Timescales of Massive Human Entrainment

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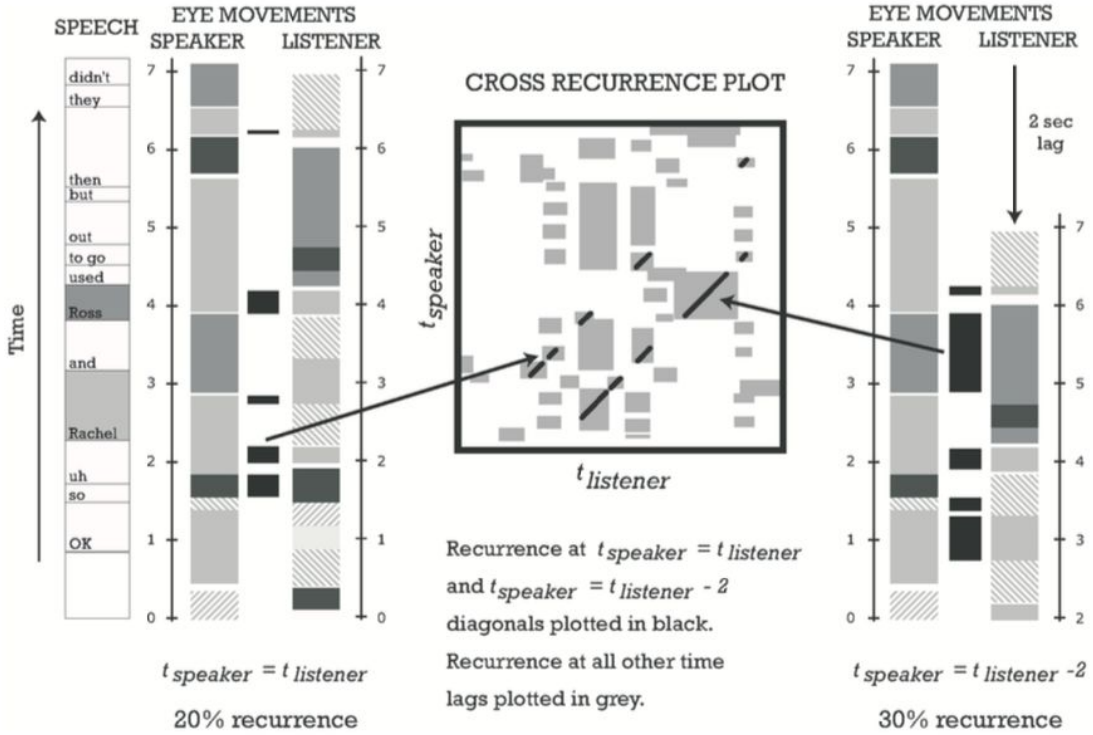
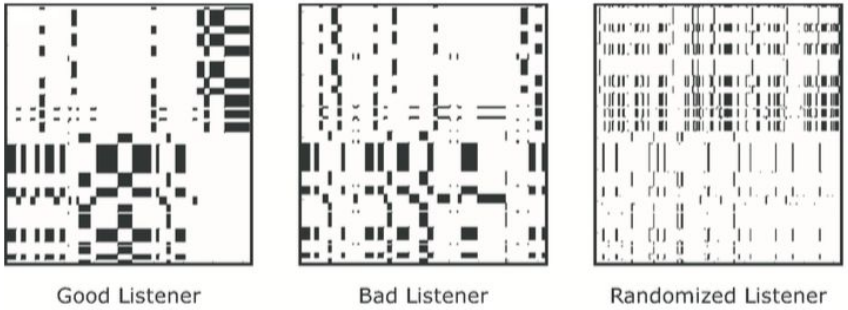
Coordination in human interaction

- Joint attention:
  - Important for communication (Clark, 1996) and language acquisition (Tomasello, 1986).
  - Achieved through gesture (pointing, nudging), eye gaze, or verbal cues.

