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

Yingjie Zhang

University of Texas at Dallas

Beibei Li, Xueming Luo, and Xiaoyi Wang

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.
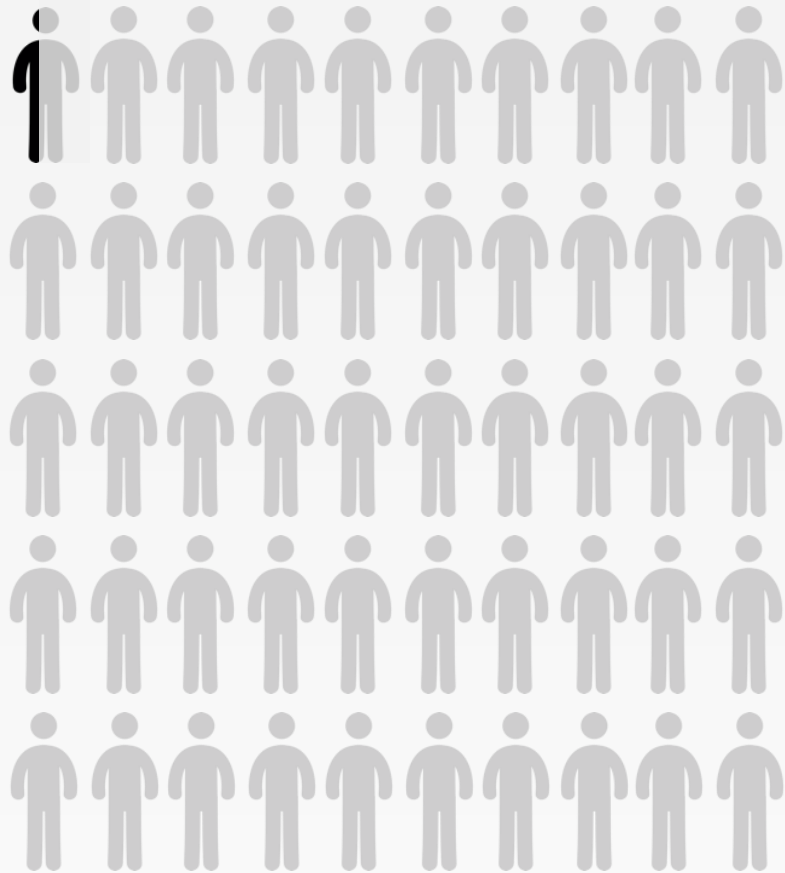
Facebook 3m ago

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!

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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?

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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)

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3-Step Research Design

- Step 1: Randomized field experiment
  $\rightarrow$ average causal effects of different promotions

- Step 2: FHMM
  $\rightarrow$ detection of user engagement using tapstream data
  $\rightarrow$ heterogeneous treatment effects

- Step 3: Simulation
  $\rightarrow$ 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	7/2 16:25							4115294	第一一六章 基	1
1087	/4/2 9:30	386299128	红河边的花腰	26	社科	4	包月	386299271	第二节村落空	1
2398	8/6/20 19	390 2883	范古红吃天地	42	生活	0	免费	390053884	第1章 给全家	0

