

Supplementary Appendix

Supplement to: “Evaluating the Impact of a Game (Inner Dragon) on User Engagement Within a Leading Smartphone App for Smoking Cessation: A Randomized Controlled Trial.”

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Table S1. Descriptive statistics with test of the difference in means by arm

	Mean		Difference in means	P-value
	Control (n = 238)	Treated (n = 241)		
Panel A. Demographics				
Age, in years	37.4	38.5	1.0	0.32
Gender, %				
Female	76.1	73.4	-2.6	0.51
Male	23.1	24.5	1.4	0.73
Non-binary/other	0.8	2.1	1.2	0.26
Race and ethnicity, %				
Non-Hispanic White	76.5	77.2	0.7	0.85
Non-Hispanic Black	10.9	9.1	-1.8	0.51
Hispanic	3.8	7.9	4.1	0.06
Other	8.8	5.8	-3.0	0.21
Household income, %				
Less than \$20,000	14.7	14.5	-0.2	0.95
Between \$20,000 and \$40,000	27.3	26.1	-1.2	0.77
Between 40,000 and \$60,000	21.4	21.2	-0.3	0.94
Between 60,000 and \$80,000	10.1	13.3	3.2	0.28
Between 80,000 and \$100,000	7.6	8.7	1.2	0.65
More than \$100,000	18.9	16.2	-2.7	0.43
Education, %				
High school diploma or less	23.1	18.7	-4.4	0.23
Some college or technical school	35.3	38.6	3.3	0.46
Bachelor's or associate degree	28.6	34.4	5.9	0.17
Graduate degree	13.0	8.3	-4.7	0.09
Panel B. Smoking characteristics				
Cigarettes per day	15.3	15.8	0.5	0.47
Fagerström Test	4.9	5.2	0.3	0.20
Past quit attempts	6.5	6.7	0.2	0.82
Years since initiated	19.5	20.6	1.0	0.35
Used ENDS in last 30 days, %	25.6	23.7	-2.0	0.62
Used NRT in last 30 days, %	18.1	23.2	5.2	0.16
Panel C. Other				
Frequency played video games, %				
Not at all	24.8	23.7	-1.1	0.77
Less than once a month	10.5	14.9	4.4	0.15
At least monthly but not weekly	10.5	10.8	0.3	0.92
At least weekly but not every day	16.8	20.3	3.5	0.32
Every day	37.4	30.3	-7.1	0.10

Note: The p-value is from a *t*-test of the difference in means.

Table S2. Descriptive statistics for game feature use

Game feature	Mean (SD)	Median (IQR)
Breathing exercise	3.6 (8.2)	1 (0-4)
Cleaned dragon	4.8 (10.4)	1 (0-5)
Fed dragon	4.9 (10.6)	1 (0-5)
Memory minigame	2.5 (4.9)	1 (0-3)
Customization changes	2.4 (4.4)	1 (0-2)
Opened guide	7.7 (12.5)	3 (1-8)
Visited Dragon Park	3.0 (4.7)	1 (0-4)
Gifts received	4.7 (7.7)	1 (0-6)
Read user profiles	2.2 (4.1)	1 (0-2)
Sent messages	0.9 (2.5)	0 (0-1)
Times awarded experience points	45.2 (104.8)	9 (0-43)

Note: Inner Dragon game features were available to those in the treated group only.

