coded tokens for the male

T T T T S S -- Emotion coded tokens for the female

Couple A - 4 sessions Couple B - 10 sessions Couple C - 4 sessions

- An *emotion episode* is a sequence of codes (or emotion-coded tokens) of the same emotion (Tension, Anger, Joy or Sadness) being expressed by one of the participants.
- The time between emotion episodes, when no emotion was noted for an individual, is defined as a *neutral period*.
- The length of an emotion episode or neutral period is given in terms of the number of words in sequence coded for that episode or period. Emotion episodes and neutral periods also have lengths measured in terms of the time elapsed in milliseconds.
- *Couples A and C (four sessions each) were coded by coder 1 and couple B (ten sessions) by coder 2*

Hypothesis 1: Couples will differ in terms of the extent to which they are emotionally expressive.

Hypothesis 2: Couples will each have one or more dominant emotions.

Hypothesis 3: In a couple, one person is more expressive of his or her emotions than the other.

Hypothesis 4: A couple will have a pattern of emotion expression. Specifically, couples will differ in the extent to which they experience the same emotions at the same time and in the emotions that are expressed at the same time.

Hypothesis 1 - Couples will differ in terms of the extent to which they are emotionally expressive

Total number the number of emotion-coded tokens for each emotion in each of the sessions, concatenating female and male counts.
An independent-samples t-test was conducted to compare these numbers for couples A and B, A and C, and B and C.
There was a significant difference in the scores for B (M=759, SD=1109) and C (M=187, SD=286) with $t(100) = 4.27$ and $p = 4.45 \times 10^{-5}$.
To a lesser extent there was a significant difference in the scores for A (M=866, SD=1729) and C (M=187, SD=286) with $t(33) = 2.19$ and $p = 3.6 \times 10^{-2}$.

These results suggest that couples B and C differed in the extent to which they were expressive of their emotions, with A and C also differing but to a lesser extent.

Hypothesis 2: Couples will each have one or more dominant emotions.

The percentages of time – in terms of frequency of emotion-coded tokens – that each emotion was expressed across all sessions for each couple. Tension was dominant for all three couples, suggesting that Hypothesis 2 should be rejected. Couples B and C both spent a notable amount of time expressing Joy but that emotion was not in any way dominant

Table 6. Percentage of time (in frequency of emotion-coded tokens) for each emotion for each couple

	Tension	Anger	Sadness	Joy
Couple A	81%	9%	2%	8%
Couple B	61%	10%	8%	22%
Couple C	49%	4%	16%	31%

Hypothesis 3: In a couple, one person is more expressive of his or her emotions than the other.

We tested Hypothesis 3 using the total number of emotion-coded tokens for the four emotions across the sessions, taking female and male separately. Independent-sample t-tests for each couple failed to support the hypothesis that one member of a couple was more emotionally expressive than the other.

Hypothesis 4: A couple will have a pattern of emotion expression. Specifically, couples will differ in the extent to which they experience the same emotions at the same time and in the emotions that are expressed at the same time.

For each of our three couples we examined the co-occurrence of emotions in the male and the female across all sessions. We counted the frequency of occurrence with which emotion x in the male coincided temporally with emotion y in the female and similarly for the female, using the number of emotion-coded tokens in each case. There could be high synchrony between the members of a couple, with Joy in the male accompanied by Joy in the female and vice versa, for instance. Or one person's Anger may be coupled with the other person's Sadness.

