

A hand is holding a smartphone and a US dollar bill. The smartphone screen shows icons for Gmail, Play Music, and Camera. The dollar bill is a one-dollar bill with the serial number L25177487K. The background is a blurred outdoor scene.

Personalized Mobile Targeting with User Engagement Stages: Combining Structural Forward-Looking Hidden Markov Model and Field Experiment

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Apps are trying to understand users



GrubHub 1h ago



Hello and Welcome to GrubHub! Fill out your profile for a 20% off coupon.

Best Buy 16m ago



View today's Deal of the Day. Quantities are limited.

Facebook 3m ago



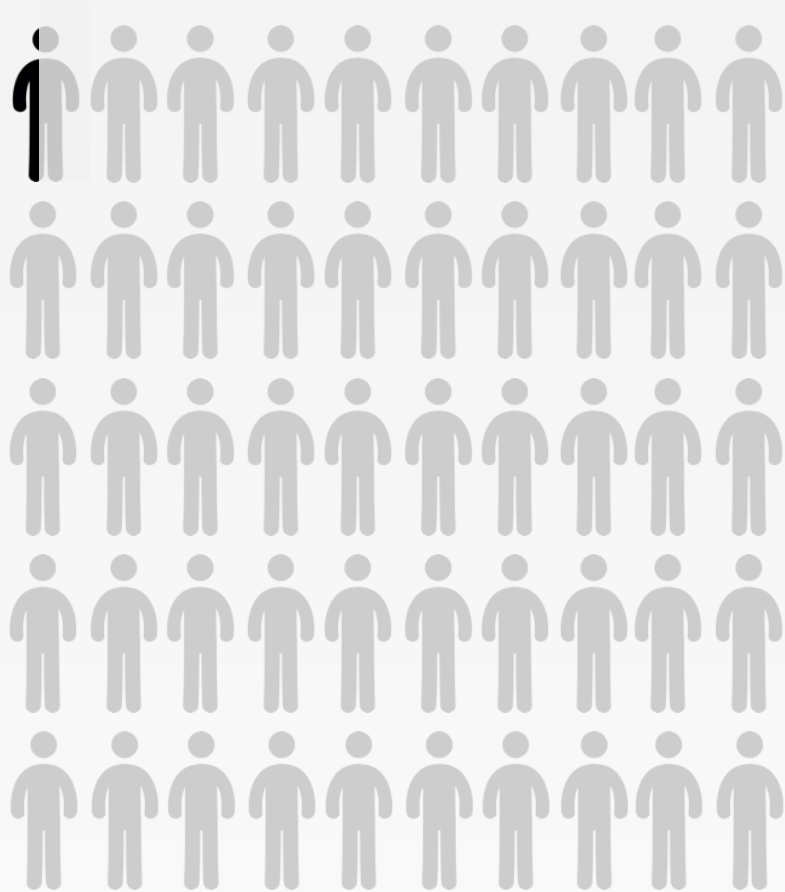
Your last post was 15 days ago. Tell friends what you're up to now.

Level 5m ago



Yingjie! You've spent less than 50% of your Spendable this week! Good job!

Are their strategies effective?



In 2015, the average mobile app retention rate was **42%** after the first month, and **25%** after the first three months.

2% of users paid for in-app content

Half of the revenues were contributed by **0.2%** of users (Feb 2016)

Can we design better marketing strategies to improve mobile user engagement?

What have been done in the literature?

User engagement

Measure with recent activities: Claussen et al. (2013), Qi et al. (2011)

Survey-based data: Kim et al. (2013)

Mobile app platform

Aggregated-level analysis: Garg and Telang (2013), Liu et al. (2013)

Individual-panel data: Ghose and Han (2014)

3-Step Research Design

- Step 1: Randomized field experiment
 - average causal effects of different promotions
- Step 2: FHMM
 - detection of user engagement using tapstream data
 - heterogeneous treatment effects
- Step 3: Simulation
 - engagement-based targeting strategies