Table S3. Covariate-adjusted differences in outcomes by study group

	Coef.	95% CI	p-value	N
<i>Panel A. User engagement</i>				
No. app sessions	4.57	(-2.18,11.31)	0.18	479
Minutes per session	0.83	(-0.19, 1.85)	0.11	479
No. days with a session	2.15	(-0.44, 4.74)	0.10	479
Index of core feature use	6.60	(-0.39,13.59)	0.06	479
Use of core features				
No. cravings reported	0.85	(0.02, 1.69)	0.05	479
No. diary entries	2.72	(0.07, 5.36)	0.04	479
No. missions completed	0.97	(-0.77, 2.71)	0.28	479
No. chatbot sessions	1.42	(-0.53, 3.38)	0.15	479
<i>Panel B. Point-prevalence abstinence</i>				
7-day point-prevalence abstinence at 2 months, in pp				
Self-reported, missing = smoking	-2.36	(-11.09, 6.38)	0.60	479
Self-reported, complete cases	-12.40	(-22.68, -2.11)	0.02	292
Verified, missing = smoking	-2.71	(-10.01, 4.60)	0.47	479
Verified, complete cases	-7.20	(-21.81, 7.40)	0.33	128
30-day point-prevalence abstinence at 2 months, in pp				
Self-reported, missing = smoking	1.44	(-5.97, 8.85)	0.70	479
Self-reported, complete cases	-2.51	(-13.40, 8.38)	0.65	292
Mean repeated 1-day abstinence, in pp				
Self-reported, missing = smoking	4.45	(0.18, 8.72)	0.04	4.45
Self-reported, complete cases	10.06	(1.58,18.54)	0.02	10.06
<i>Panel C. Satisfaction and motivation</i>				
Satisfaction with app	0.04	(-0.22, 0.31)	0.75	271
Recommend app to friends	-0.12	(-0.38, 0.15)	0.39	271
Motivation to (stay) quit	-0.12	(-0.64, 0.39)	0.63	144
Digital therapeutic alliance index	-0.11	(-0.68, 0.47)	0.71	268

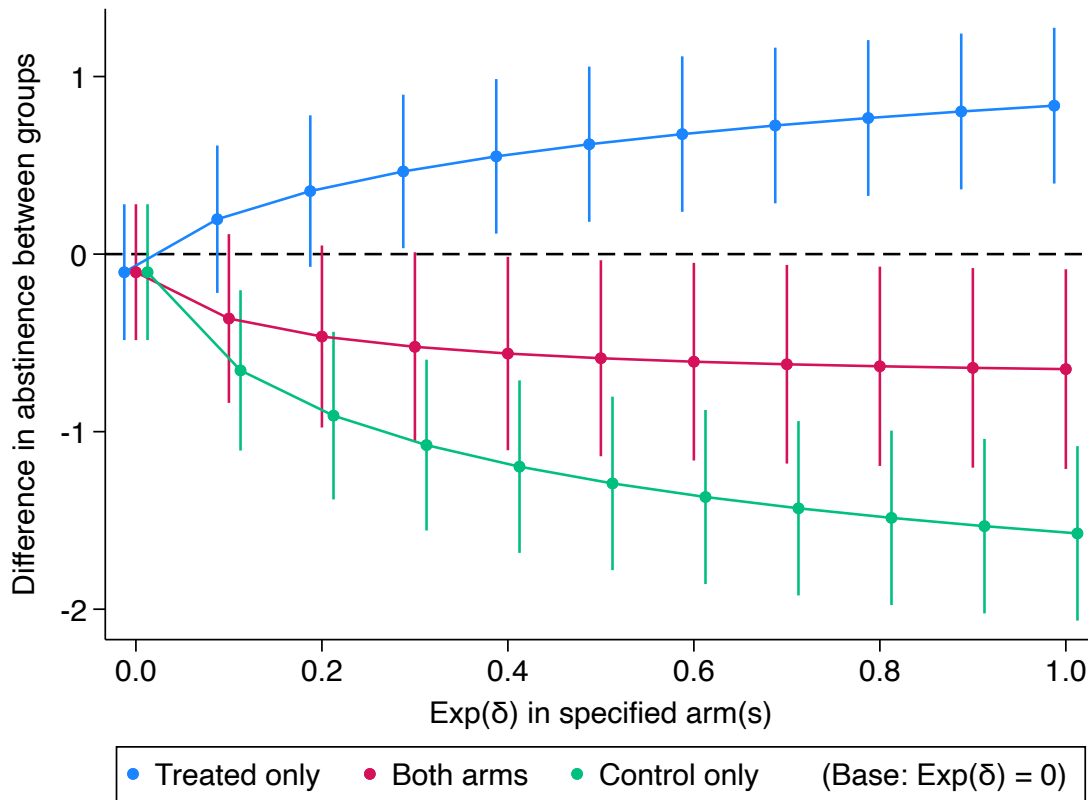
Note: The coefficient denotes the difference between the treated and control groups. Regressions are adjusted for the demographic, smoking history, and gaming experience characteristics listed in Table 1. Linear regressions are used for continuous outcomes and logistic regressions, with coefficients expressed as risk differences, for binary outcomes.