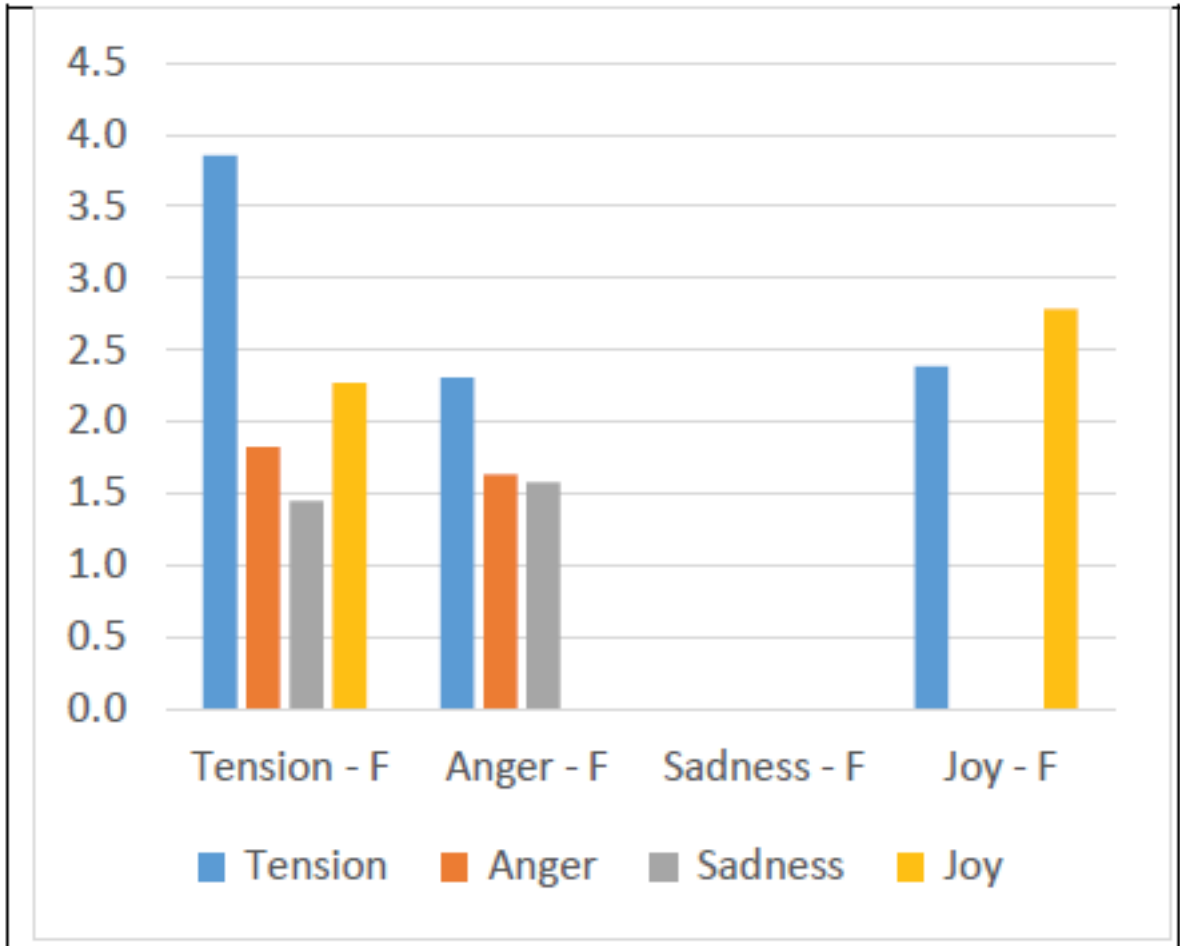


Figure 1. Couple A - Co-occurring motions of Male, relative to emotions of Female (log 10 scale)

