

# Limits of Predictability in Human Mobility

Chaoming Song,<sup>1,2</sup> Zehui Qu,<sup>1,2,3</sup> Nicholas Blumm,<sup>1,2</sup> Albert-László Barabási<sup>1,2,\*</sup>

A range of applications, from predicting the spread of human and electronic viruses to city planning and resource management in mobile communications, depend on our ability to foresee the whereabouts and mobility of individuals, raising a fundamental question: To what degree is human behavior predictable? Here we explore the limits of predictability in human dynamics by studying the mobility patterns of anonymized mobile phone users. By measuring the entropy of each individual's trajectory, we find a 93% potential predictability in user mobility across the whole user base. Despite the significant differences in the travel patterns, we find a remarkable lack of variability in predictability, which is largely independent of the distance users cover on a regular basis.

When it comes to the emerging field of human dynamics, there is a fundamental gap between our intuition and the current modeling paradigms. Indeed, al-

though we rarely perceive any of our actions to be random, from the perspective of an outside observer who is unaware of our motivations and schedule, our activity pattern can easily appear

random and unpredictable. Therefore, current models of human activity are fundamentally stochastic (1) from Erlang's formula (2) used in telephony to Lévy-walk models describing human mobility (3–7) and their applications in viral dynamics (8–10), queuing models capturing human communication patterns (11–13), and models capturing body balancing (14) or panic (15). Yet the probabilistic nature of the existing modeling framework raises fundamental questions: What is the role of randomness in human behavior and to what degree are individual human actions predictable? Our goal here is to quantify

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Animal

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# Predictability in Baboon Movement

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# Goals

- Characterize Predictability in Existing Baboon Data
    - Compare to Human
  - Develop Pipeline for Analysing Predictability in Animal Movement
    - MoveBank
  - Look at Impact of Coarse Graining Predictability Metrics
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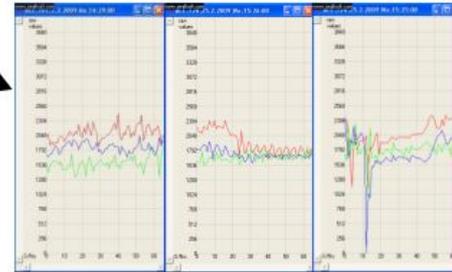
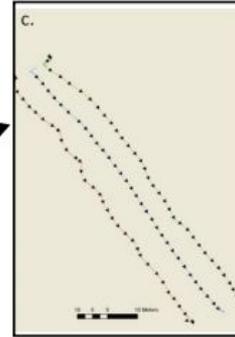
# Collection





GPS sampling @ 1 Hz

3D accelerometry



# Collection

# Human Data

D1: 14 weeks, 10 million users

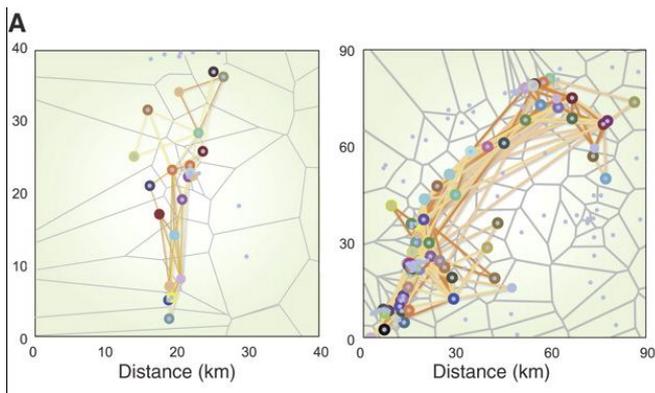
Routing tower location each time a user initiates or receives a call or text message.

D2: 8 days, 100 users

Routing tower location independent of usage.

Both analyzed at 1 hour resolution.