Table S4. Intent-to-treat abstinence estimates reported in previous RCTs of app-based smoking cessation interventions with follow-up of 1 to 3 months

	First author	Year	Treated arm	Control arm	No. Treated	No. Control	N	Type	Abstin. period, days	Follow-up, mos.	No. Abstain, Treated	No. Abstain, Control	Abst. %, T	Abst. %, C	ITT Effect
1	Baskerville [1]	2018	Crush the Crave	Self-help guide	820	779	1599	Self-report	7	3	105	107	12.8%	13.7%	-0.9
2	BinDhim [2]	2018	SSC App	Info-only app	342	342	684	Self-report	90	3	59	27	17.3%	7.9%	9.4
3	Bricker [3]	2014	SmartQuit	QuitGuide	98	98	196	Self-report	30	2	10	7	10.2%	7.1%	3.1
4	Bricker [4]	2020	ICanQuit	QuitGuide	1214	1201	2415	Self-report	7	3	285	168	23.5%	14.0%	9.5
5	Crane [5]	2019	Smoke Free - full	Smoke Free - lite	14228	13884	28112	Self-report	90	3	234	124	1.6%	0.9%	0.8
6	Goldenhersch [6]	2020	Mindcotine	Peer-to-peer support	60	60	120	Self-report	1	3	14	3	23.3%	5.0%	18.3
7	Herbec [7]	2019	NRT2Quit - full	NRT2Quit - minimal	16	25	41	Saliva	28	2	4	2	25.0%	8.0%	17.0
8	Hertzberg [8]	2013	mCM	Non-contingent CM	11	11	22	CO	7	1	9	5	81.8%	45.5%	36.4
9	Jackson [9]	2023	Smoke Free	None	1564	1579	3143	Self-report	90	3	45	54	2.9%	3.4%	-0.5
10	Krebs [10]	2019	QuitIT game	Telecounsel., Rx	18	20	38	CO	7	1	4	2	22.2%	10.0%	12.2
11	Krishnan [11]	2019	COach2Quit	Brief advice	50	52	102	CO	7	1	9	2	18.0%	3.8%	14.2
12	Masaki [12]	2020	CureApp + CO checker	CureApp - reduced	285	287	572	CO	90	3	215	190	75.4%	66.2%	10.8
13	Pallejà-Millán [13]	2020	Tobbstop	Information	284	318	602	Self-report	90	3	72	13	25.4%	4.1%	21.3
14	Webb [14]	2020	Quit Genius	Brief advice	265	265	530	Self-report	7	1	118	75	44.5%	28.3%	16.2