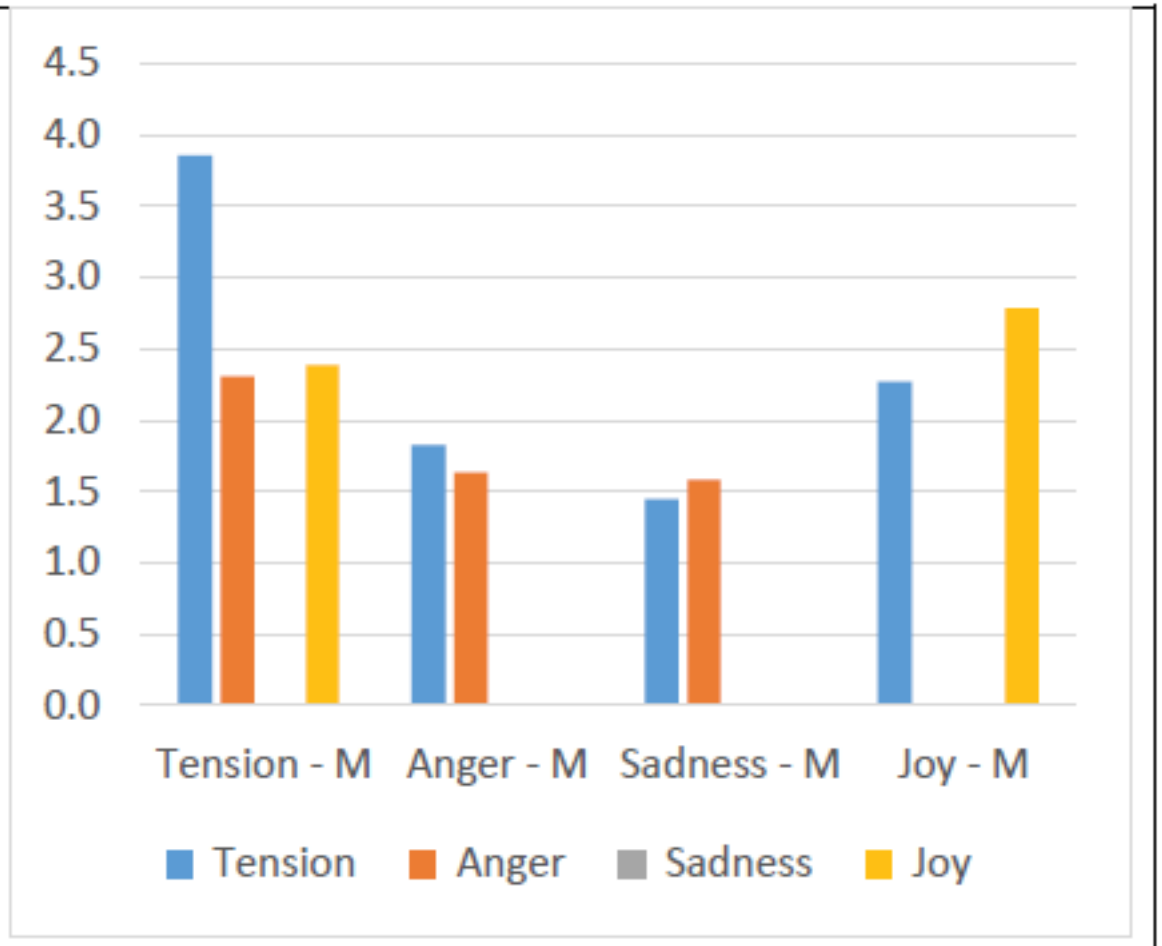


Figure 2. Couple A - Co-occurring emotions of Female, relative to emotions of Male (log 10 scale)