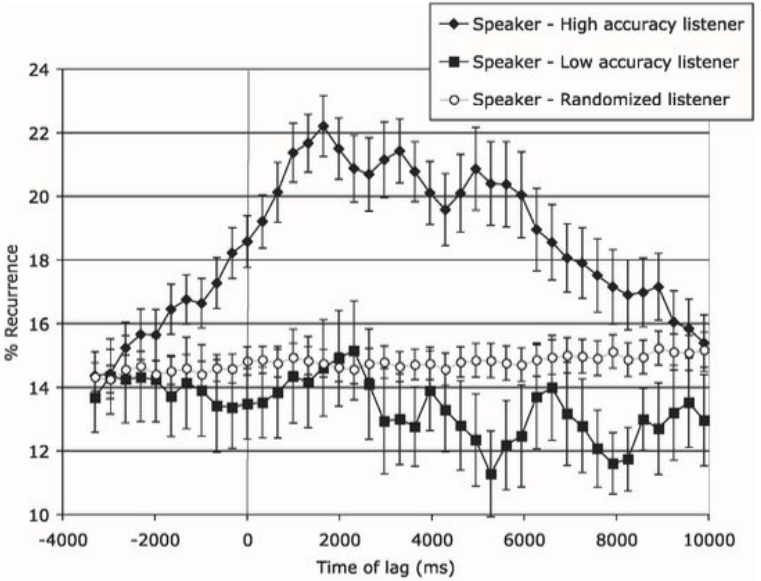
Richardson & Dale, 2005



Richardson & Dale, 2005

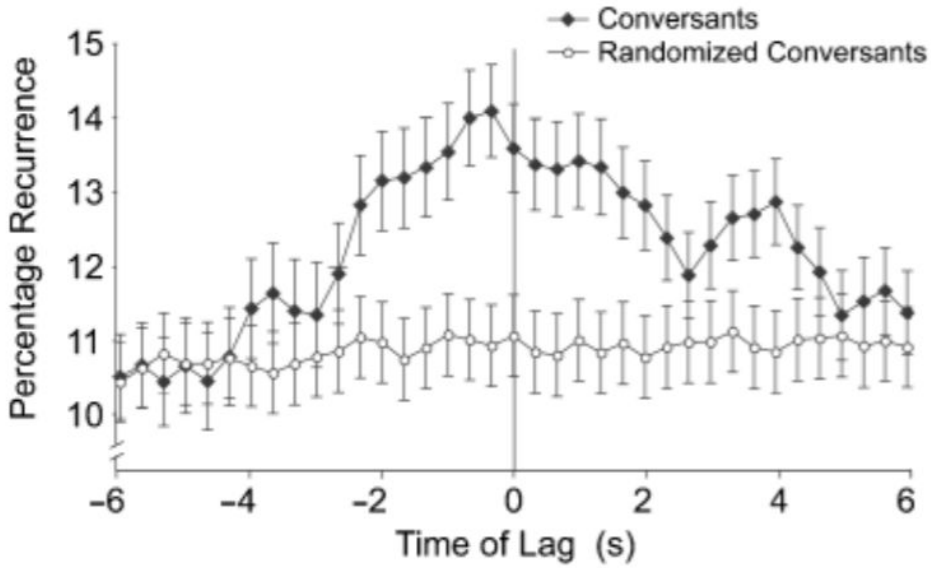


Recurrence peak at 200ms



Richardson, Dale, & Kirkham, 2007

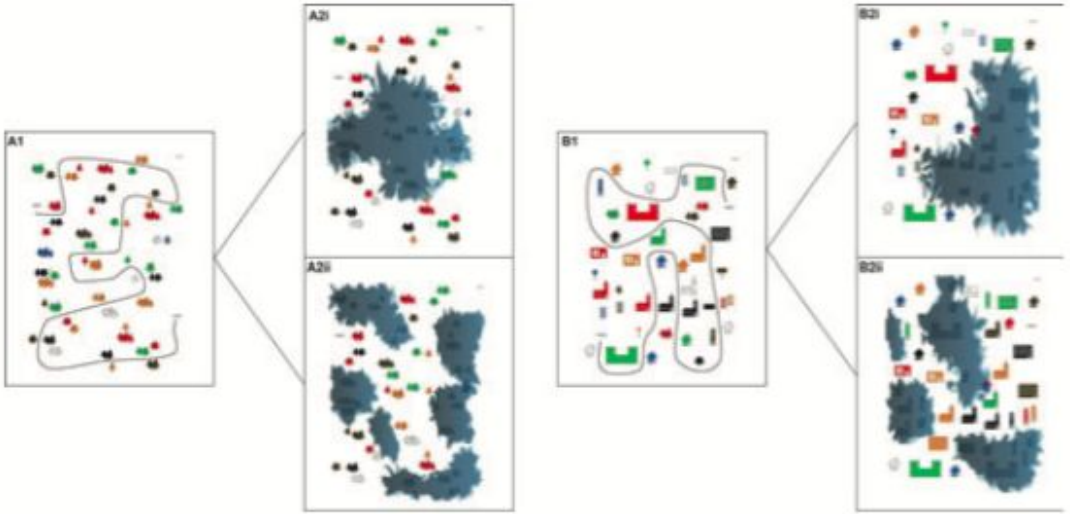
Recurrence peak at 0ms



Coordination in human interaction

- Joint attention:
  - Important for communication (Clark, 1996) and language acquisition (Tomasello, 1986).
  - Achieved through gesture (pointing, nudging), eye gaze, or verbal cues.
- Multi-modal coordination

Louwerse et al., 2012



Coded behaviors

Table 1
Overview of behavioral coding schemes by modality group and channel (Ekman et al., 2002 codes in parentheses)