Song et al. 2010



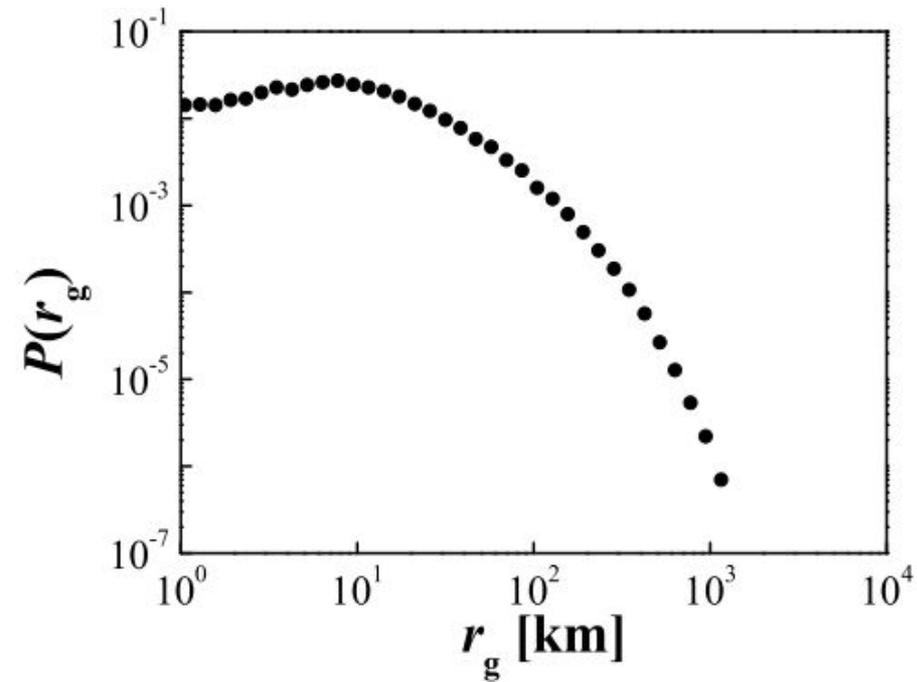
# Baboon Data

2-32 Days, 26 individuals

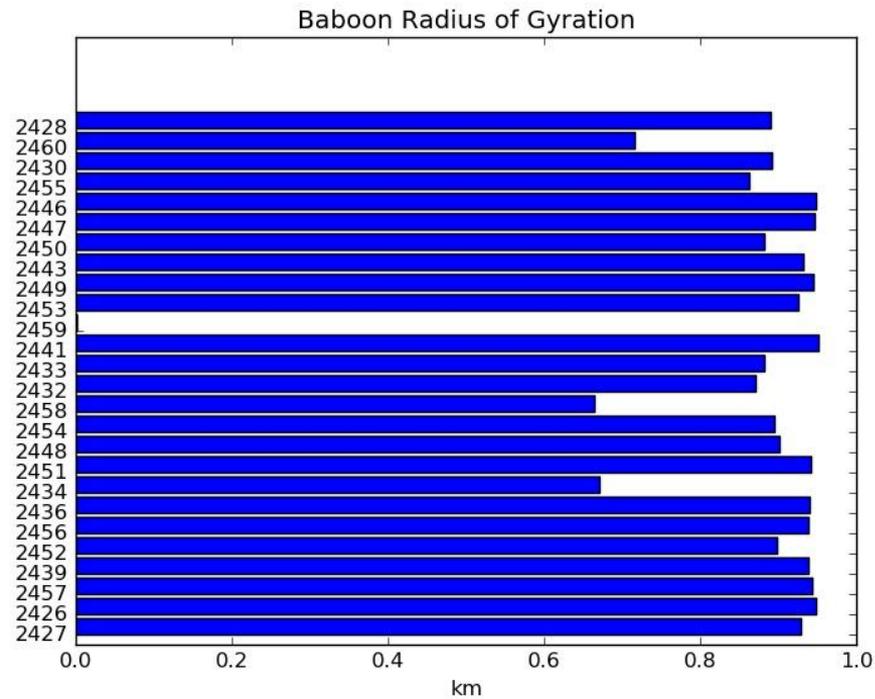
GPS at 1 meter by 1hz resolution.