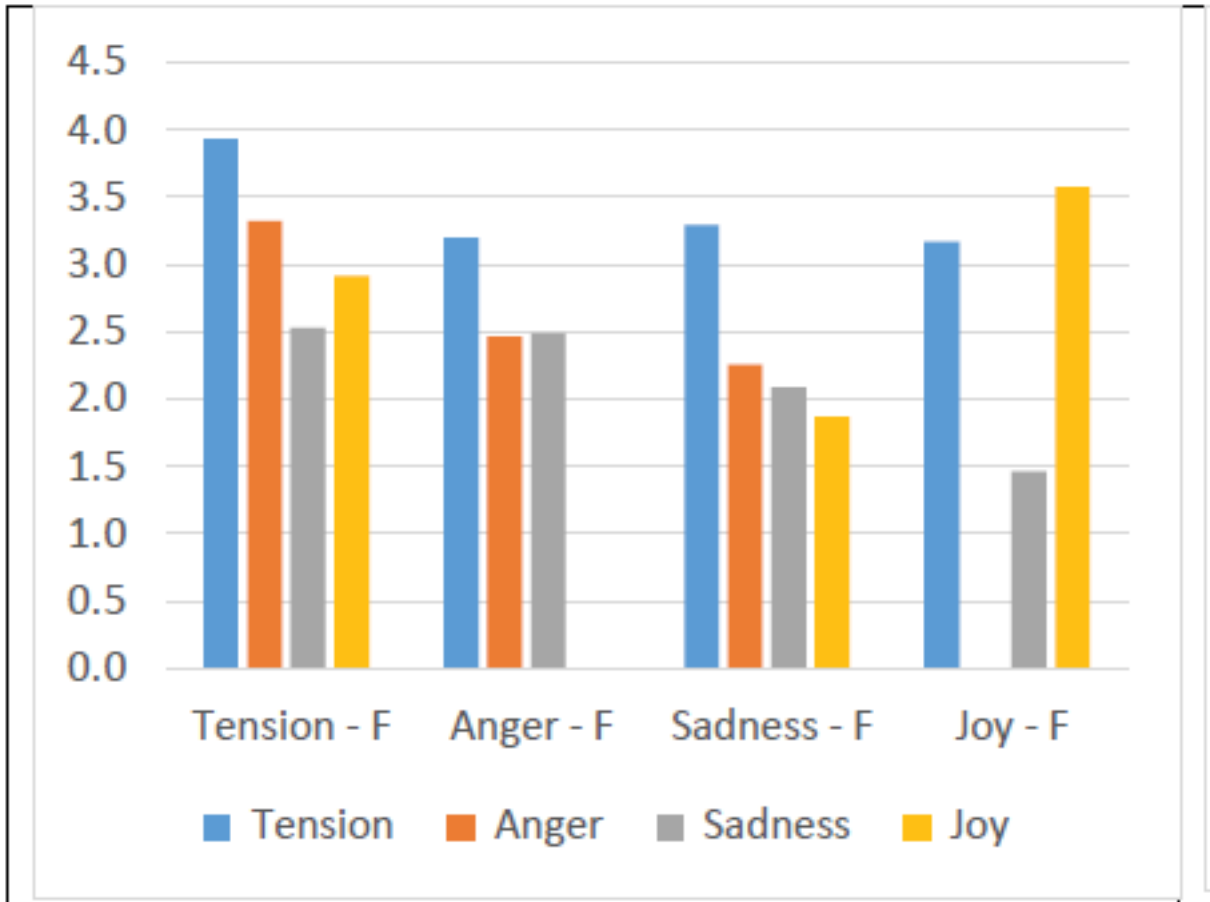


Figure 3. Couple B - Co-occurring emotions of Male, relative to Female (log 10 scale)