Experiment Design

Treatment 1

Price promotion

Treatment 2

Free content promotion

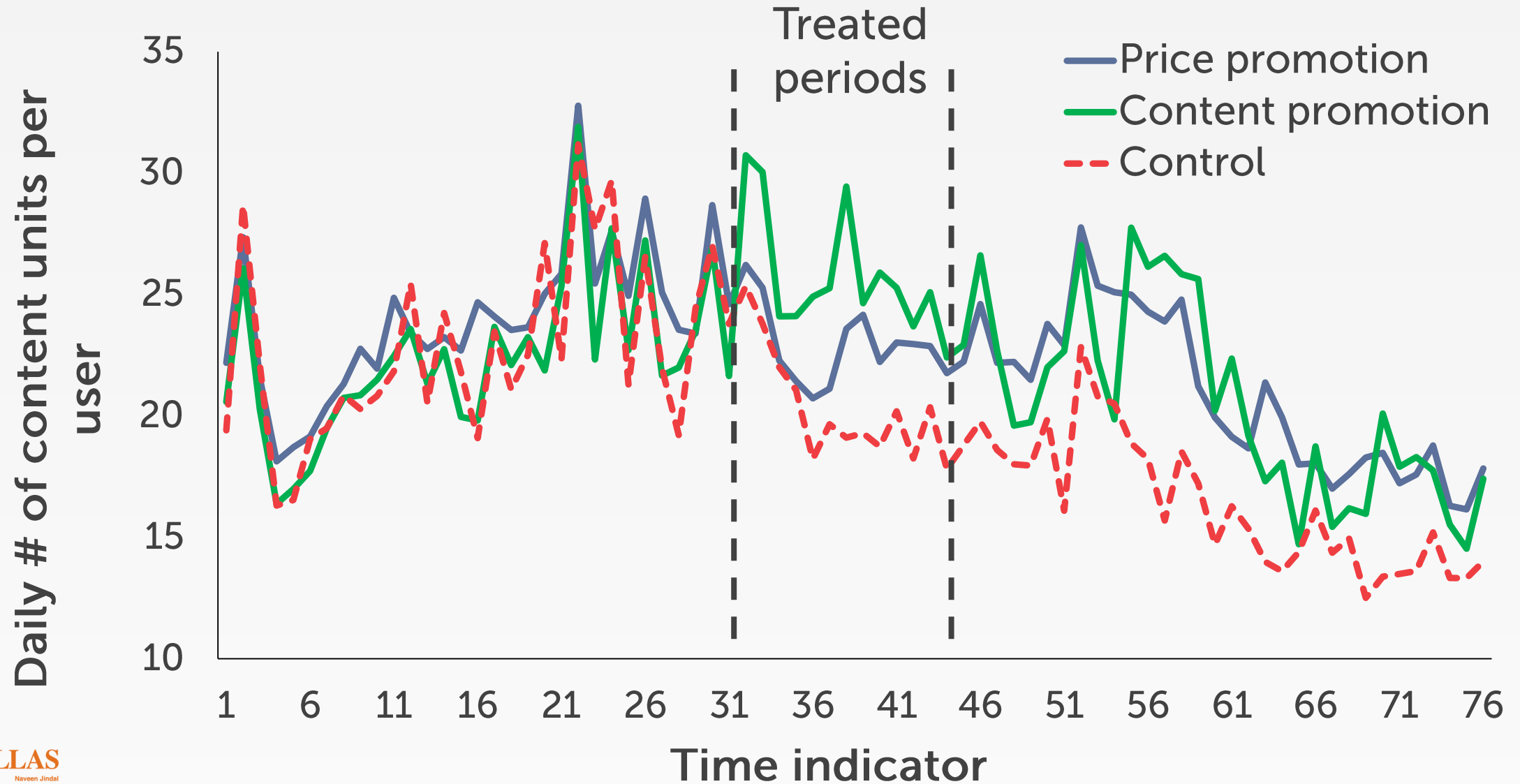
Control

Non-pricing placebo messages

User ID	Time Stamp	Book ID	Book name	Genre ID	Genre Name	Payment ID	Payment	Chapter ID	Chapter Name	Free or not
85	7/22/2015 20:10	403696444	我的刁蛮女上	11	都市	15	按章	404509159	第七十八章落	1
20	8/3/2015 14:04	388917988	藏獒，远去的	41	纪实	0	免费	388918491	序言	0
504	7/28/2015 16:25	386299128	红河谷的花腰	26	社科	4	包月	386299271	第二节村落空	1
1087	8/4/2015 19:30	386299128	红河谷的花腰	26	社科	4	包月	386299271	第二节村落空	1
2398	8/6/2015 19:19	386299128	红河谷的花腰	26	社科	4	包月	386299271	第二节村落空	1

user ID, time stamp, content information, payment option

Overall Treatment Effect



Average Treatment Effects

$$Y_{it} = \alpha_0 + \alpha_1 Test_t + \alpha_2 Treat1_i \times Test_t + \alpha_3 Treat2_i \times Test_t + \alpha_4 postTest_t + \alpha_5 Treat1_i \times postTest_t + \alpha_6 Treat2_i \times postTest_t + \xi_i + \varepsilon_{it}$$