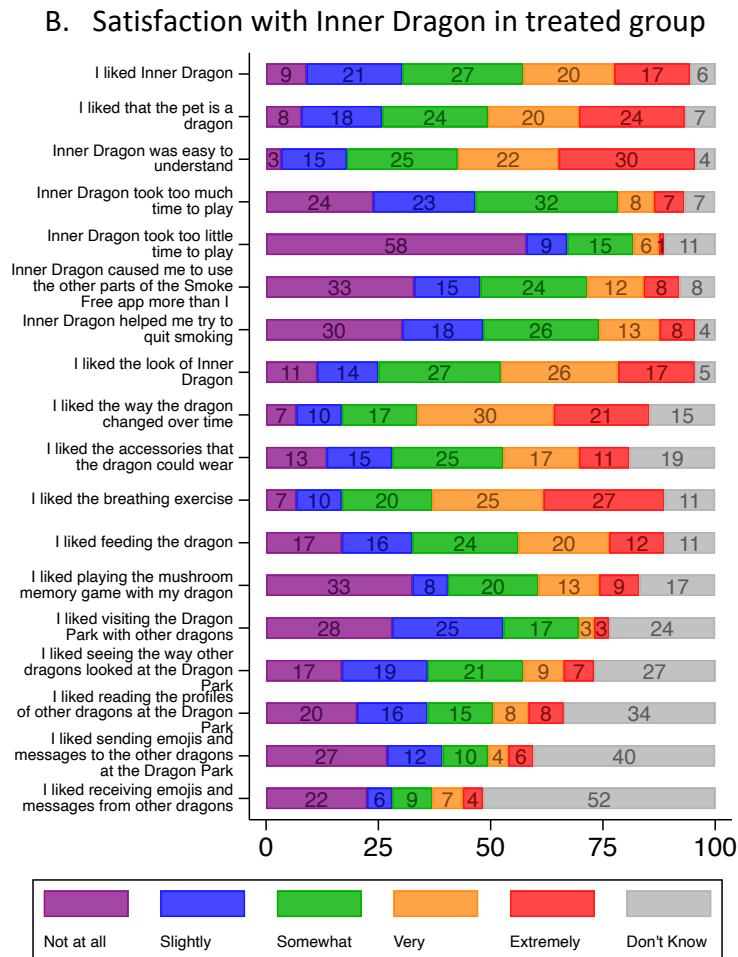
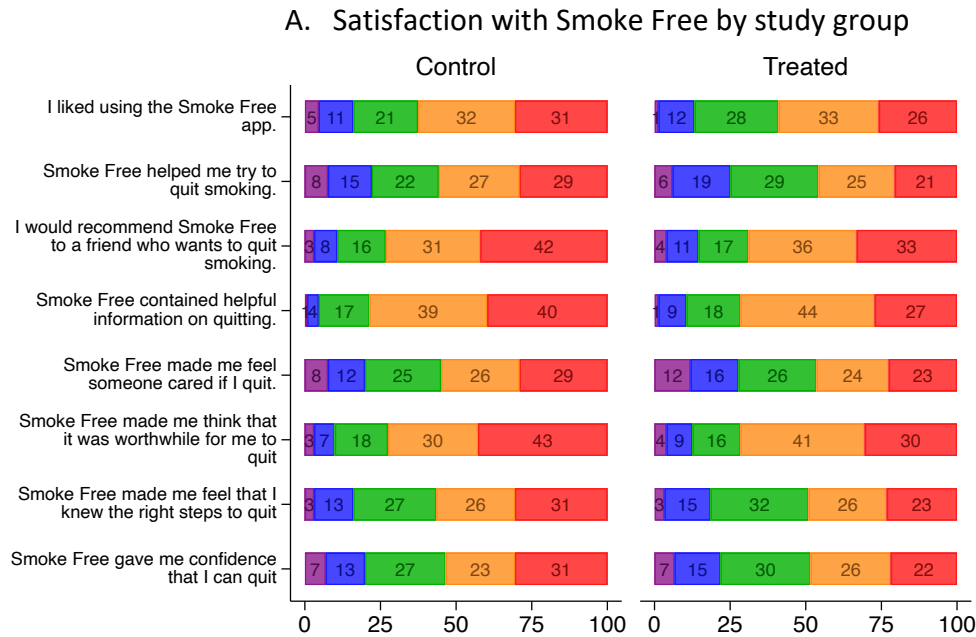
Note: This table summarizes RCTs of app-based smoking cessation interventions. Studies were identified through prior systematic reviews and meta-analyses [15-22], online searches of studies citing those articles, and knowledge of the authors. Sample sizes, number and percent abstaining by arm, and intent-to-treat effect were calculated by the authors, when not directly reported.