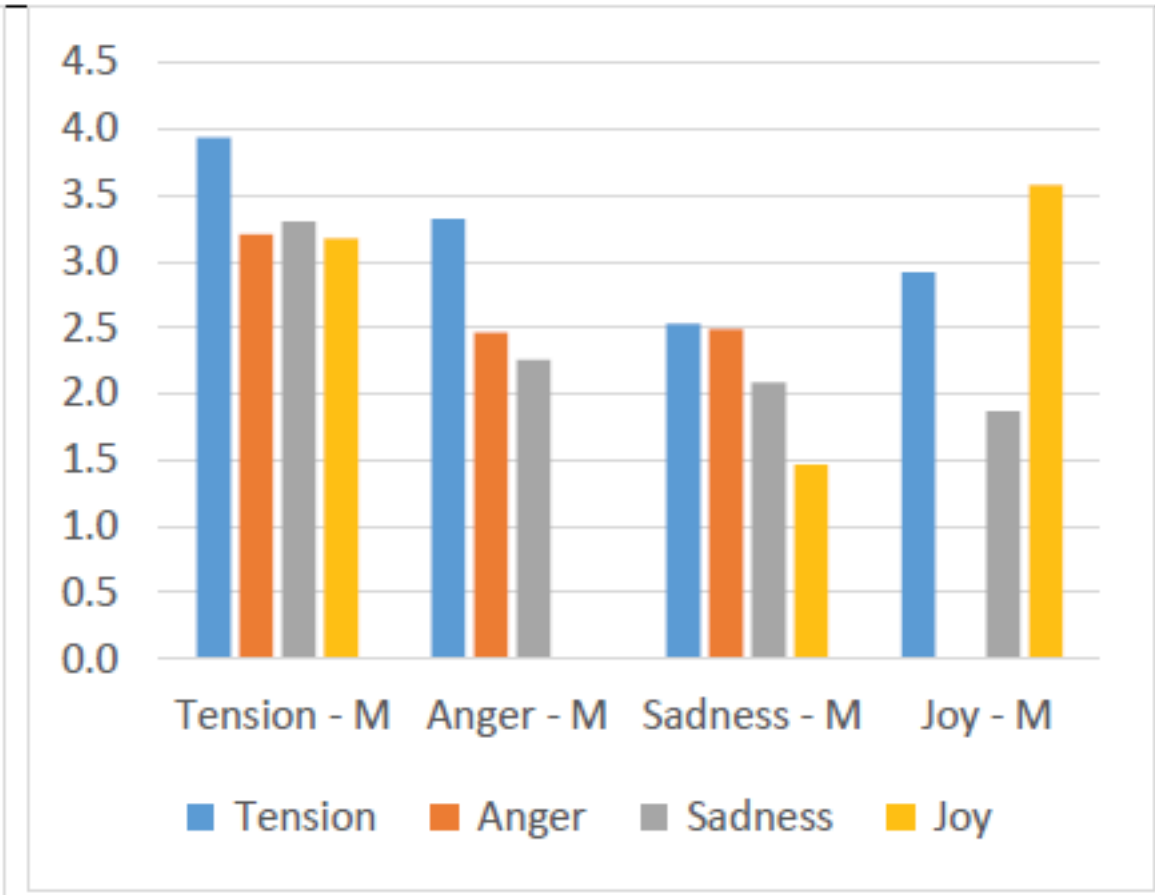


Figure 4. Couple B - Co-occurring emotions of Female, relative to Male (log 10 scale)