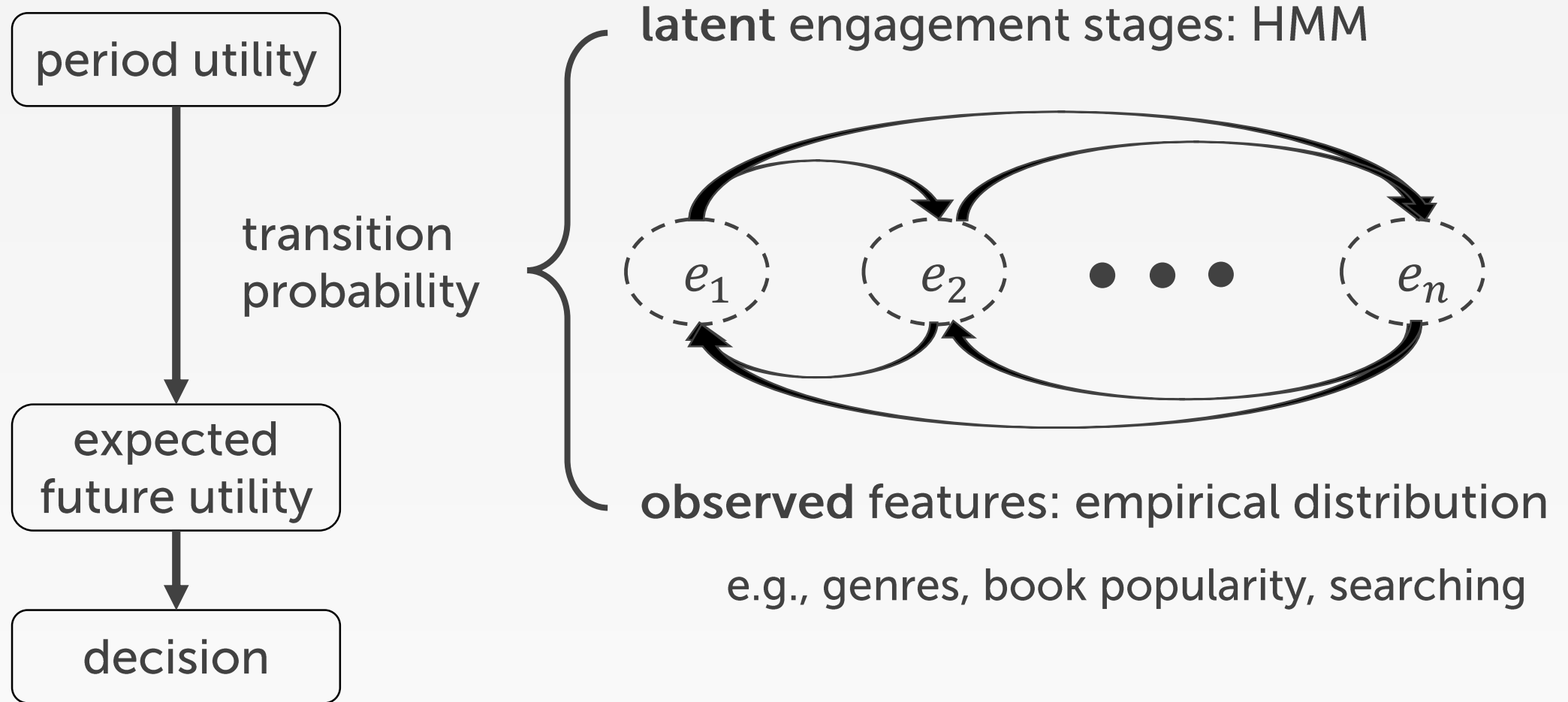
Table 3 Field Experiment Analysis

Y_{it}	With active users only				With all users			
	# of units		# of free units		# of units		# of free units	
Treat1	1.0026*	0.9435*	0.1306	0.1117	1.0811***	1.0811***	0.2375***	0.2375***
×Test	(0.4492)	(0.4663)	(0.1374)	(0.1352)	(0.0964)	(0.0956)	(0.0328)	(0.0305)
Treat2	0.8152*	0.7839*	0.2543*	0.213*	0.3280***	0.3280***	0.0888**	0.0888*
×Test	(0.4294)	(0.4453)	(0.1314)	(0.1291)	(0.1004)	(0.0995)	(0.0341)	(0.0318)
Test	-1.1543***	-1.2993***	-0.4301***	-0.3597***	-0.3833***	-0.3833***	-0.1786***	-0.1786*
	(0.3346)	(0.3469)	(0.1024)	(0.1006)	(0.0738)	(0.0731)	(0.0251)	(0.0234)
Treat1		1.7882***		0.0120		1.4968***		0.2287***
×postTreat		(0.3842)		(0.1114)		(0.0703)		(0.0225)
Treat2		1.8568***		0.0418		0.2482***		0.0012
×postTreat		(0.3670)		(0.1064)		(0.0732)		(0.0234)
postTreat		-2.3748***		-0.3070***		-1.4124***		-0.5674***
		(0.2890)		(0.0838)		(0.0538)		(0.0172)
Observations	322,328	569,696	322,328	569,696	1,193,680	2,109,760	1,193,680	2,109,760

Notes: ***p<0.001; **p<0.01; *p<0.05.

Forward-looking Hidden Markov Model (FHMM)

Input: decision sequence, observed content features
Output: engagement stage, consumer preference



Heterogeneous Treatment Effects

Table 7 **Estimated Transition Matrix of Engagement Stages**

$f(e' e, \bar{CF}, SP)$		$e' = 1$ (aware)	$e' = 2$ (exploring)	$e' = 3$ (active)	$e' = 4$ (addicted)
Control: without promotion	$e = 1$	0.9993	0.0002	0.0005	0.0000