Modality Group	Channels			
Face and Head	Mouth	Eyes	Eyebrows	Head
	Laughing Lip tightener (AU23) Mouth in "o"-shape (AU27) Mouth open (AU25/26) Pout (AU17) Pucker (AU23) Smile (AU12)	Blink (AU45) Rolling eyes (M68) Squinting (AU44) Widening eyes (AU5)	Asymmetrical Down-frowning (AU4) Outer brow raiser (AU2)	Nodding Shaking
Manual gesture	Beat	Deictic	Iconic (route/landmark)	Metaphoric Symbolic
Touch face	Touching cheek	Chin rest		
Language	**Dialog Acts**		**Discourse Connectives**	**Descriptions**
	Acknowledgment Align Check Clarify Explain Instruct	Query-W Query-YN Ready Reply-N Reply-W Reply-Y	*Alright* *No* *Ok* *Um* *Well* *Yes*	Color Compass direction Digit Relative direction Spatial prepositions

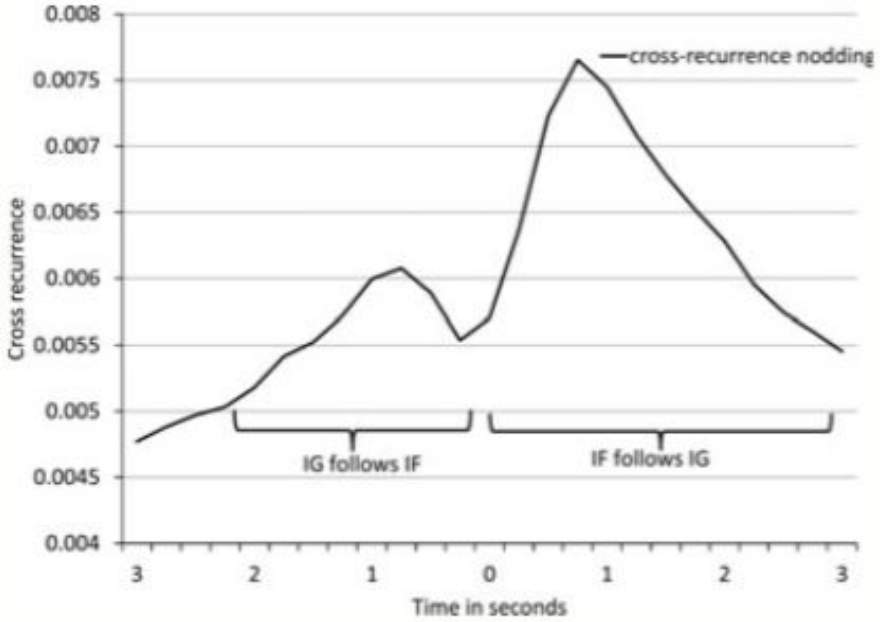
Significant cross-recurrence

Table 2
Significant cross-recurrence between interlocutors for all actions

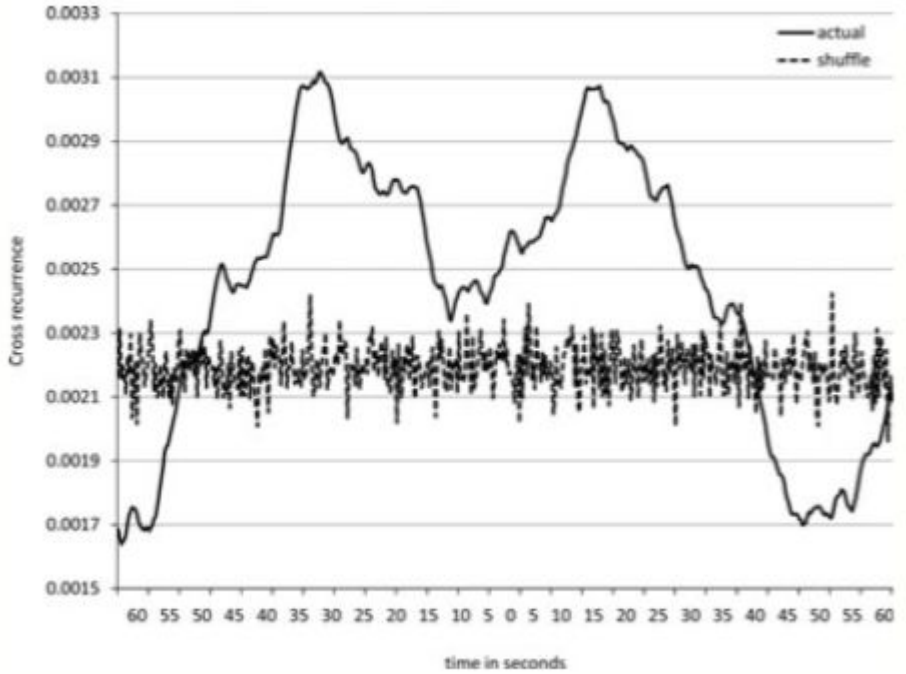
Channels		Observed from Base Line	Excursion (|Secl)	Cross-Recurrence versus Baseline ($v_1 = 1$)		Order		Peak Height		
Modality	Action	Start - End	Peak lag	v_2	F	IG-IF	IF-IG	IG>IF	Dialog No.	Difficulty
Face & Head	Laughing	0–4.75	0	13,792	122.61	++	++			++
	Smile	0–7.75	0	23,008	1,333.88	++	++	–		++
	Eyebrow down	0–2.75	1.25	5,344	3.85	+	+		++	++
	Eye squint	0–1.75	1	4,576	7.54	++	++			
	Nodding head	0–3.75	0.75	9,952	62.21	++	++	++	++	++
	Shaking head	0–3.00	1	9,952	37.82	++	++	++	++	++
Gesture	Deictic	10.00–37.50	25.00	83,680	107.99	++	++	++	++	++
Touch face	Chinrest	12.50–50	27.50	172,000	11.42	++		++	++	
	Touch cheek	0–40.00	18.75	114,400	181.25	++	++		++	–
Language:	Acknowledgment	0.25–1.75	0.75	3,808	33.73	++		++	++	
Dialog acts	Clarify	2.25–8.00	6.75	17,632	12.54	++		++		++
	Explain	2.75–27.75	15.00	49,888	111.75	++	++	++	++	++
	Query-YN	10.50–22.75	16.25	37,600	35.19	++	++	++	++	++
	Reply-N	0–1.75	1.00	4,576	60.18	++	++	++		
Discourse	*Alright*	0.75–4.75	1.50	6,112	3.86	+		++	++	–
Connectives	*No*	0–2.50	0.75	7,648	56.25	++	++	++	++	++
Descriptions	Compass	1.00–16.75	8.75	45,280	59.25	++	++	++	–	
	Color	1.75–17.00	9.75	32,992	366.30	++	++	–	–	–
	Digit	2.75–27.75	17.50	68,320	226.25	++	++		++	++