Figure S1. Sensitivity of changes in abstinence to assumptions about missingness using pattern mixture model



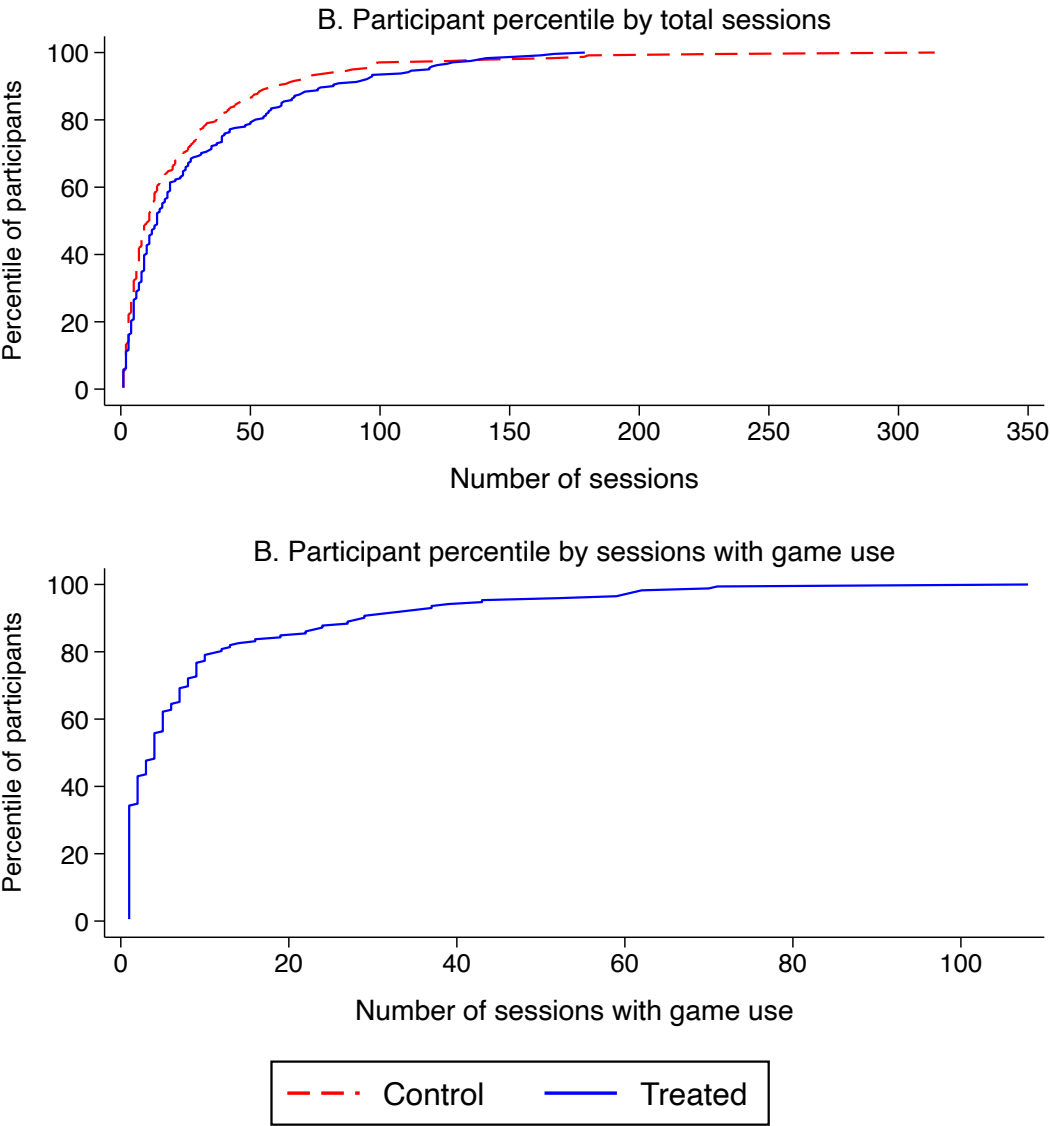
Note: This figure shows the estimated treatment effect (equal to treated group minus control group) for self-reported 7-day point-prevalence abstinence from a pattern-mixture model that varies the informative missingness odds ratio ($\exp(\delta)$), or IMOR. Following the procedure by White et al. (2011, *BMJ*), the IMOR is the odds ratio between the outcome and an indicator for missingness, adjusting for covariates. The base value of $\exp(\delta)$ of 0 corresponds to missingness at random, equivalent to an assumption of missing = smoking. The data series in blue varies $\exp(\delta)$ for individuals in the treated group while assuming $\exp(\delta) = 0$ for the control group. The data series in green varies $\exp(\delta)$ for individuals in the control group while assuming $\exp(\delta) = 0$ for the treated group. The data series in red varies $\exp(\delta)$ for all individuals in both groups.