	$e = 2$	0.9771	0.0024	0.0080	0.0125
	$e = 3$	0.6677	0.0071	0.2645	0.0607
	$e = 4$	0.3429	0.1773	0.2580	0.2218
Treatment 1: price promotion	$e = 1$	1.0000	0.0000	0.0000	0.0000
	$e = 2$	0.7685	0.0875	0.0040	0.1400
	$e = 3$	0.2847	0.7122	0.0018	0.0013
	$e = 4$	0.1195	0.0565	0.2234	0.6007
Treatment 2: free- content promotion	$e = 1$	0.9997	0.0003	0.0000	0.0000
	$e = 2$	0.5326	0.3053	0.0428	0.1194
	$e = 3$	0.2901	0.0286	0.1259	0.5554
	$e = 4$	0.1925	0.1249	0.3819	0.2965

Heterogeneous Treatment Effects

Table 8 Field Experiment Analysis by Segment

Engagement Stage	Without post-treatment period				With post-treatment period			
	$e = 1$	$e = 2$	$e = 3$	$e = 4$	$e = 1$	$e = 2$	$e = 3$	$e = 4$
Treat1	1.9754*	2.8907	2.6116	6.7371*	1.9832*	2.8562	2.7984	6.2227*
×Test	(1.0115)	(4.1255)	(5.9846)	(3.2803)	(1.0090)	(3.9856)	(5.5721)	(3.2435)
Treat2	1.0968*	4.0066	4.0339	7.7964*	1.2421	3.8507	4.1725	7.0252*
×Test	(1.0529)	(4.0760)	(5.9526)	(3.3015)	(1.0609)	(3.9359)	(5.5356)	(3.2553)
Test	-1.4397**	4.4666	-5.0889	-7.5515**	-1.5865**	-4.2040	-5.5133	-7.3530**
	(0.6057)	(3.9705)	(5.8600)	(3.1431)	(0.6123)	(3.8276)	(5.4367)	(3.1033)
Treat1					2.9279*	4.4983	-0.6426	1.6779
×postTreat					(1.2983)	(4.9389)	(2.8639)	(2.0801)
Treat2					3.4285**	5.56678	-0.8956	2.0980
×postTreat					(1.1628)	(4.9058)	(2.8279)	(2.1053)
postTreat					-3.0413***	-4.4841	-2.3989	-1.7587
					(0.6813)	(4.8072)	(2.6000)	(1.8171)
Observations	158,928	56,330	58,265	54,524	280,896	99,560	102,980	96,368