Note. Pluses and minuses mark positive and negative regression coefficients. IG, Instruction Giver; IF, Instruction Follower. The number of symbols indicates p-level: $++p < .01$, $+p < .05$, $-p < .01$, $-p < .05$.

Synchronization of nodding



Synchronization of cheek touching



Other patterns

- Synchronization increases
  - As experiment proceeds
  - As the task becomes more difficult

Moving from lab to big data

- Large-scale collective behavior using social media
  - Twitter:
    - Short in format
    - Widespread integration with mobile devices
- Collective attention
  - Entrainment
- Pros and Cons?

Event: 2012 US presidential debates

- Participant:
  - Candidates: Barack Obama and Mitt Romney
  - Moderator
- Audio recordings and transcripts
  - National Public Radio (www.npr.org).

Twitter data

- Random sample of approximately 10% of all public tweets collected during each 90-minute presidential debate.
- Filtered tweets to select only those that mentioned "Obama" or "Romney," either in the text or in their hashtag,
- Excluded tweets containing URLs (to exclude spambot-generated tweets).

Debate	Total tweets	Retweets	Mean tweets / sec (SD)	"Obama"	"Romney"
1	713642	381797	110.4 (47.2)	411391	468583
2	686805	368010	104.5 (47.9)	375506	462159
3	406368	212262	63.0 (27.8)	231778	266801

Sum of "Obama" and "Romney" may exceed total tweet count because tweets can mention both of them.

doi:10.1371/journal.pone.0122742.t001

Hypotheses

- Three different timescales:
  - Interactional entrainment
  - Content entrainment
  - Long-term attention decay

First Timescale: Interactional entrainment.

- Assertive behaviors
  - Keeping the ground
  - Interrupting the adversary

Second Timescale: Content entrainment

- Pointed or “salient” remarks that became memes
- Requires more intensive cognitive processing
    - Responses start later
    - Stay longer

Third Timescale: Long-term attention decay

- Attention is unlikely maintained all the way
- General interest in the debate should decay after initial burst

Models - Overview

- Independent variables
  - Current Speaker
  - Speaking Time
  - Interruption
- Dependent variables
  - Tweet mentions of the candidate per second
    - No notion of positive/negative mentions

Models - First Timescale (Interaction)

- Tested two linear mixed-effect models, for each debate
- First Model
  - Speaker, duration of turn, and interaction between them as fixed effects
  - Turn number as random effect with nested slopes for candidate identity and time within turn
- Second Model
  - Same, with interruptions as additional fixed factor

Models - Second Timescale (Content)

- Exponential decay ($N(t) = e^{-ƛt}$) coupled w/ sigmoid ($M(t) = 1 / (1+e^{-m(t-s)})$)
  - Sigmoid captures hypothesis of self-sustaining factor (meme virality)
  - *s*: point (in seconds) when meme tweet rate is highest
  - *m*: slope of mention rate at time *s*
  - Used product: M(t)[N(t) - b], where *b* is mean base tweet rate in final 100s
  - Found parameters with simple search across reasonable values, maximizing correlation between data and model