Collar Number	Sex	Age	Battery	Capture Date	Tracking Start Date	Tracking End Date	Days Tracked
2426	Male	Sub-adult	D	7/21/2012	8/1/2012	8/31/2012	31
2427	Male	Adult	D	7/21/2012	8/1/2012	9/4/2012	35
2428	Female	Sub-adult	C	7/29/2012	8/1/2012	8/15/2012	15
2430	Female	Adult	D	7/28/2012	8/1/2012	8/3/2012	3
2432	Male	Sub-adult	C	7/22/2012	8/1/2012	8/5/2012	5
2433	Male	Sub-adult	D	7/22/2012	8/1/2012	8/6/2012	6
2434	Male	Adult	D	7/22/2012	8/1/2012	8/2/2012	2
2436	Male	Sub-adult	D	7/22/2012	8/1/2012	9/2/2012	33
2439	Female	Adult	D	7/21/2012	8/1/2012	9/4/2012	35
2441	Female	Sub-adult	C	7/22/2012	8/1/2012	8/29/2012	29
2443	Male	Sub-adult	D	7/23/2012	8/1/2012	9/2/2012	33
2446	Female	Adult	D	7/25/2012	8/1/2012	9/2/2012	33
2447	Female	Adult	D	7/24/2012	8/1/2012	8/31/2012	31
2448	Male	Juvenile	C	7/22/2012	8/1/2012	8/17/2012	17
2449	Female	Adult	D	7/23/2012	8/1/2012	8/31/2012	31
2450	Female	Sub-adult	D	7/24/2012	8/1/2012	8/5/2012	5
2451	Female	Adult	D	7/22/2012	8/1/2012	9/2/2012	33
2452	Male	Sub-adult	C	7/12/2012	8/1/2012	8/14/2012	14
2453	Female	Adult	D	7/25/2012	8/1/2012	8/3/2012	3
2454	Male	Juvenile	C	7/22/2012	8/1/2012	8/14/2012	14
2455	Female	Sub-adult	D	7/28/2012	8/1/2012	8/8/2012	8
2456	Female	Adult	D	7/22/2012	8/1/2012	8/31/2012	31
2457	Male	Adult	D	7/21/2012	8/1/2012	9/4/2012	35
2458	Female	Adult	D	7/22/2012	8/1/2012	8/2/2012	1
2460	Female	Adult	D	7/28/2012	8/1/2012	8/2/2012	1

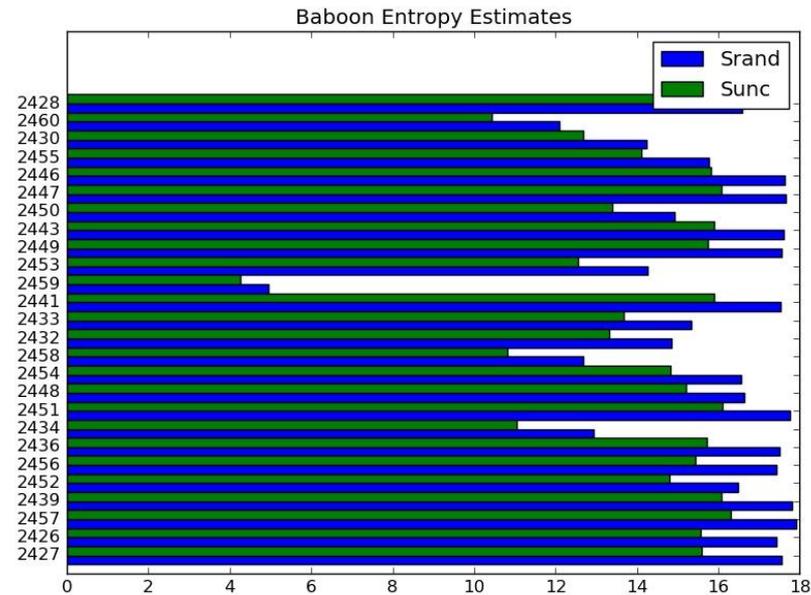
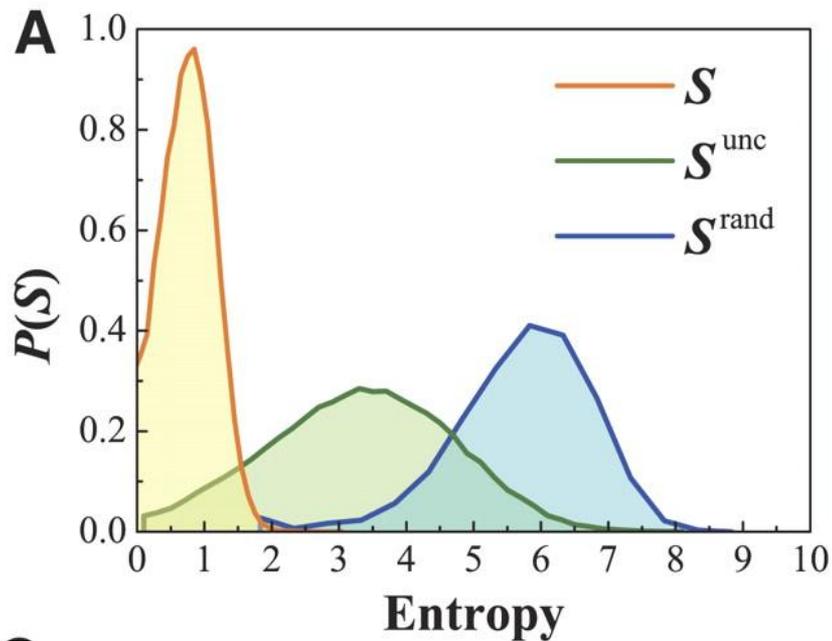
Table S1. Collar ID, age/sex class and tracking details for GPS-collared baboons.