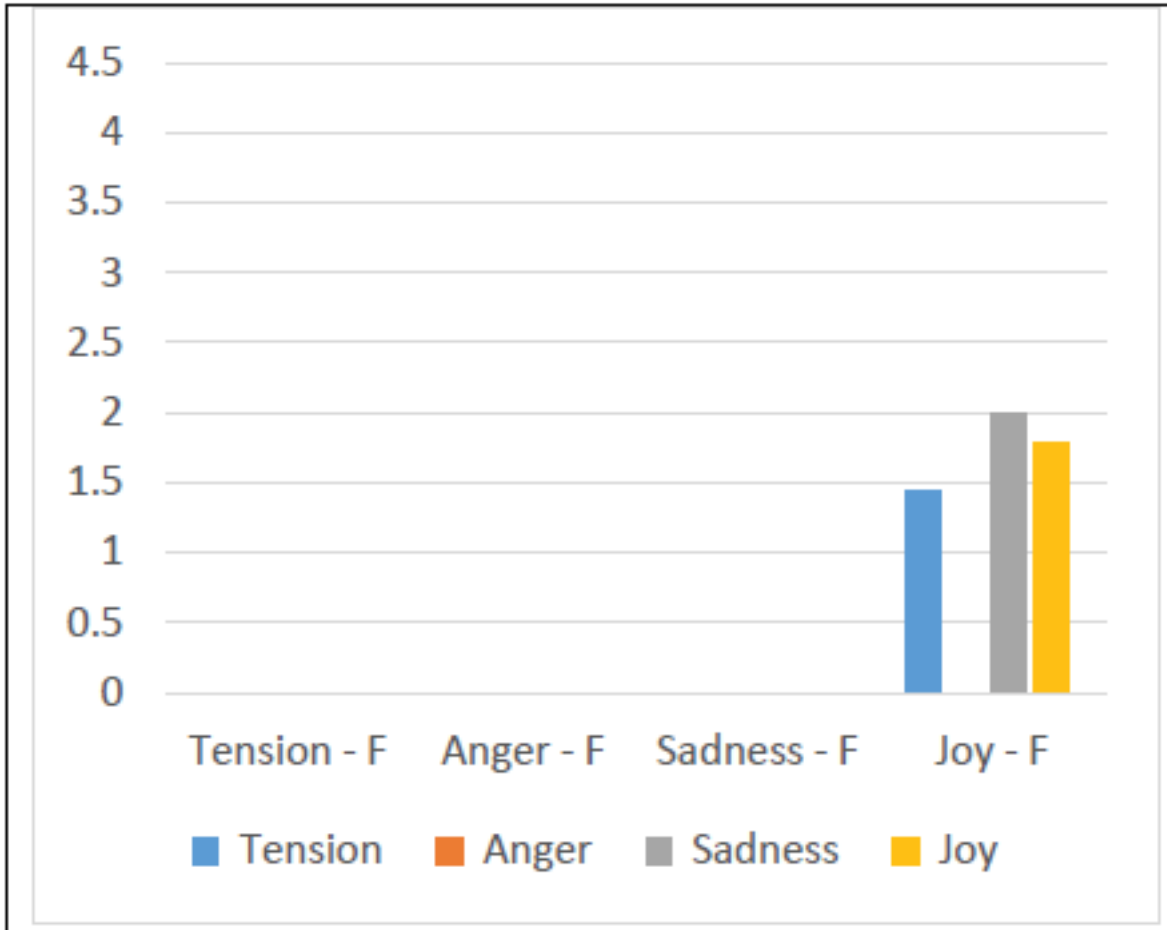


Figure 5. Couple C - Co-occurring emotions of Male, relative to Female (log 10 scale)