Models - Third Timescale (Long-Term Attention)

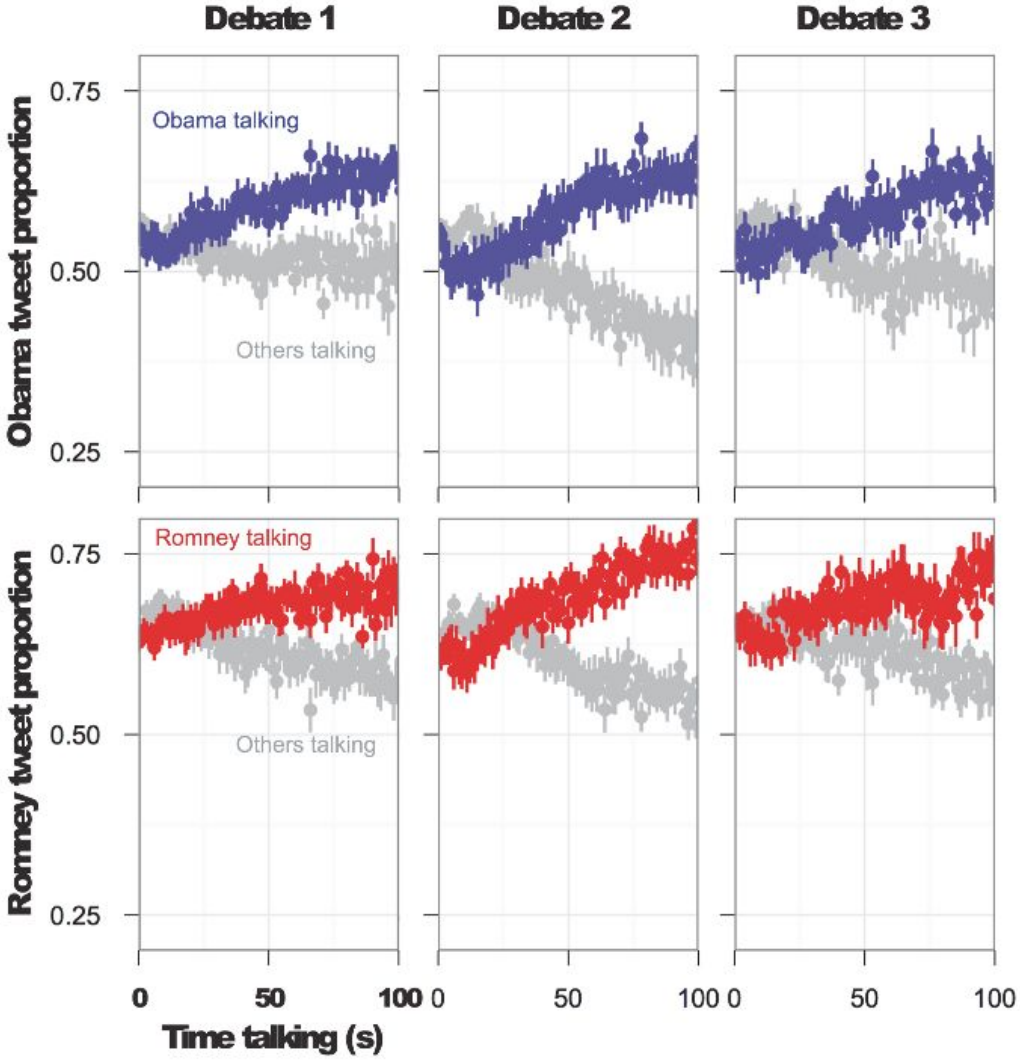
- Linear multiple regression model
  - Independent variable: second-order polynomial
  - Dependent variable: tweets per second
- Also assessed fit of just the quadratic time term (capturing decay) in second half of debate

Models - Combined

- Unified model to predict tweet number
  - Independent variables: speaker duration, interruption, salient moment, quadratic time
  - Dependent variables: tweets per second

