北京交通大学
交通系统科学与工程研究院
INSTITUTE OF TRANSPORTATION SYSTEM SCIENCE AND ENGINEERING





The Growth Pattern of Traffic Oscillations: A Comparison Study between China and USA

Shi-Teng Zheng

Email: stzheng@bjtu.edu.cn

Beijing Jiaotong University

4th Sep 2019

Presentation Structure

- Traffic oscillation introduction
- Detailed description of data
- Study 1: growth pattern of oscillations
- Study 2: straight track v.s. circular track
- Study 3: model test
- Conclusion and outlook

➢ What is traffic oscillations ?

Extra fuel consumption and emission

Driving discomfort

More safety risks

Stop-and-go driving is a nuisance for motorists throughout the world.

(Laval and Leclercq, 2010)

➢ Formation of traffic oscillation

- **Form at the bottlenecks**
  - **Highway lane drops**

    (Bertini and Leal, 2005)
  - **Lane changes near merges and diverges**

    (Mauch and Cassidy, 2002; Cassidy, 2005; Menendez, 2006; Laval and Daganzo, 2006; Laval et al., 2007; Ahn and Cassidy, 2007)
- **In the absence of bottlenecks and lane changing.**

  (Sugiyama et al., 2008; Stern et al., 2017)





➢ Empirical observation

Amplitude

- **Oscillations do increase in amplitude while propagating upstream** (Mauch and Cassidy, 2002; Ahn et al., 2005).
- **Grow to their full amplitudes while propagating upstream** (Mauch and Cassidy, 2002).

Frequency

- **Typical periods seem to be somewhere between 2 and 15 min** (Mauch and Cassidy, 2002; Ahn et al., 2004; Ahn, 2005; Laval et al., 2009).

A relation of between amplitude and frequency

- **Long periods are accompanied by large oscillation amplitudes and high frequencies result in low amplitudes** (Gartner et al., 1992).

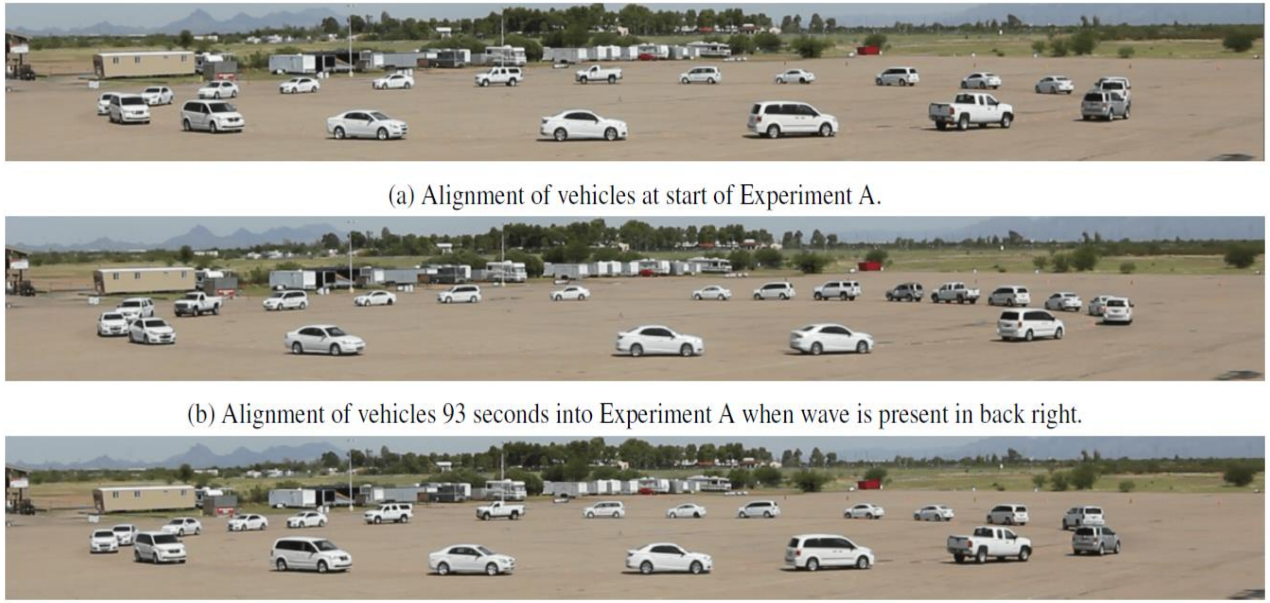
Propagation velocity

- **Propagate at speeds of about 19 to 20 km/h on OR-217 in the United States, 16 km/h on the A9 in Germany, and 14 km/h on the M4 in the United Kingdom.** (Zielke et al., 2008)

➢ Field experiment

- A circular track: **230** m
- The vehicle number: **22**

(Sugiyama et al., 2008)



(a) Alignment of vehicles at start of Experiment A.

(b) Alignment of vehicles 93 seconds into Experiment A when wave is present in back right.

(c) Alignment of vehicles 327 seconds into Experiment A when the CAT Vehicle is actively dampening the wave.

- A circular track: **260** m
- The vehicle number: **19 ~ 22**

(Stern et al., 2018; Wu et al., 2019)

Field experiment

- **25-car-platoon experiment** (Jiang et al., 2014,2015)

  The experiment of 25-car-platoon was carried out on January 19, 2013 on a 3.2 km stretch of the Chuangxin Avenue in a suburban area in Hefei, China.

