

Cross Recurrence Quantification Analysis (CRQA)

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Nonlinear Methods for Psychological Science

APA Advanced Training Institute University of Cincinnati June 15-19, 2015



Outline: Part 2

- Theoretical preamble – Coupled conversation partners...
- The cross recurrence plot and quantification (CRQA)
- Results obtained using these analyses



Coupling in Other Dimensions



- Face-to-face communication involves multi-dimensional management
 - Eyes, visual common ground
 - Gestures
 - Pitch, rate, etc.
 - Words, sentences, topics, etc.
 - Turn taking



Coupling

- An analogy to the beam is perhaps the "common ground" shared between conversants
 - Knowledge (local, global), goals, affinity, etc.
- Like the pendula, conversants may synchronize in a similar manner



Language Development



- Synchronization of bodily movements with speech (e.g., Condon & Sander, 1974).
- Synchrony between caregivers and their own children (e.g., Bernieri, et al., 1988).
- Mother-child synchrony offered as one factor influencing child socialization, e.g., antisocial behavior (Criss, et al., 2003).

Alignment = Recurrence

- At least 4 benefits to recurrence methods for exploring psycholinguistic alignment
- Benefit 1: Naturally applied to naturalistic data
- Benefit 2: Amenable to categorical units of measure (e.g., words, sentence structure, topic, etc.)

Alignment = Recurrence

- Benefit 3: Flexible exploration of coupling dynamics (e.g., temporal lag)
- Benefit 4: Flexible metrics (e.g., syntactic similarity, semantic similarity, etc.)
- Benefit 5: Despite such extensive, flexible application, the result is subjected to common statistical tests (e.g., GLM, etc.)

Mutuality, "coordination"

Barbosa, ..., Vatikiotis-Bateson, 2010 Oberg & Vatikiotis-Bateson, 2013 Fusaroli & Tylén, 2011 Tylén et al., 2010 Galati & Brennan, 2010 Brown-Schmidt et al., 2008 Clark, 1996 Fay et al., 2010 Tomasello, 2009 Shockley et al., 2008 M. J. Richardson et al., 2005 Barr, 2004 Shintel & Keysar, 2009 Apperly et al., 2006 Pickering & Garrod, 2004 Wilson & Wilson, 2006 Meltzoff & Decety, 2003 Tversky & Hard, 2009 Sebanz et al., 2006 Castiello et al., 2010 Chartrand & Bargh, 1999 Bailenson & Yee, 2005 Fowler, 2010 Hove & Risen, 2009 Oullier et al., 2007 Ramseyer & Tschacher, 2008 Horton & Gerrig, 2005 Decety & Jackson, 2004 Rizzolatti & Craighero, 2004 Sadler et al., 2010

Synchrony





































Recap: Auto Recurrence

"Auto recurrence":

Same time series on x and y axis

Points show where series is recurring in time...

Always symmetrical around line of identity

Quantify plot:

How many points, overall? (%REC) How often in sequences (%DET) How long a sequence on avg.? (mean line)

Recap: Cross Recurrence

"Cross recurrence":

Different time series on x and y axis (e.g., network 1, network 2)

Points show when series are in the same state

Most often *not* symmetrical around *line of synchronization* (main diagonal)



Quantify plot:

•••

How many points, overall? (%REC) How often in sequences (%DET) How long a sequence on avg.? (mean line)

...

Recap: Cross Recurrence

"Cross recurrence" additional analysis:

Exploit the line of synchronization to see whether two systems are coupled: more points ("matches" in their behavior) should fall at or around the line of synchronization.





Exercise 1: Diag. Rec. Profile

Which networks are coupled?

























Syntactic Time Series

- Raw syntactic time series for caregiver and child
 - No plural marking (subject-verb agreement)
 - Auxiliary verbs used
 - Proper nouns used
- 6 most common:
 - Verbs (22%), nouns (15%), pronouns (15%), communicators (6%), determiners (6%), prepositions (6%)

Dale & Spivey, 2006, Lang. Learn.



















Dyadic Coupling

- Responsiveness of caregiver may be crucial to development... (Lewis, Fogel, Oller, etc.)
- Feedback loop hypothesis: Vocalization by infant supported by adult responses, which elicits further vocalization, etc. (Warlaumont et al., 2010; Warlaumont et al., 2014).
- Suggests that language disorders may involve a *breakdown* of this social dynamic.
- E.g.: ASD.







Visual "Common Ground"

- Joint attention often considered fundamental to emergence of language
 - Evolution (Tomasello, 2001)
 - Development (Baldwin, 1995)
- Coordination of attention across visual field fundamental to communication (Clark, 1996)
 - Gestures, actions, pointing, etc. (e.g., Clark & Krych, 2004)

Eye Movements and Language

- Speakers fixate objects to be named ~1000ms prior to naming them (e.g., Griffin & Bock, 2000)
- Listeners may require approx. 500-1000ms to fixate on a mentioned object (e.g., Tanenhaus et al., 1995)
- Time course of eye-movement coordination in ongoing comprehension?

Eye-Tracking & Comprehension

- 4 individuals generated narrative stimuli
- Viewed scene w/ television characters, discuss for ~60 seconds
- Eyes tracked
 - Which panel/character was being fixated was sampled at 33ms
 - Unique speaker eye-movement time signature over 60 seconds...