Figure S2. Satisfaction with Smoke Free by study group



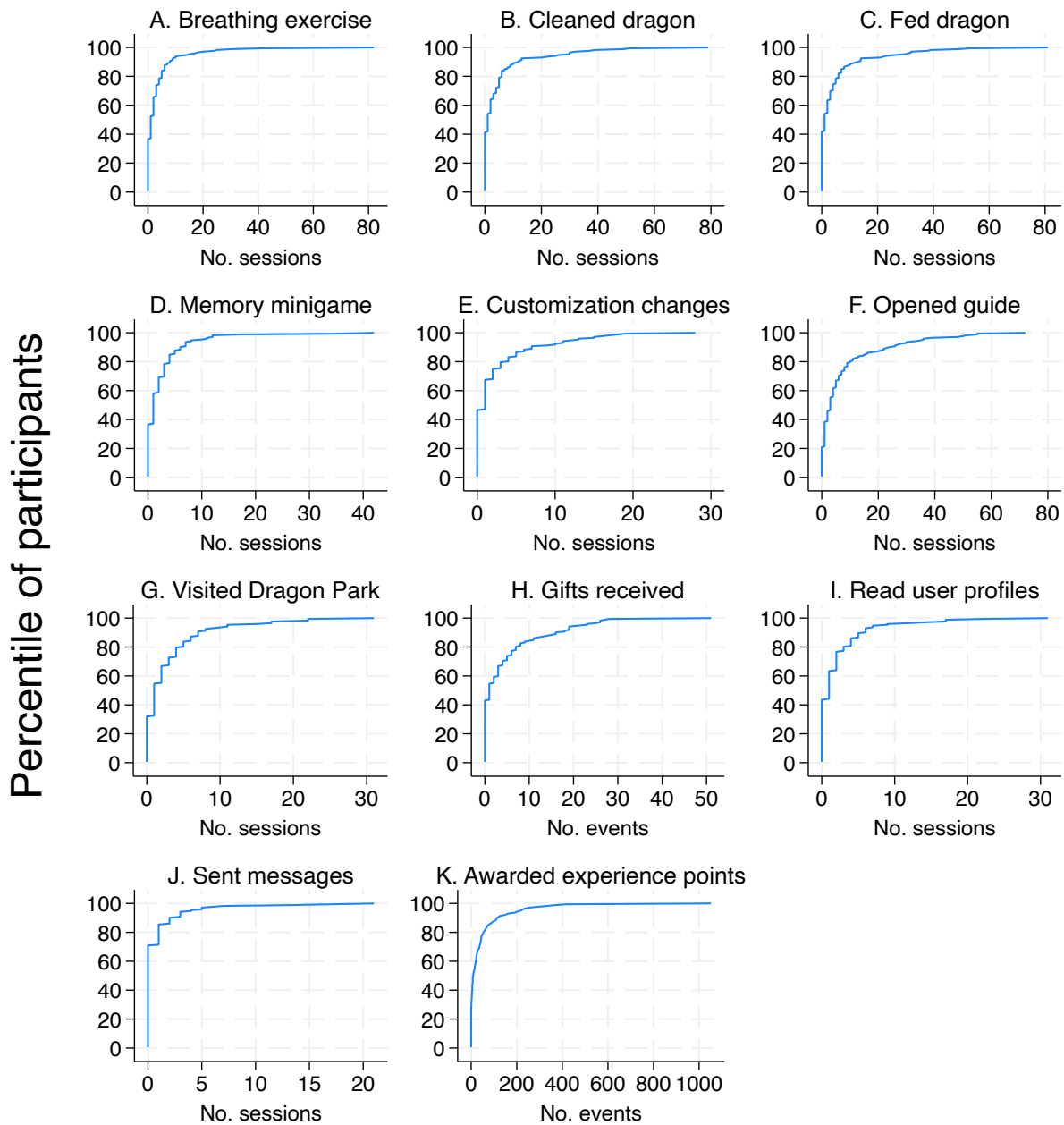
Note: Inset labels indicate the percentage of participants selecting that option.