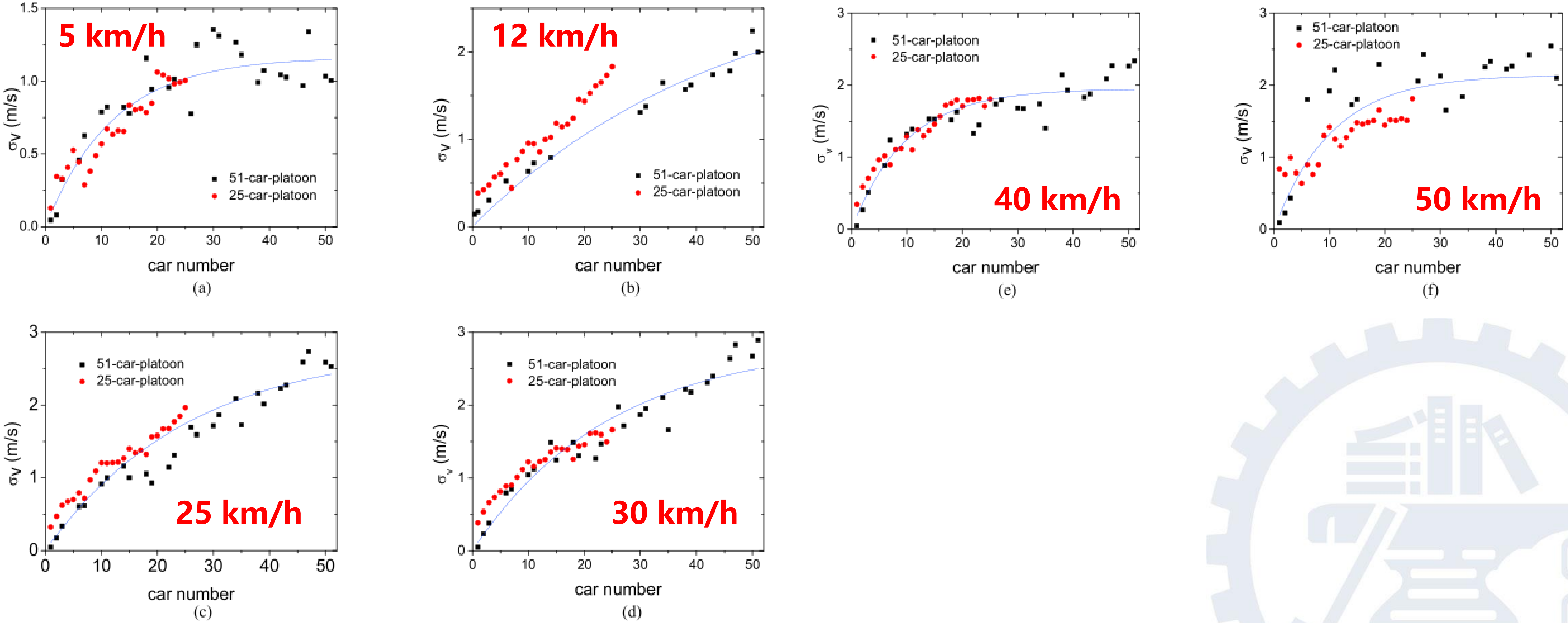
- **51-car-platoon experiment** (Jiang et al., 2017,2018)

  The experiment of 51-car-platoon was carried out on December 15, 2013 on the runway and taxiway of the old airport (which was closed) in Hefei, China.

- **11-car-platoon experiment** (high-speed experiment, Huang et al., 2018)

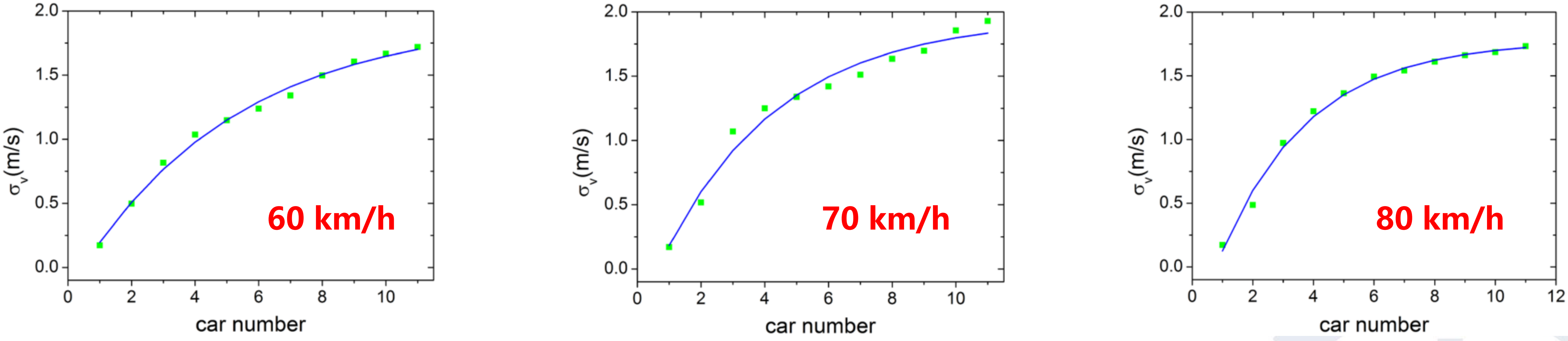
The location and speed of each individual car have been recorded by high precision GPS devices (within ± 1 m for location and within ± 1 km/h for velocity).

25&51-car-platoon experiment



(Jiang et al., 2017)

11-car-platoon experiment



(Huang et al., 2018)

Conclusion: **The speed standard deviation increases in a concave way along the platoon in the oscillations, whether in the low-speed or high-speed experiments.**