user ID, time stamp, content information, payment option

Overall Treatment Effect
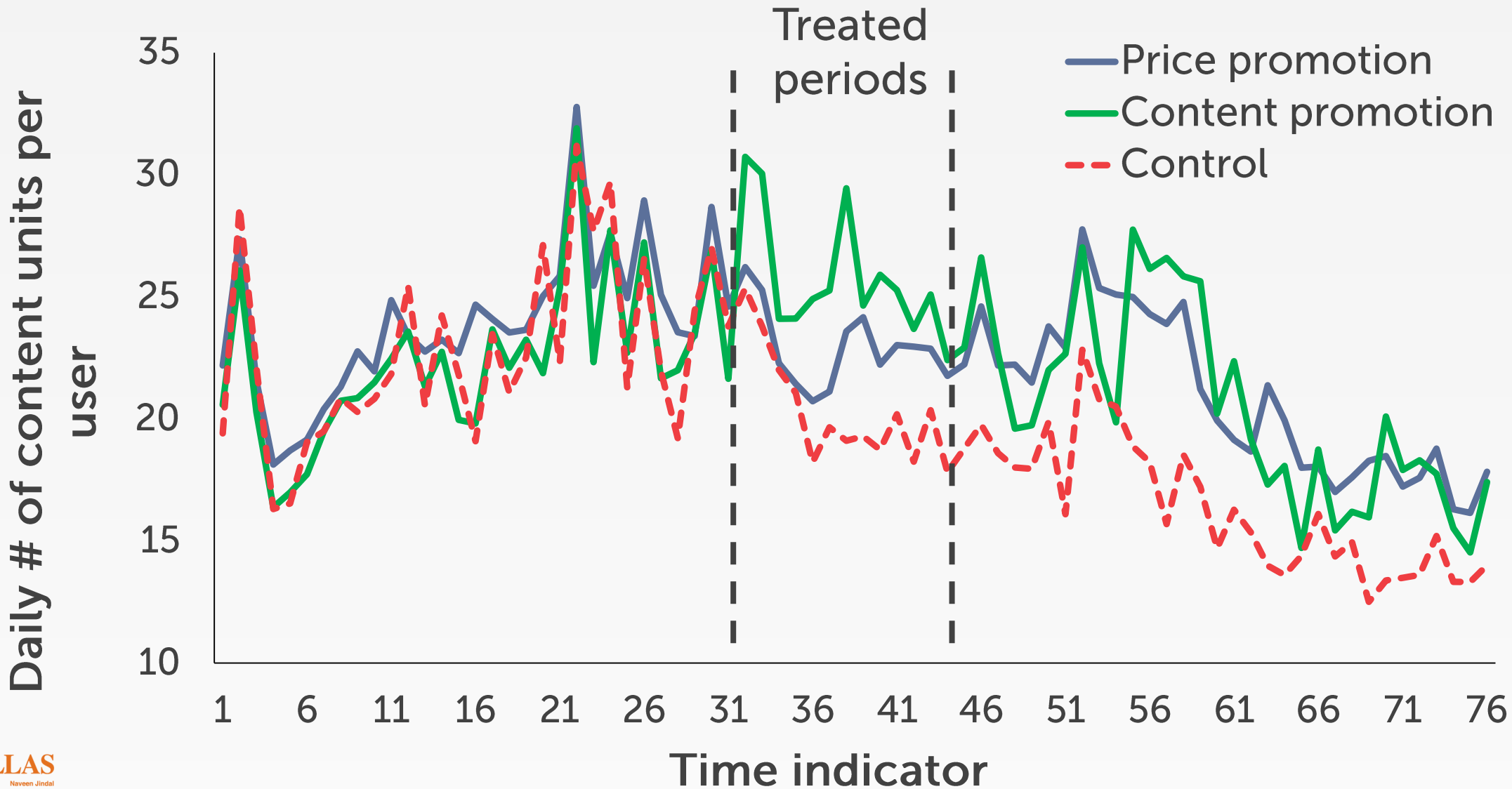
Average Treatment Effects