Listeners

- 49 participants acted as listeners
- On headphones, listened to stories recounted by speakers
- Eyes similarly tracked
- Tested w/ 4 comprehension questions concerning remarks by the speakers



















Exercise 3: Dialogue

Eye-movements during dialogue











Leading and Following

- Abe exhibits small tendency to lead caregiver
 - Abe farthest in grammatical development (meanlength of utterance)
- Sarah exhibits small tendency to follow caregiver
 - Sarah delayed relative to Abe in grammatical development
- Naomi shows no significant leading or following across transcripts



Extract Profile Features

Tangram task: two people work together to identify unfamiliar shapes. *1 is director ; 1 is matcher*



Extensive work has shown entrainment: they come to employ similar phrases...



Round 1

"The guy kind of carrying the triangle and walking..."

"Oh yeah, oh yeah..."

"The guy with the triangle again..." Round 2 "Yup..."

"Triangle guy..." Round 3

"Got it..."

Dale, Kirkham, & Richardson, 2011, Front. Psych.















Table 1 Overview	of coding schemes for face, ges	ture dialog act and langu	age actions (Ekman et al. 201)? codes in narenthese
Modality Group	-,, 8, 9, 8	Channels		
Face And Head	Mouth	Eyes	Eye Brows	Head
	Smile (AU12)	Blink (AU45)	Inner brow raiser (AU1)	Nodding
	Lip tightener (AU23)	Squinting (AU44)	Outer brow raiser (AU2)	Shaking
	Pucker (AU23)	Widening eyes (AU5)	Down-frowning (AU4)	
	Mouth open (AU25/26)	Rolling eyes (M68)	Asymmetrical	
	Mouth in 'o'-shape (AU27)			
	Biting lip (AD32)			
	Pout (AU17)			
Manual Gesture	Beat	Iconic	Symbolic	
	Deictic	Metaphoric		
Touch Face	Touching face			
	Chin rest			
Language	Dialog	Acts	Connectives	Descriptives
	Instruct	Acknowledgment	Alright	Relative direction
	Explain	Reply-Y	No	Compass direction
	Check	Reply-N	Ok	Color
	Align	Reply-W	Um	Digit
	Query-YN	Clarify	Well	Spatial prepositions
	Query-W	Ready		



Louwerse et al., 2012, Cognitive Science















Channels		Observed excursion from base line (Sec)		Cross-recurrence vs baseline ($v_1 = 1$)		s Order		Dialog Number	Ink Blots
Face and head	Eye squint	0 - 1.75	1.00	4576	7.54**	\checkmark	\checkmark		
	Eyebrow down	0 - 2.75	1.25	5344	3.85*	\checkmark	\checkmark	++	++
	Laughing	0 - 4.75	0	13792	122.61**	\checkmark	\checkmark		++
	Smile	0 - 7.75	0.	23008	1333.88**	\checkmark	\checkmark		++
	Nodding head	0 - 3.75	0.75	9952	62.21**	\checkmark	\checkmark	++	++
	Shaking head	0 - 3.00	1.00	9952	37.82**	\checkmark	\checkmark	++	++
Gesture	Deictic concrete	10.00 - 37.50	25.00	83680	107.99**	\checkmark	\checkmark	++	++
Touch face	Chinrest	12.50 - 50	27.50	172000	11.42**	\checkmark		++	
	Stroking	0 - 40.00	18.75	114400	181.25**	\checkmark	\checkmark	++	
Dialogue acts	Acknowledgment	0.25 - 1.75	0.75	3808	33.73**	\checkmark		++	
	Clarify	2.250 - 8.00	6.75	17632	12.54**	\checkmark			++
	Explain	2.75 - 27.75	15.00	49888	111.75**	\checkmark	\checkmark	++	++
	Query-YN	10.50 - 22.75	16.25	37600	35.19**	\checkmark	\checkmark	++	++
	Reply-N	0 - 1.75	1.00	4576	60.18**	\checkmark	\checkmark		
Connectives	Alright	0.75 - 4.75	1.50	6112	3.86*	\checkmark		++	
	No	0 - 2.50	0.75	7648	56.25**	\checkmark	\checkmark	++	++
Descriptives	Compass direction	1.00 - 16.75	8.75	45280	59.25**	\checkmark	\checkmark		
	Color	1.75 - 17.00	9.75	32992	366.30**	\checkmark	\checkmark		
	Digit	2.750 - 27.75	17.50	68320	226.25**	\checkmark	\checkmark	++	++
Note. Pluses a	nd minuses mark p	ositive and ne	gative regressi	ions. ++ p	o < .01, +	p < .05	, p	< .01, -	p < .(

Synchronization in Multimodal Communication 20

Multiple, different scales?

Smile <>	<> Face-touch
<>	<>
<>	<>
Smile	Face-touch
Smile	<>
Smile	Face-touch
<>	<>
<>	<>
<>	<>
<>	<>

Multiple, different scales?

1	<>
<>	1
<>	<>
<>	<>
1	1
1	<>
1	1
<>	<>
<>	<>
<>	<>
<>	<>

Multiple,	different sca	les?
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1		12
1	1	1
1	1	12
1	1	12
1		1
1		12
1		1
1	1	12
1	1	12
1	1	12
1	1	12



Exercise 5

- Open exercise, if there's time...
- Linguistic translation tools allow you to rapidly create your own linguistic time series for RQA/CRQA...

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