Model simulation results

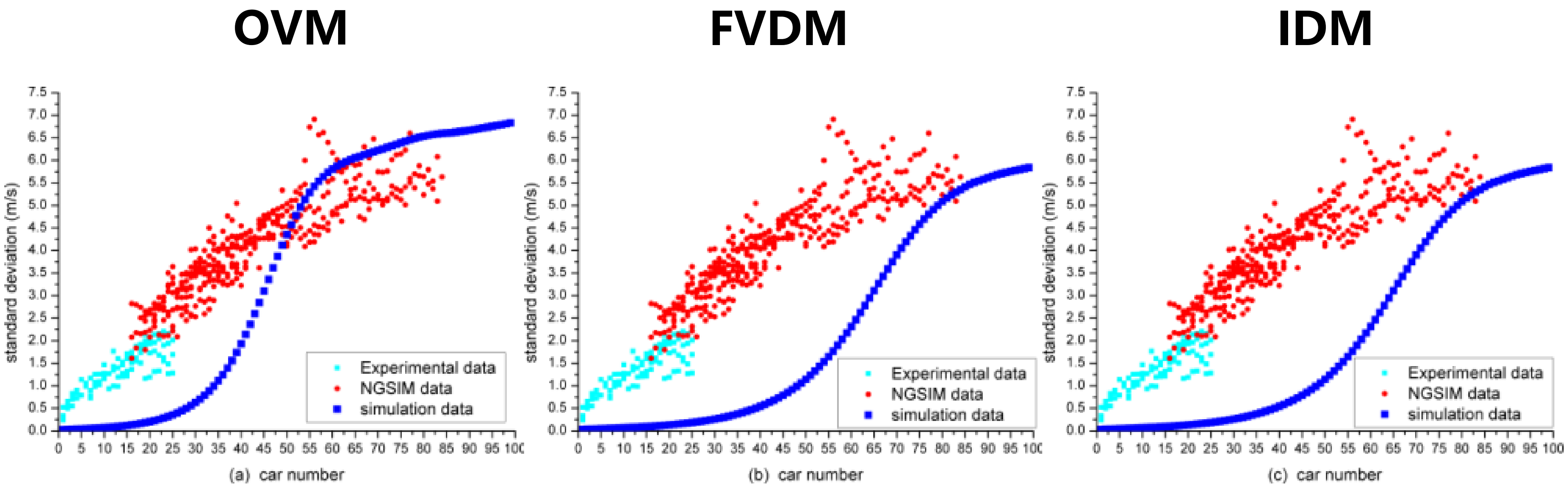


Figure 7. Simulation results of the standard deviation of the speed of each car. (a) the OVM, (b) the FVDM, (c) the IDM. The parameters of these three models are the same as that in Jiang et al. (2014).

* **OVM:** Optimal Velocity Model; **FVDM**: Full Velocity Difference Model; **IDM**: Intelligent Driver Model

(Tian et al., 2016)

Conclusion: The speed standard deviation of simulation results (the blue line in Figure) initially increases in a convex way, which contradicts with the experimental findings.

It was proposed that oscillations form and grow due to the cumulative effect of stochastic factors.

- Kim and Zhang (2008) adopted a **stochastic** approach to model the wide scatter in congested flow.
- Yeo and Skabardonis (2009) conjectured that the cause for oscillations might be **human error**, i.e. **anticipation and overreaction**.
- Laval et al. (2014) suggested that the formation and propagation of oscillations without lane changes can be explicated by **the stochastic nature of acceleration processes of the drivers**.





The initial growth pattern of oscillations (less than 2 m/s) of the US is not clear.

NGSIM

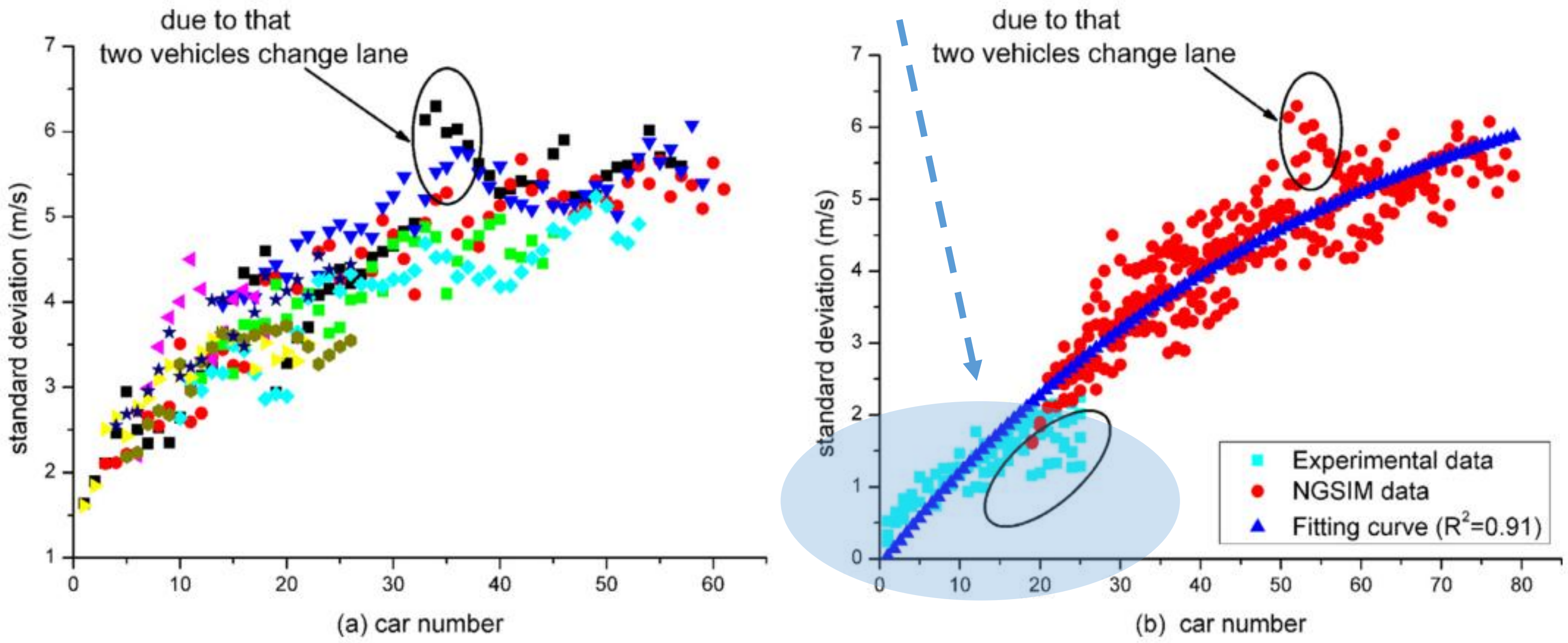


Fig. 4. (a) The standard deviation of the speed of each vehicle in all empirical examples. (b) Merging the empirical data and the experimental data. The fitting curve is given by $y = a\ \exp(-x/x_0) + y_0$, where $a = -7.91$, $x_0 = 55.8$, $y_0 = 7.8$.

(Tian et al., 2016)

Tian et al. (2016) have investigated the growth pattern of traffic oscillations in the NGSIM vehicle trajectory data. It was found that the speed standard deviation also grows concavely and is highly compatible with that in Chinese car-following experiments.