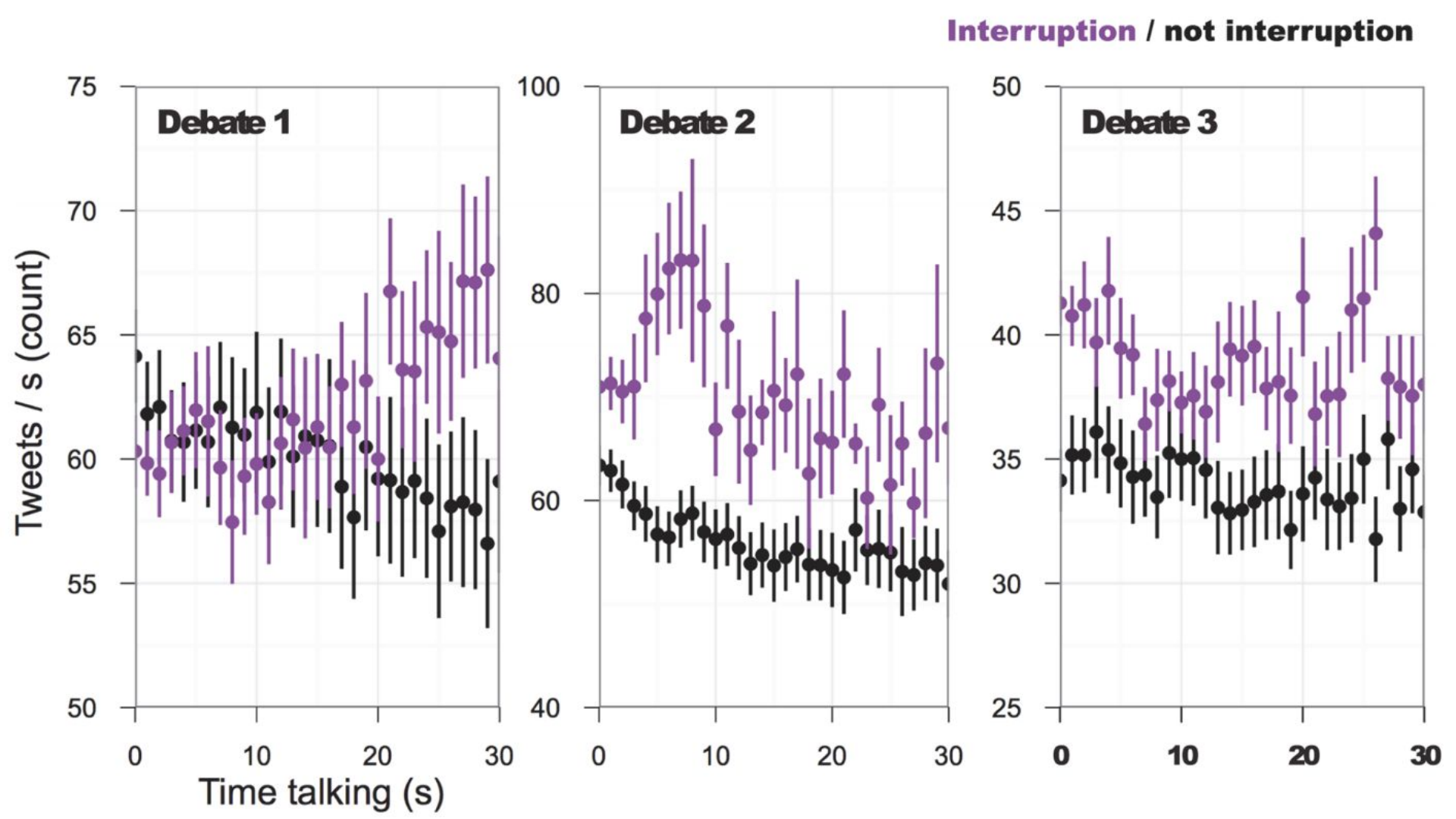
Results - Interaction - Speaker co-variance

- Mentions of a candidate increased when they were talking
- Model explained at least 10% of variance in all three debates, and over 30% for the second
- Effect of duration was negative, but outweighed by positive factor of current speaker
- As each turn got longer, tweets slowed down, but focus remained on speaker


Debate 1
Debate 2
Debate 3
Obama tweet proportion
Obama talking
Others talking
Romney tweet proportion
Romney talking
Others talking
0.75
0.50
0.25
0
50
100
Time talking (s)