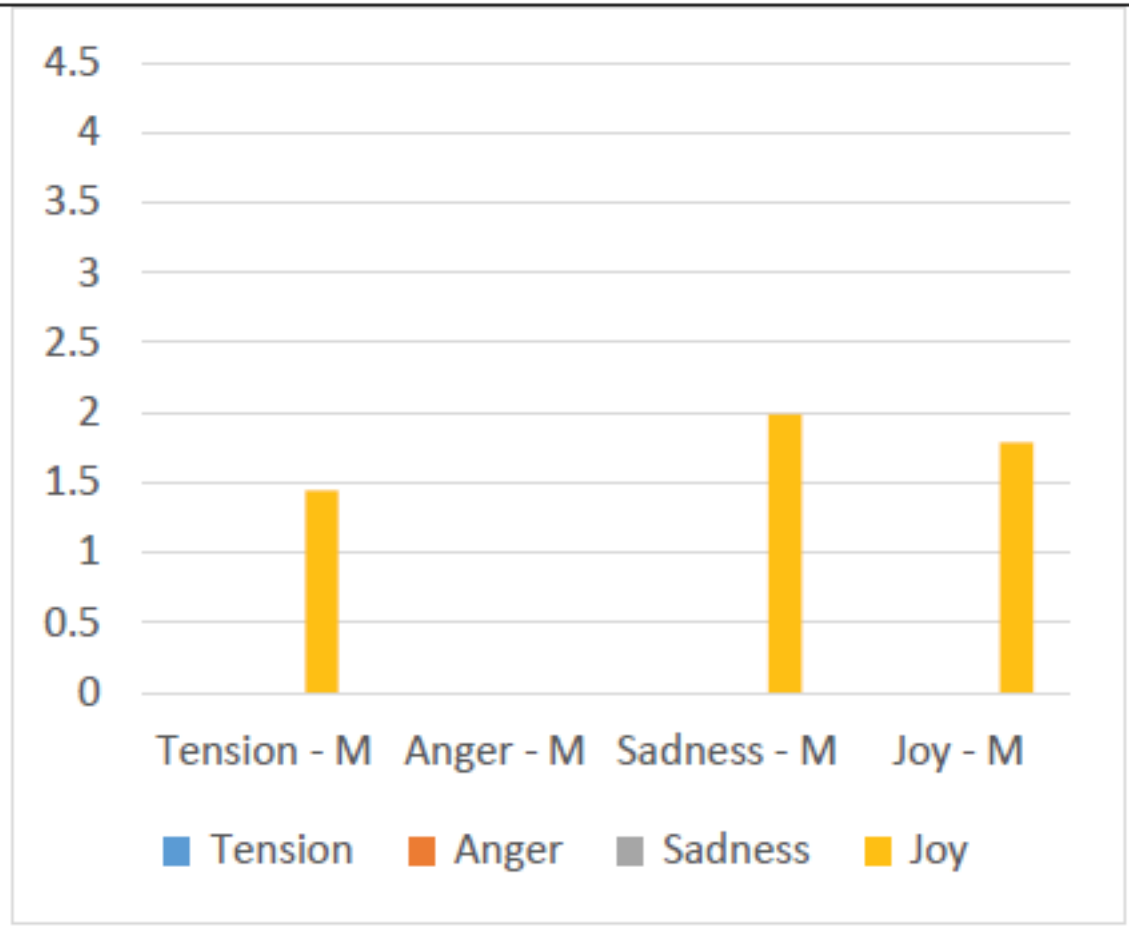


Figure 6. Couple C - Co-occurring emotions of Female, relative to Male (log 10 scale)

Notes made by the therapist after conducting the sessions with C focus on the male's difficulty with the emotions of the female. The male is said to find it difficult to "focus on" the female's feelings and to "tune in" to what they are. He says: "For me, when she talks about emotional stuff like that I feel like I have to sit there and listen." He talks about having an "emotional" sister and "not knowing what to do," about his father being "numb to any feelings." The therapist also comments that "when [the female] talks, [the male] looks sleepy, when [the male] talks, [the female] looks sleepy, but both [are] alert when [the] therapist talks."

When the therapist talks!!!

Recognizing Emotion in the Brain

What does this mean?

One possible research project: Use brain imaging (e.g., fMRI) to identify the areas of the brain that are active when someone is experiencing given emotions, fear or sadness, for example.

The Suppes Emotion Project: Build a statistical model to identify the emotions expressed by one person A, as recognized by another person B listening to and observing A, using EEG recordings of B's brain activities.

Not this research project: Build a statistical model to identify the emotions expressed by a person A using EEG recordings of A's brain activities while A is expressing (experiencing) given emotions.