Presentation Structure

- Traffic oscillation introduction
- **Detailed description of data**
- Study 1: growth pattern of oscillations
- Study 2: straight track v.s. circular track
- Study 3: model test
- Conclusion and outlook

➢ Detailed description of data

Cognitive and Autonomous Test (CAT)

can be transitioned between **manual velocity control** and **autonomous velocity control**.

- A circular track: **260** m
- Experiment A: **21** vehicles
- Experiment B: **21** vehicles
- Experiment C: **22** vehicles

(Stern et al., 2018)

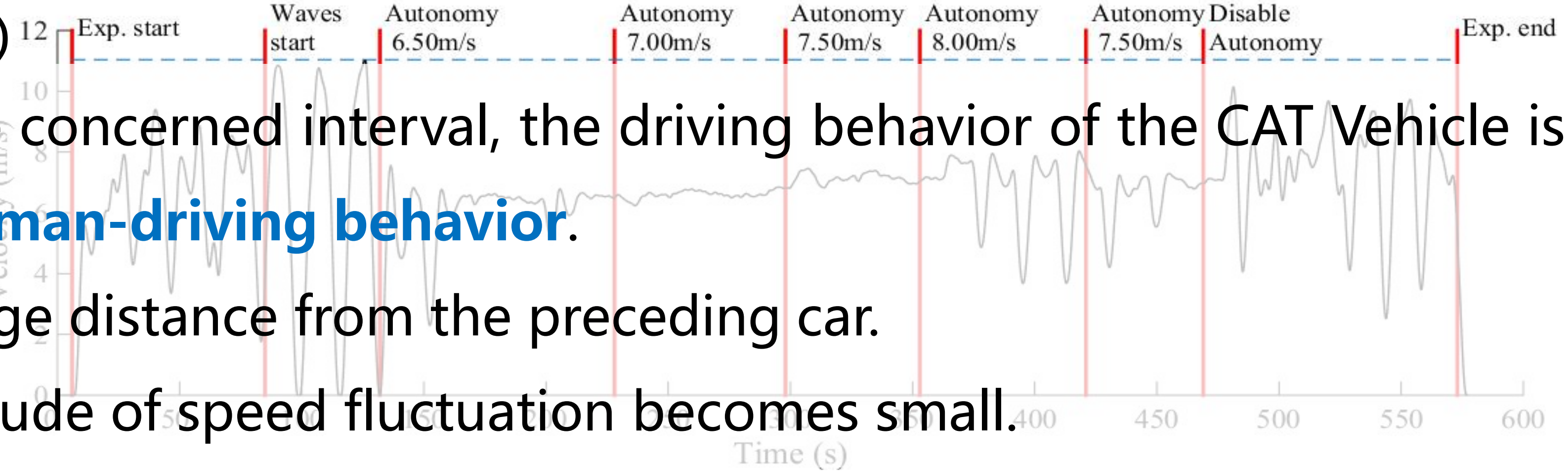
- A circular track: **260** m
- Experiment F: **19** vehicles
- Experiment G: **21** vehicles
- Experiment H: **22** vehicles

(Wu et al., 2019)

Dissipation of stop-and-go traffic waves via control of a single autonomous vehicle

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
RUTGERS
TEMPLE UNIVERSITY
THE UNIVERSITY OF ARIZONA

(a)



- During the concerned interval, the driving behavior of the CAT Vehicle is no longer **the typical human-driving behavior**.
- It has a large distance from the preceding car.
- The amplitude of speed fluctuation becomes small.

(b)

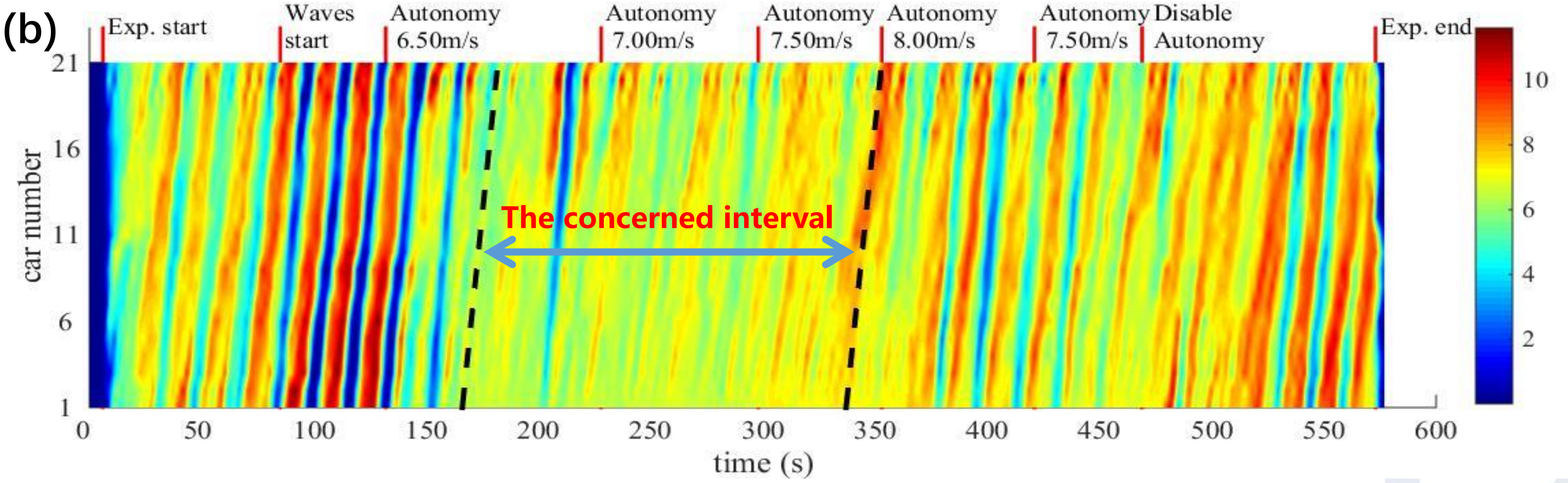


Fig. (a) Velocity profile of the CAT Vehicle (the leading car) in Exp A.