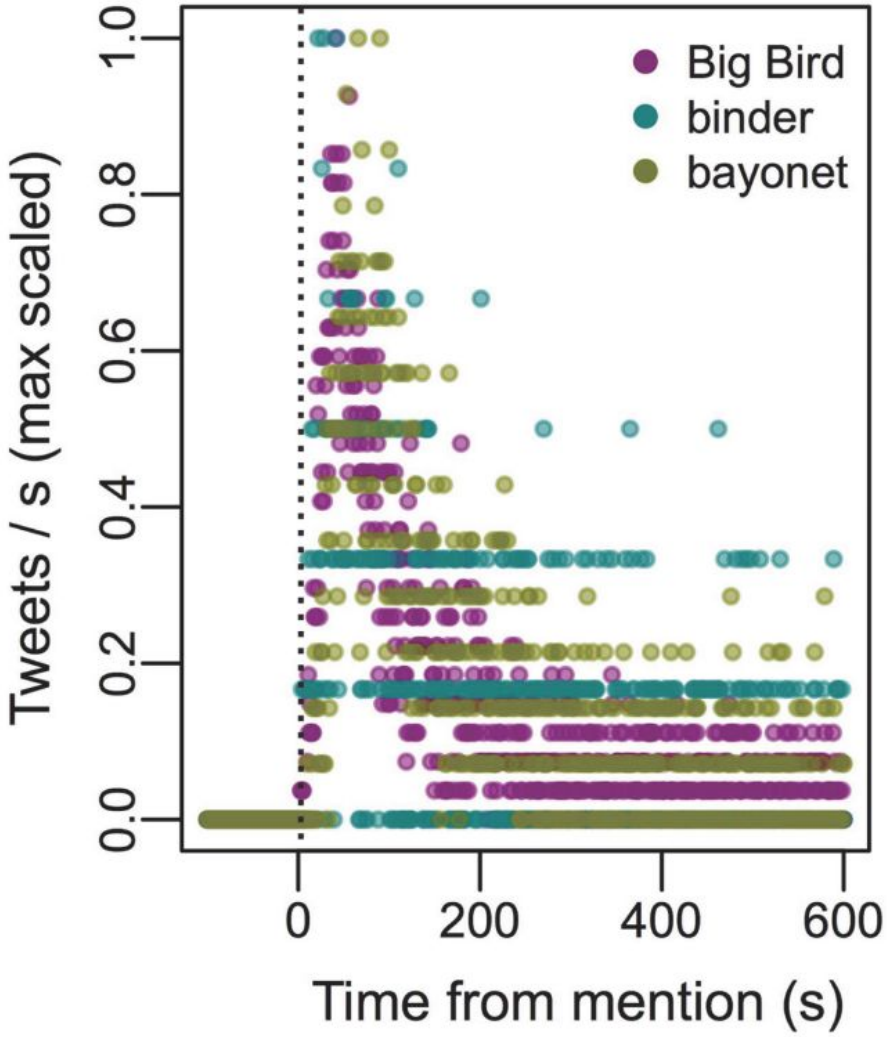
Results - Interaction - Interruptions

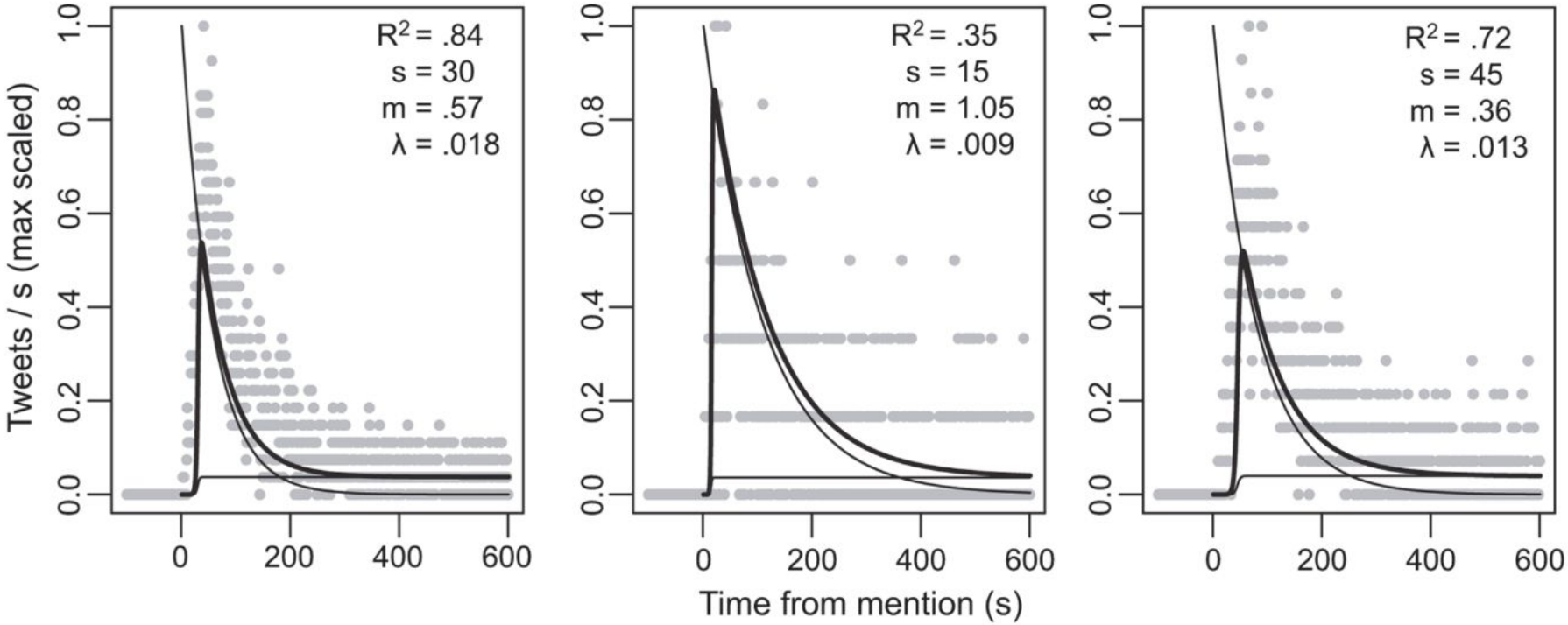
- General increase in mentions of all participants when turn started with an interruption
- Effect was much smaller than speaker identity, but significant in all three debates