Figure S3. Cumulative distribution of the number of total sessions and sessions with game use



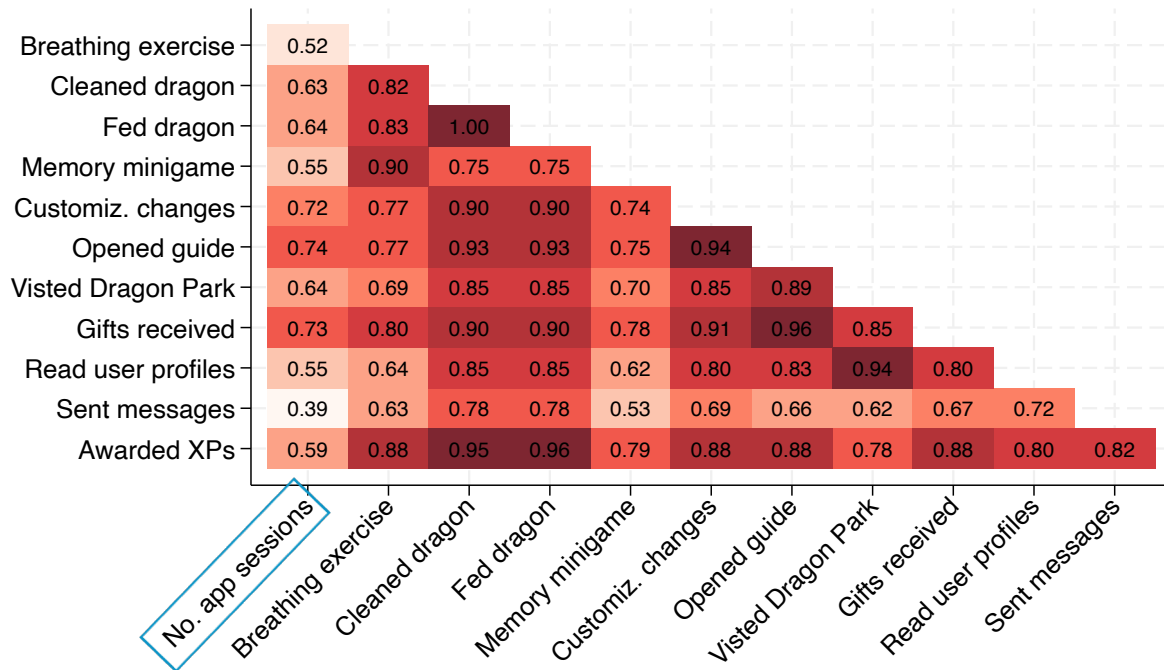
Note: Panel A shows the cumulative distribution function of the total number of sessions. Panel B shows the number of sessions with game use (treated group only). For example, in Panel A, the 75th percentile of treated participants had 39 sessions, and the 75th percentile of control participants had 30 sessions.

Figure S4. Distribution of game feature use



Note: Each panel shows the cumulative distribution function of the total number of sessions (Panel A-G, I-J) or total number of events (Panels H and K) with different types of game events. For example, in Panel A, the 75th percentile of treated participants had 4 sessions in which the user completed a breathing exercise.