(b) Evolution of the spatiotemporal pattern of car velocity (unit m/s) for Exp A.



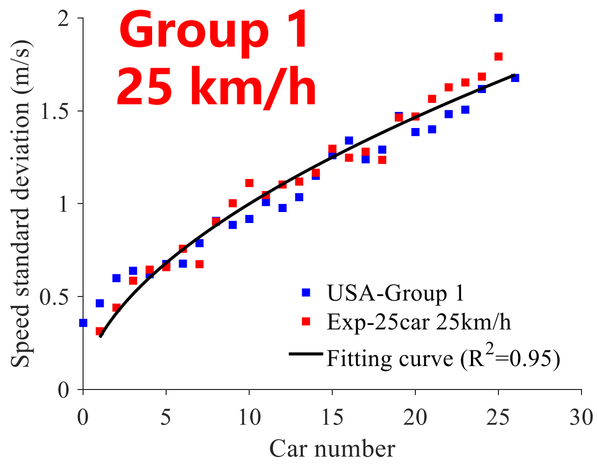


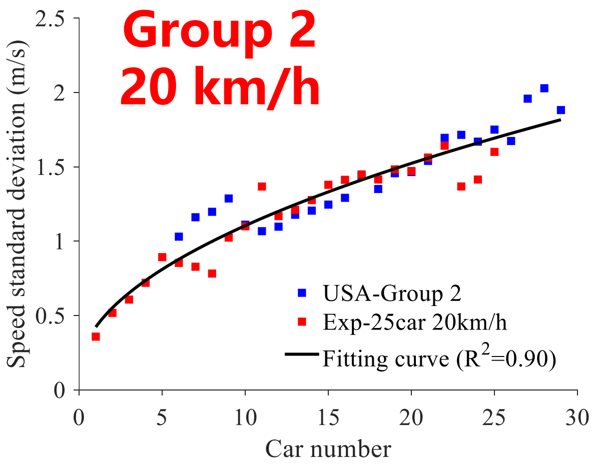
Presentation Structure

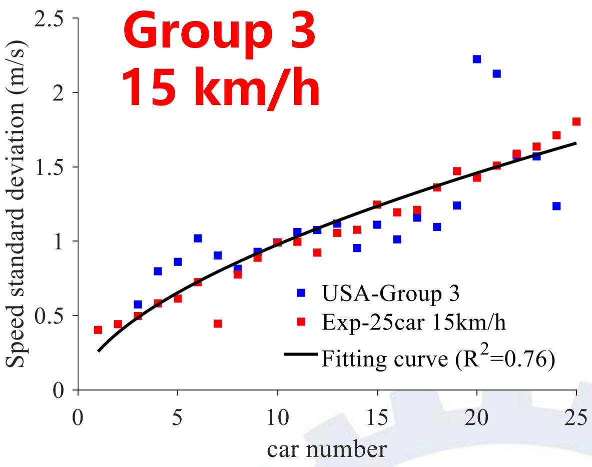
- **Traffic oscillation introduction**
- **Detailed description of data**
- **Study 1: growth pattern of oscillations**
- **Study 2: straight track v.s. circular track**
- **Study 3: model test**
- **Conclusion and outlook**

	Group 1		Group 2			Group 3
	Exp A	Exp B	Exp C	Exp F	Exp G	Exp H
Duration	~ 170 s	~ 155 s	~ 150 s	~ 95 s	~ 235 s	~ 230 s
Average speed of the leading car	6.65 m/s (23.9 km/h)	6.60 m/s (23.8 km/h)	5.78 m/s (20.8 km/h)	5.30 m/s (19.1 km/h)	5.81 m/s (20.9 km/h)	4.61 m/s (16.6 km/h)

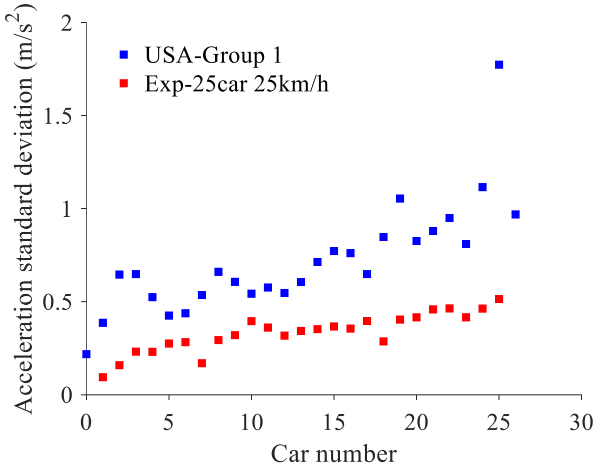
σ_v

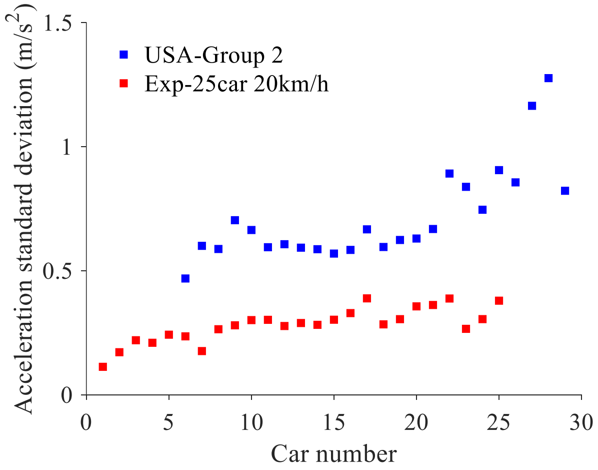


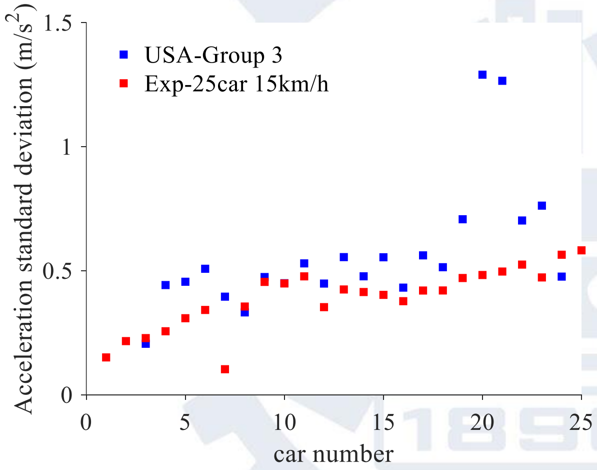




σ_a











Presentation Structure

- **Traffic oscillation introduction**
- **Detailed description of data**
- **Study 1: growth pattern of oscillations**
- **Study 2: straight track v.s. circular track**
- **Study 3: model test**
- **Conclusion and outlook**