Interruption / not interruption
Debate 1
Debate 2
Debate 3
Tweets / s (count)
Time talking (s)
75
70
65
60
55
50
100
80
60
40
50
45
40
35
30
25
0
10
20
30

Results - Content

- Mentions of the salient moments (memes) spiked after about a minute, then decayed over the next few minutes


Big Bird
binder
bayonet
Tweets / s (max scaled)
0.0
0.2
0.4
0.6
0.8
1.0
0
200
400
600
Time from mention (s)

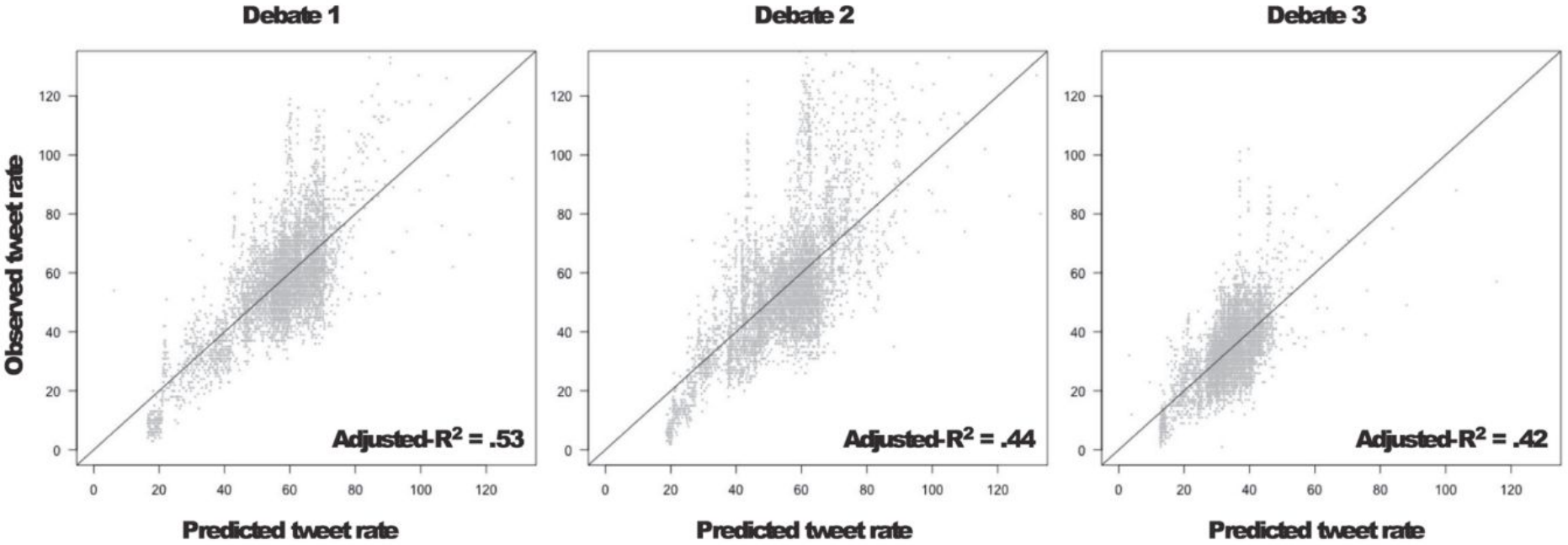

Tweets / s (max scaled)
0.0
0.2
0.4
0.6
0.8
1.0
0
200
400
600
R² = .84
s = 30
m = .57
λ = .018
R² = .35
s = 15
m = 1.05
λ = .009
R² = .72
s = 45
m = .36
λ = .013
Time from mention (s)

Results - Long Term Decay

- Predicted with first- and second-order time terms, both of which account for >20% of variance in each debate
- Linearly increasing term (.28) less than quadratic term (.34)
  - Latter half characterized by decay

Results - Combined

- When including all above factors in the analysis, over 50% of variance in tweet rate was explained
  - Each variable uniquely contributed
- Model for the first debate explained ~10% of variance in second and third


Debate 1
Debate 2
Debate 3
Observed tweet rate
Predicted tweet rate
Predicted tweet rate
Predicted tweet rate
Adjusted-R2 = .53
Adjusted-R2 = .44
Adjusted-R2 = .42
0
20
40
60
80
100
120

Future Work

- Positive/Negative mentions
- Political leanings of users
- Effect on public opinion

Conclusion

- Evidence of entrainment in humans, similar to effects documented in fireflies, starlings, fish, etc
    - Effects visible in hundreds of thousands of individuals within minutes or seconds
- Social media enhances these effects (faster, stronger)

Discussion

- What are the merits and drawbacks of performing this type of study compared to lab experiments?
- What other phenomena can be started using “big data” from social media?

Thx for your time and questions!