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

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
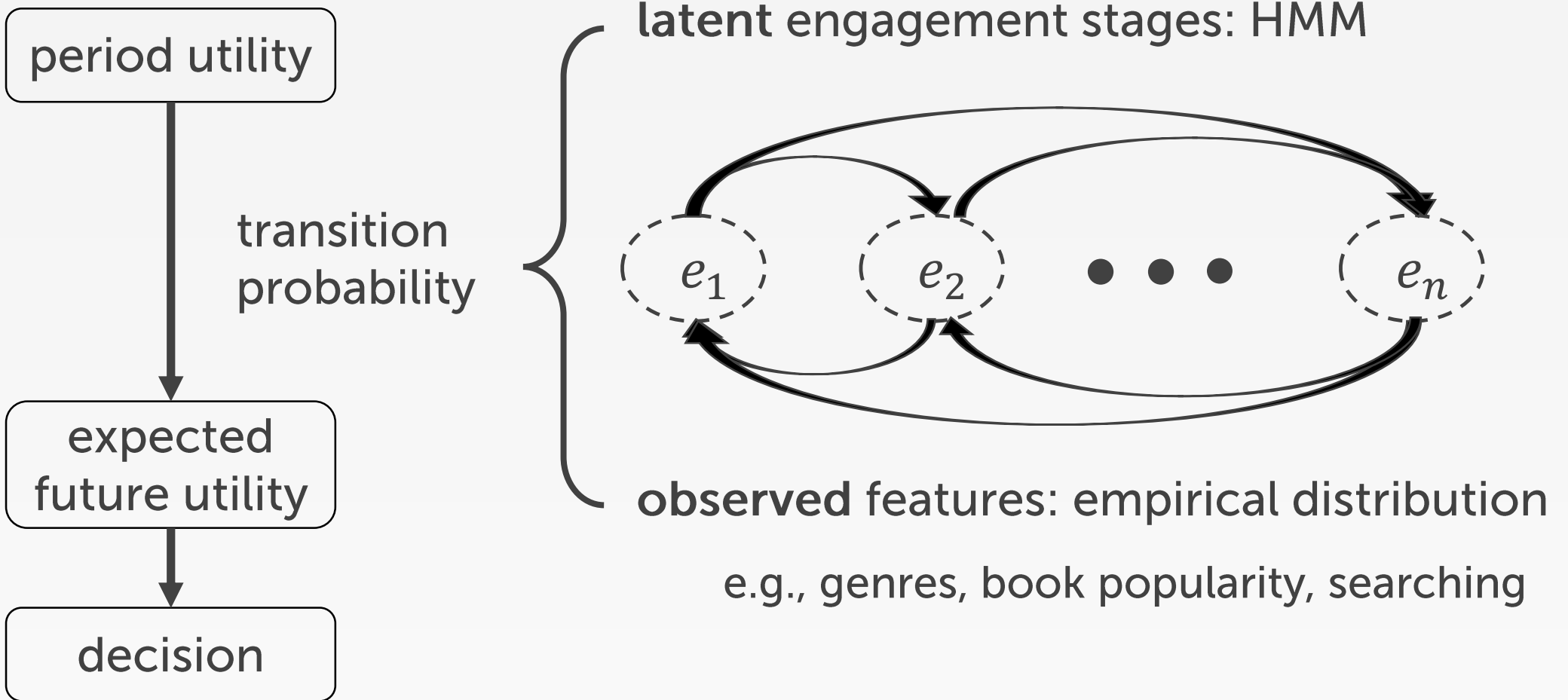
Heterogeneous Treatment Effects

Table 7	Estimated Transition Matrix of Engagement Stages			
$f(e'\|e, \bar{CF}, \bar{SP})$	$e' = 1$ (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 ×Test	1.9754* (1.0115)	2.8907 (4.1255)	2.6116 (5.9846)	6.7371* (3.2803)	1.9832* (1.0090)	2.8562 (3.9856)	2.7984 (5.5721)	6.2227* (3.2435)
Treat2 ×Test	1.0968* (1.0529)	4.0066 (4.0760)	4.0339 (5.9526)	7.7964* (3.3015)	1.2421 (1.0609)	3.8507 (3.9359)	4.1725 (5.5356)	7.0252* (3.2553)
Test	-1.4397** (0.6057)	4.4666 (3.9705)	-5.0889 (5.8600)	-7.5515** (3.1431)	-1.5865** (0.6123)	-4.2040 (3.8276)	-5.5133 (5.4367)	-7.3530** (3.1033)
Treat1 ×postTreat					2.9279* (1.2983)	4.4983 (4.9389)	-0.6426 (2.8639)	1.6779 (2.0801)
Treat2 ×postTreat					3.4285** (1.1628)	5.56678 (4.9058)	-0.8956 (2.8279)	2.0980 (2.1053)
postTreat					-3.0413*** (0.6813)	-4.4841 (4.8072)	-2.3989 (2.6000)	-1.7587 (1.8171)
Observations	158,928	56,330	58,265	54,524	280,896	99,560	102,980	96,368