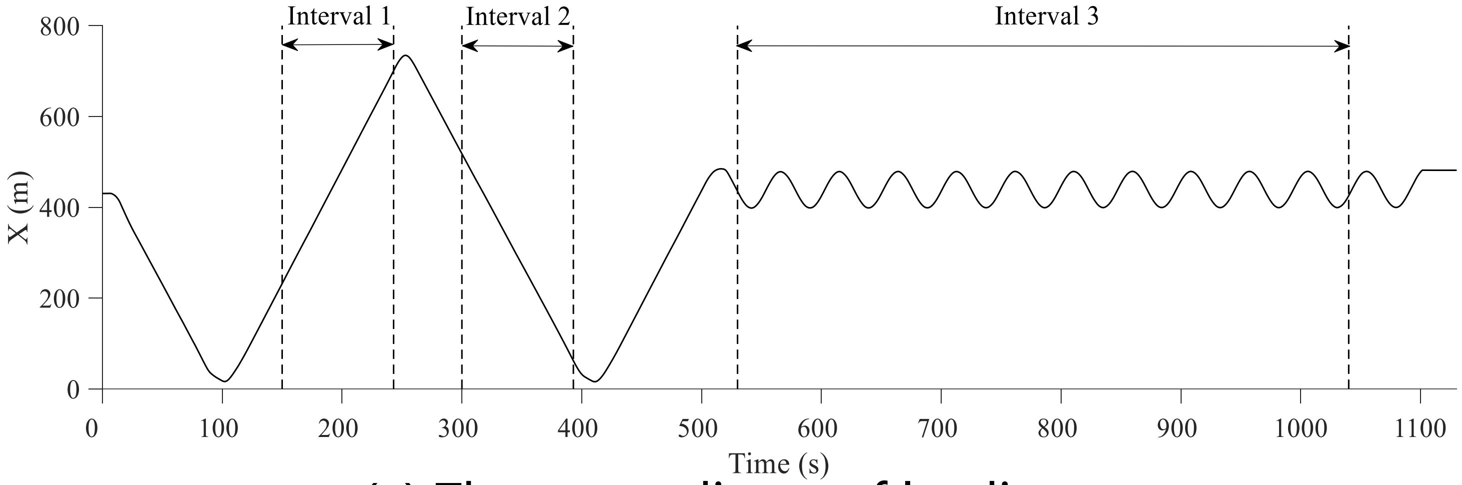
北京交通大學
交通系统科学与工程研究院
INSTITUTE OF TRANSPORTATION SYSTEM SCIENCE AND ENGINEERING

長安大學
CHANG' AN UNIVERSITY

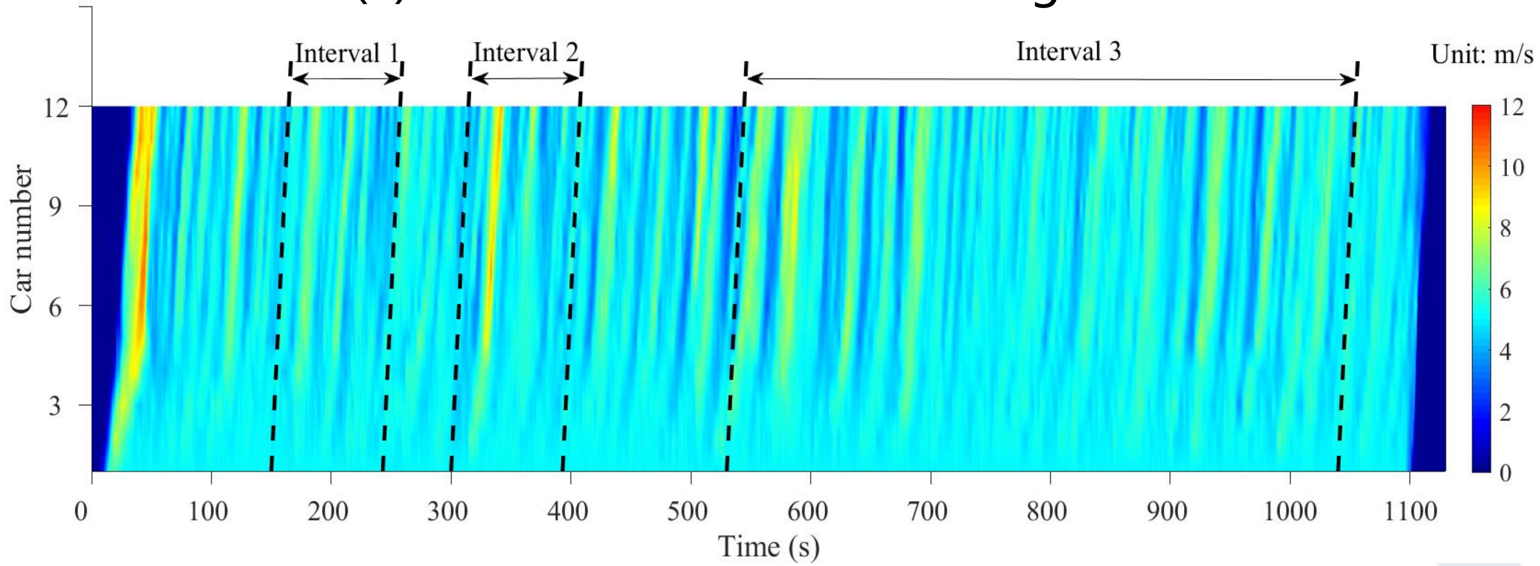
The Comparative Experiment Study on the Driving Behavior between Linear Track and Circular Track