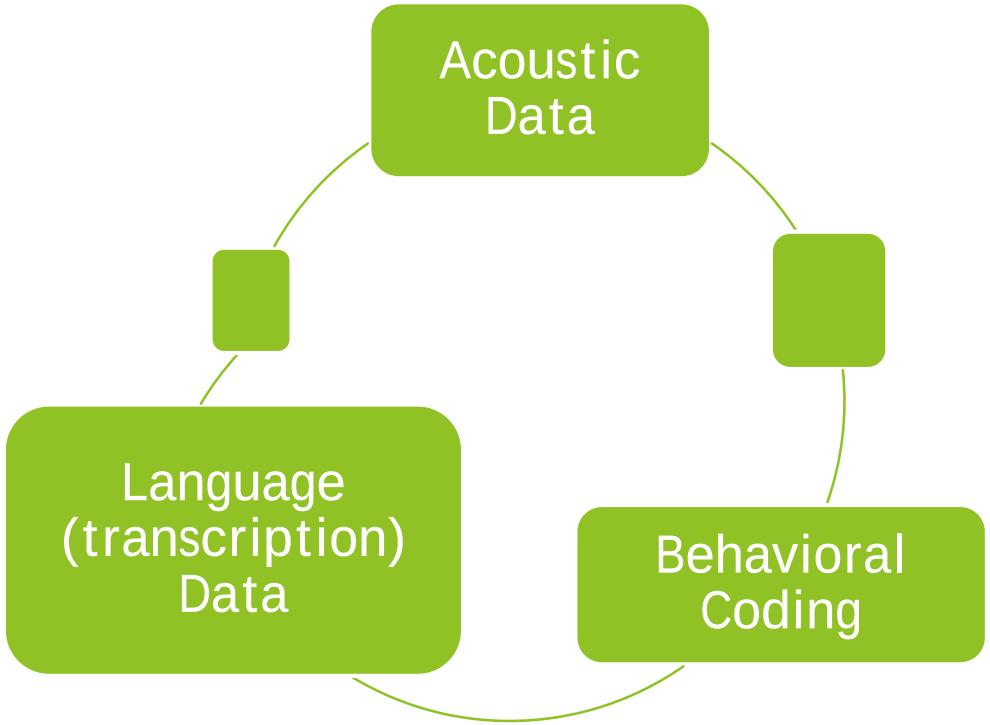
Preliminary results for one couple. By Rui Wang, PhD, Suppes Brain Lab

We recognized the emotion expressed by the female using only the male (listener)'s brain recordings.

"The samples used to train and test the emotion recognition model were the male's brain signals time-locked to the first 300ms after the onset of each emotional-coded word in female's speech."

Table 1: Binary emotion classification using 11 sessions EEG of Male of Couple B

Emotions	Total training samples	Number of test samples	Best single channel rate	Best single channel	Maximum rate using N-best channels	Number of channels
Joy - Sadness	3108	686	79.6%	93	79.6%	1
Joy - Tension	5898	732	77.7%	39	80.9%	2
Joy - Anger	3170	732	80.2%	28	85.5%	9
Joy - Neutral	5898	730	73.7%	119	73.7%	1
Sadness – Tension	3108	2020	63.1%	13	68.3%	3
Sadness - Anger	3108	1210	63.6%	89	63.6%	1
Sadness - Neutral	3108	840	61.1%	13	62.9%	8
Tension - Anger	3170	1774	65.3%	118	66.1%	6
Tension - Neutral	5968	884	61.3%	37	62.9%	2
Anger - Neutral	3170	884	61.7%	123	62.4%	4



Newest project using the Suppes Couple Therapy Dataset

To begin October 1, 2015. Funded by the US National Institutes of Health (NIH)
Principal Investigators: Colleen Crangle and Helen Longino

A Tool for Research on Emotion in Naturally Occurring Speech

A Tool for Research on Emotion in Naturally Occurring Speech

It is now widely understood that defects or limitations in emotion processing underlie many disorders such as anxiety, depression, bipolar and eating disorders. If **bio-behavioral markers of emotions** could be found, researchers would have the basis for investigating emotions in both normal mental functioning and in a wide range of mental disorders. In addition, the role of emotion in the experience of patients with cancer and other illnesses is also of growing interest to researchers.

The project will develop a statistical and software tool for research on emotion in **naturally occurring speech**. It will integrate acoustic and language analysis and provide ways specifically to study emotions of people in interaction.