Targeting-Strategy Design

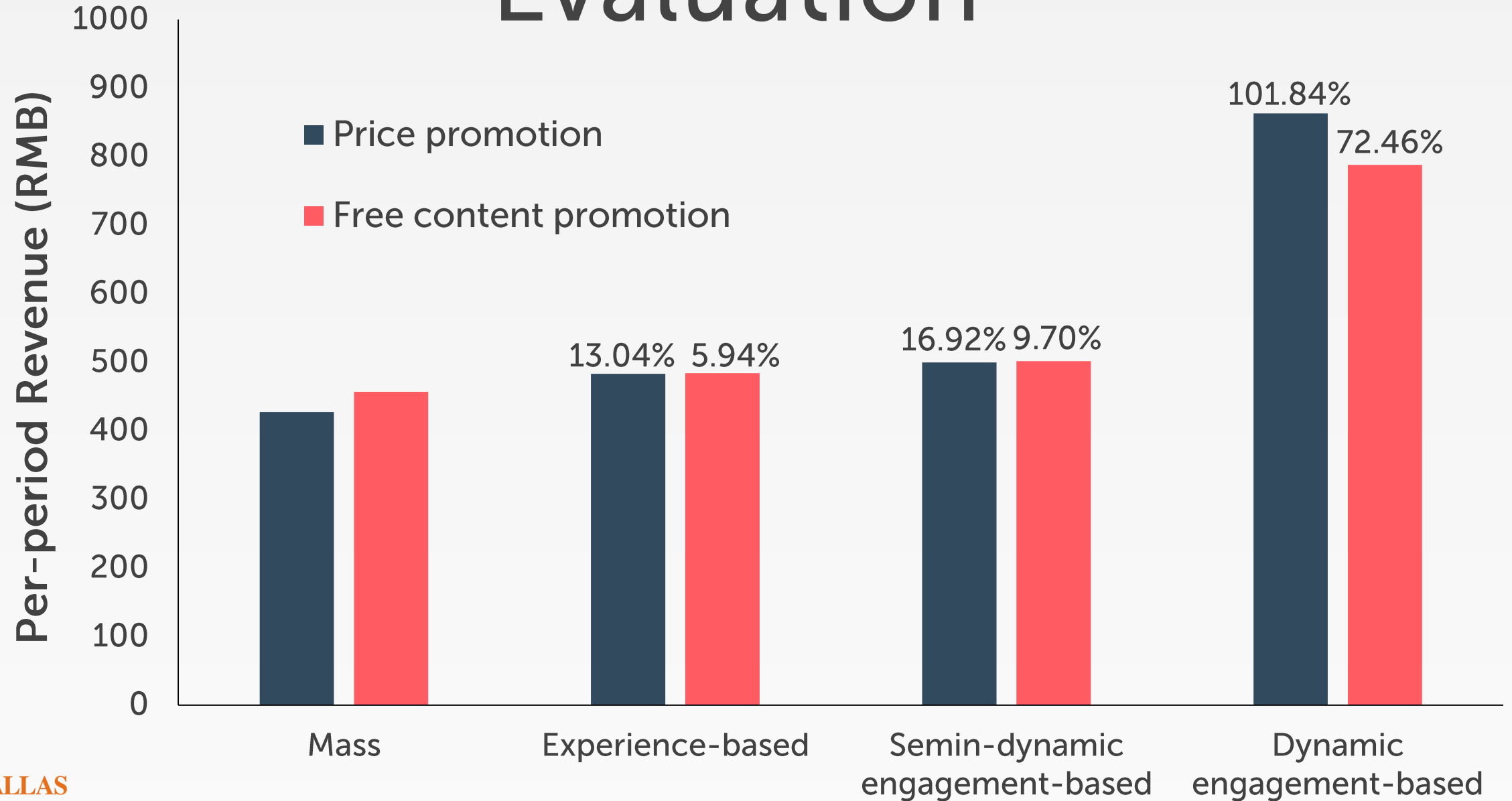**Baseline: mass promotion**

Experience-based personalized

Semi-dynamic engagement-based

K-means-based

Dynamic engagement-based

Myopic-HMM-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