December 1, 2018

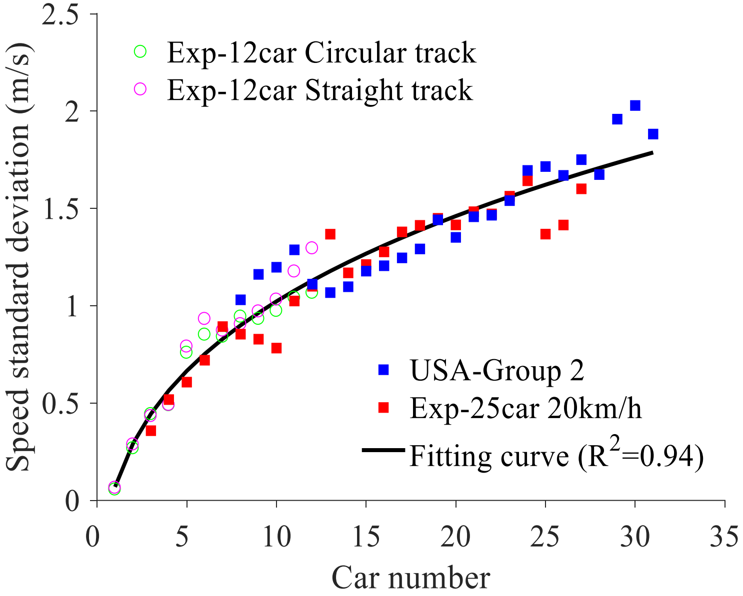
➢ 12-car-platoon experiment



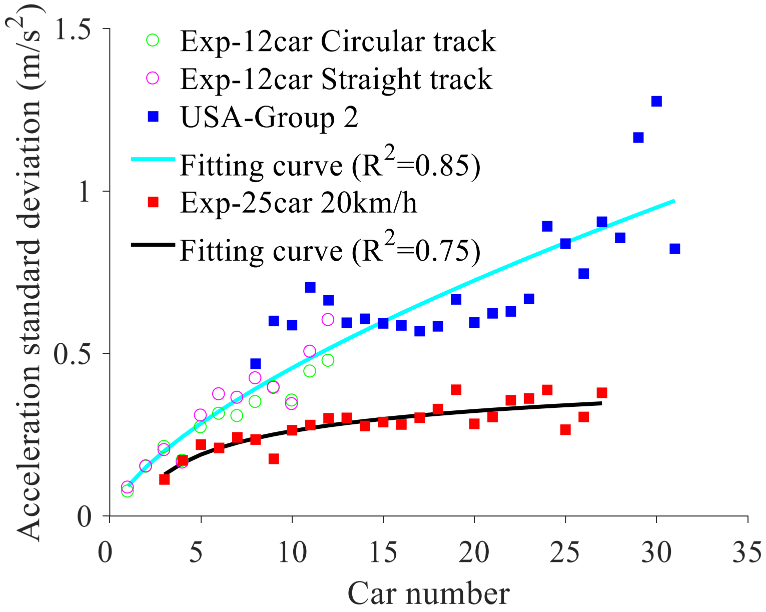
(a) The x-coordinate of leading car.



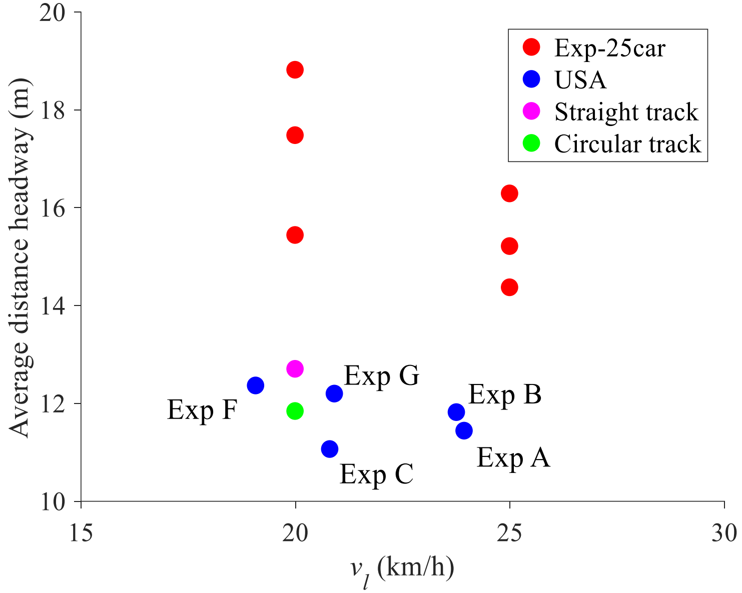
(b) The evolution of the spatiotemporal pattern of car speed in the China 12-car-platoon experiment.



(a) Speed standard deviation



(b) Acceleration standard deviation



(c) Average distance headway

- **In Fig. a&b, one can see that the data on the straight track and on the circular track are in good agreement with each other (the hollow circle in Fig. a&b).**
- **In Fig. b, the acceleration standard deviation of 12-car-platoon is larger than the 25-car-platoon data (the red data in Figure), but complementary to USA data (the blue data in Figure).**
- **In Fig. c, one can see that the results are close between the 12-car-platoon data and USA data. This confirms that, the reason why acceleration standard deviation is larger in the 12-car-platoon experiment and USA experiment is that drivers were asked to follow closely. In contrast, in the 25-car-platoon experiment, drivers were asked to drive normally instead of closely.**

Presentation Structure

- Traffic oscillation introduction
- Detailed description of data
- Study 1: growth pattern of oscillations
- Study 2: straight track v.s. circular track
- Study 3: model test
- Conclusion and outlook

➢ Model test

$$a_n(t) = a_{\max}\left(1 - \left(\frac{v_n(t)}{v_{\max}}\right)^4 - \left(\frac{v_n(t)T(t) + d_0 - \frac{v_n(t)\Delta v_n(t)}{2\sqrt{a_{\max} b}}}{d_n(\mathrm{t})}\right)^2\right)$$