Song et al. 2010

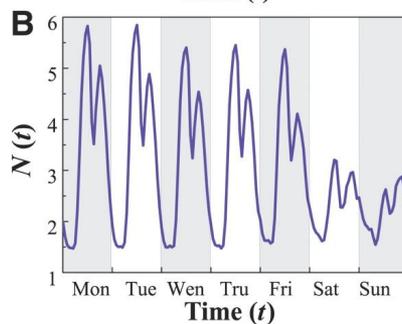
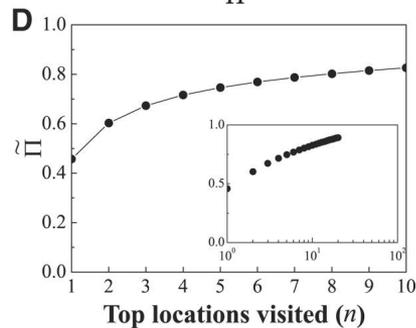
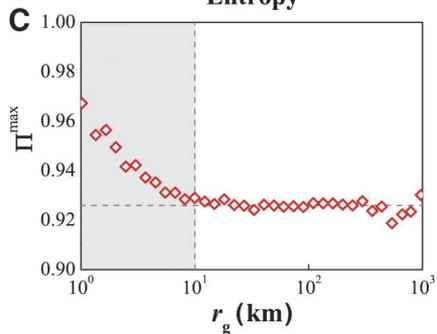
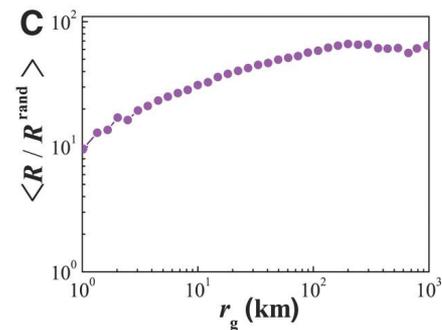
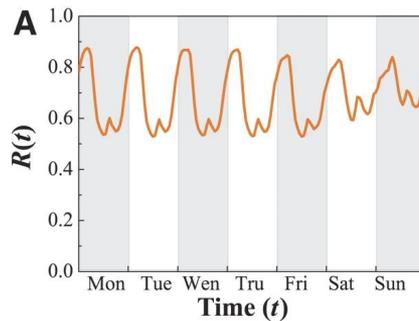
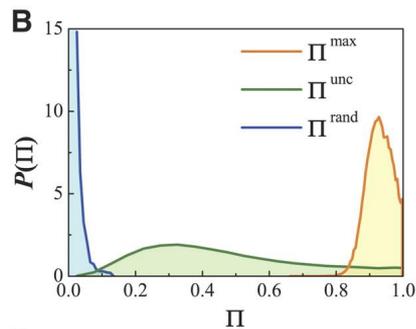
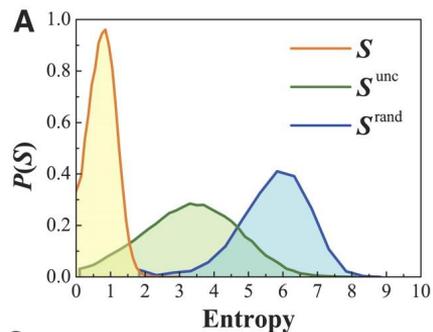


# First Pass at Entropy



Song et al. 2010

# My Week



Song et al. 2010

# Questions?

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