Targeting-Strategy Design

Baseline: mass promotion

Experience-based
personalized

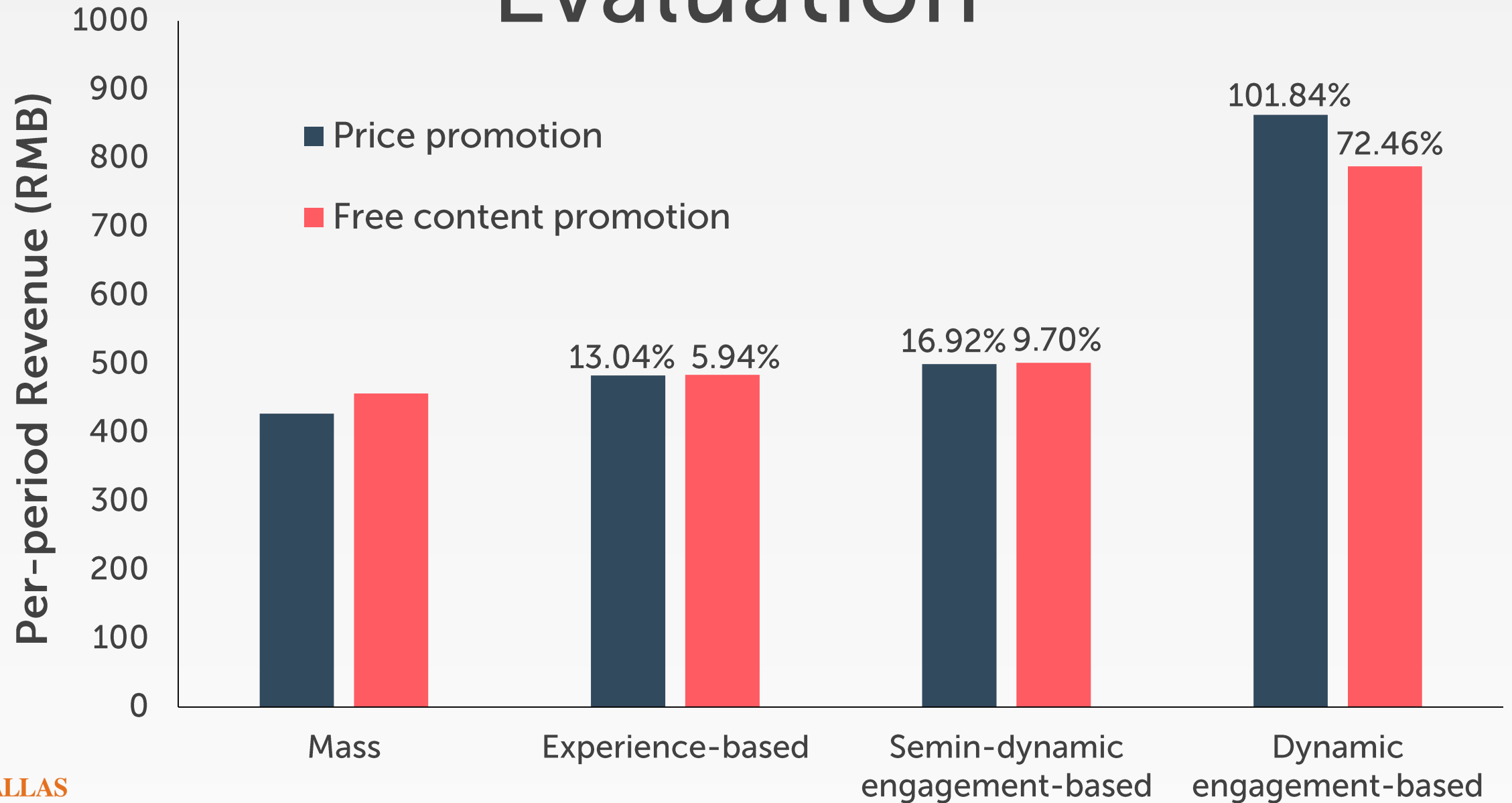
K-means-based

Myopic-HMM-based

Semi-dynamic
engagement-based

Dynamic
engagement-based

Evaluation



Contributions

- Methodological contributions



A structural model: FHMM

A randomized field experiment

A methodology combination

- Managerial contributions



An effective approach of personalizing
the interventions based on FHMM

Thank You Q&A