- **2D-IDM**

$$T(t+\Delta t) = \begin{cases} T_1 + rT_2 & \text{with probability } p, \\ T(t) & \text{otherwise.} \end{cases}$$

(Jiang et al., 2014)

- **IDM with action points**

$$\left|a_n(t) - a_n(t')\right| > \Delta a, \qquad \Delta a \sim U\left(0, \Delta a_{\max}\right)$$

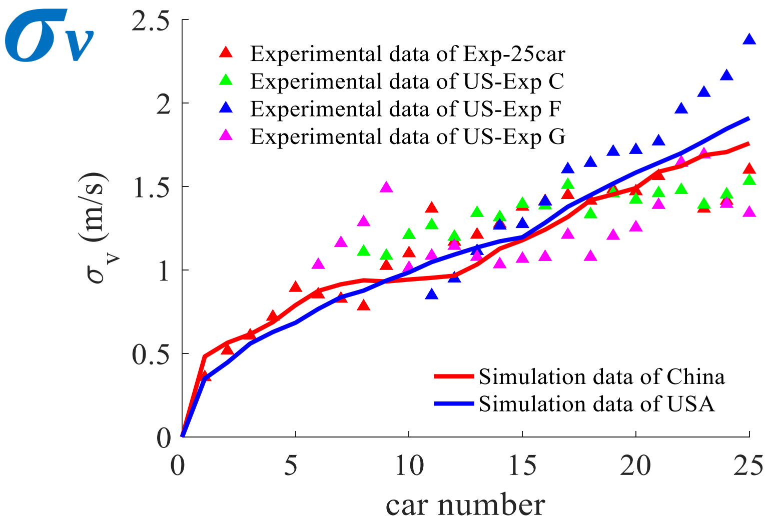
- **IDM with white acceleration noise**

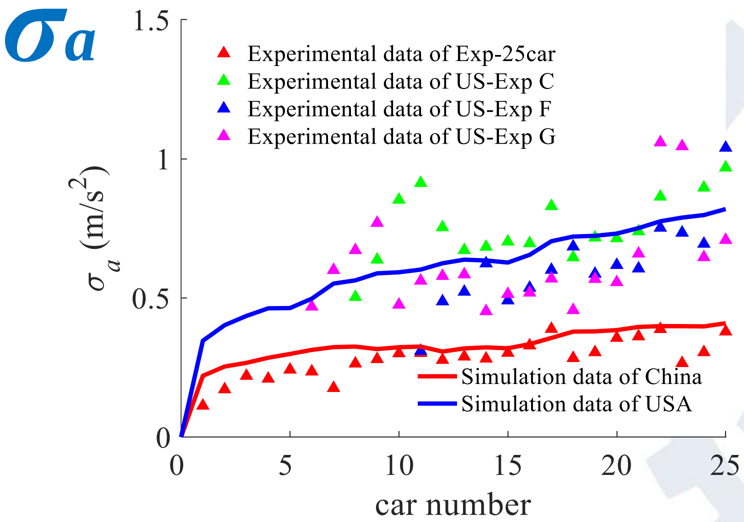
$$\dot{v}_n(t) = a_n(t) + \xi_n(t) \qquad \left\langle \xi_n(t) \right\rangle = 0 \qquad \left\langle \xi_n(t)\xi_m(t') \right\rangle = Q\delta_{nm}\delta(t - t')$$

(Treiber and Kesting, 2017)

Objective function $\min \ \omega_1 \cdot \frac{1}{M}\sum_{m=1}^{M}\frac{1}{N}\sum_{n=1}^{N}\left|\hat{\sigma}_v^{n,m}-\sigma_v^n\right| + \omega_2 \cdot \frac{1}{M}\sum_{m=1}^{M}\frac{1}{N}\sum_{n=1}^{N}\left|\hat{\sigma}_a^{n,m}-\sigma_a^n\right|$ **(Genetic algorithm)**

Parameters	Calibrated value					
	2D-IDM		IDM with action points		IDM with white acceleration noise	
	China	USA	China	USA	China	USA
Maximum acceleration a	0.43 m/s²	1.66 m/s²	0.83 m/s²	1.60 m/s²	0.50 m/s²	1.30 m/s²
Desired deceleration b	1.86 m/s²	3.38 m/s²	1.78 m/s²	2.95 m/s²	2.34 m/s²	2.90 m/s²
Jam distance d_0	0.55 m	2.33 m	2.26 m	2.26 m	1.30 m	1.84 m
Safe time headway T	T_1= 0.77 s T_2= 1.93 s	T_1= 0.45 s T_2= 0.58 s	1.57 s	0.93 s	1.97 s	0.76 s
Probability p	0.060	0.059	—	—	—	—
Maximum acceleration step Δa_{max}	—	—	0.74 m/s²	1.23 m/s²	—	—
Noise intensity Q	—	—	—	—	0.87 m²/s³	2.62 m²/s³









Presentation Structure

- **Traffic oscillation introduction**
- **Detailed description of data**
- **Study 1: growth pattern of oscillations**
- **Study 2: straight track v.s. circular track**
- **Study 3: model test**
- **Conclusion and outlook**





Conclusions

- **The set of experiment on the circular track can be considered equivalent to that on the straight track.**
- **The speed standard deviation exhibits a universal concave growth characteristic in the two countries; while the growth pattern of acceleration standard deviation is remarkably different.**
- **The acceleration standard deviation might be related to the distance headway, which can be influenced by the experimental instruction.**
- **The universal concave growth pattern of speed standard deviation and different growth pattern of acceleration standard deviation can be well reproduced.**

Outlook

In future studies, the data sets on a longer stretch of freeway with longer duration should be analyzed. Finally, larger-scale experiments in car-following should be carried out to further investigate the growth pattern of traffic oscillations.





Thanks to

Rui Jiang

Jun-Fang Tian

Xiaopeng Li

Bin Jia

Zi-You Gao

Shao-wei Yu

Thanks for your attention!

The Growth Pattern of Traffic Oscillations:
A Comparison Study between China and USA

Shi-Teng Zheng

Email: stzheng@bjtu.edu.cn

Beijing Jiaotong University

4th Sep 2019