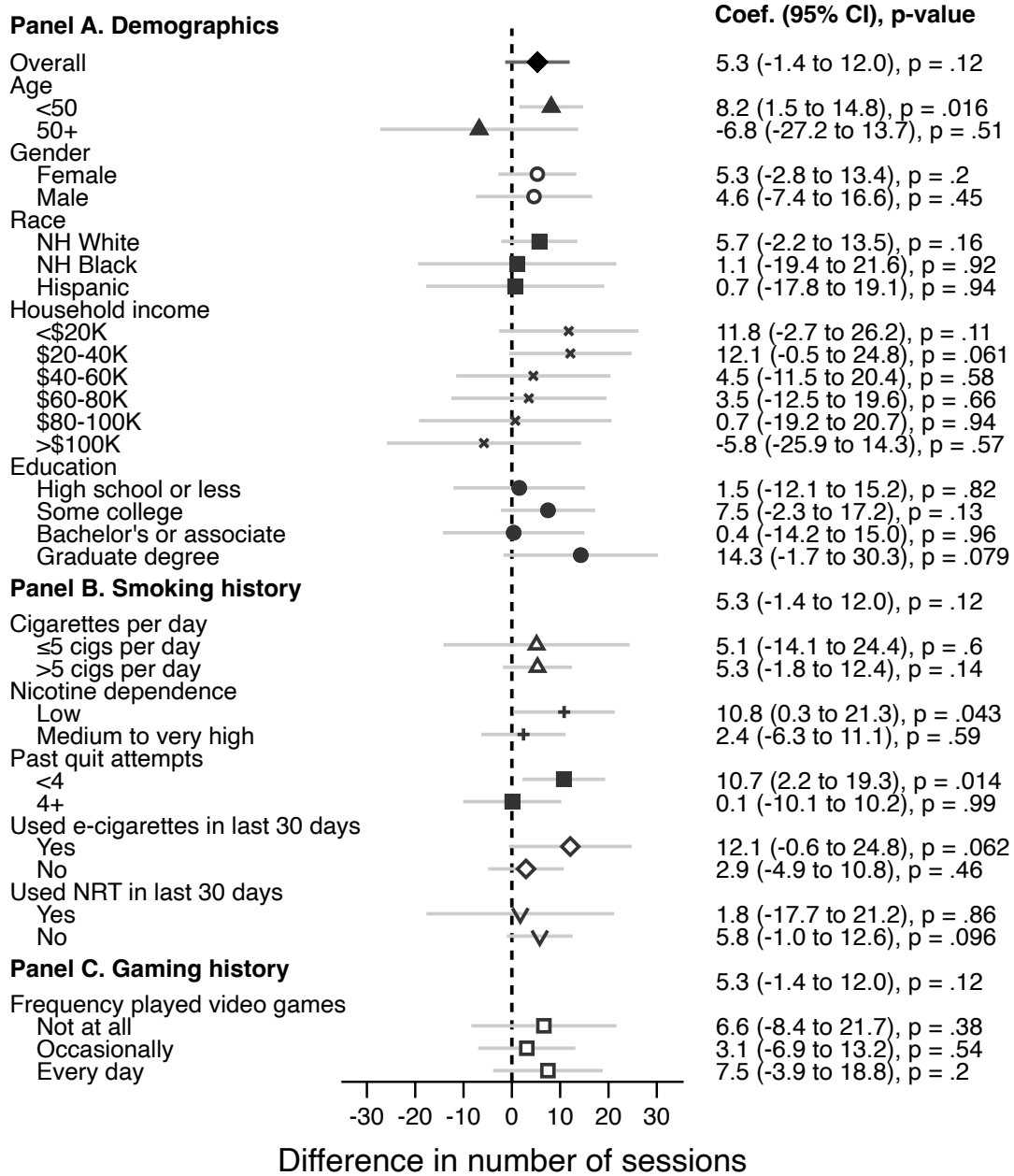
Figure S5. Correlation between total number of app sessions and Inner Dragon features



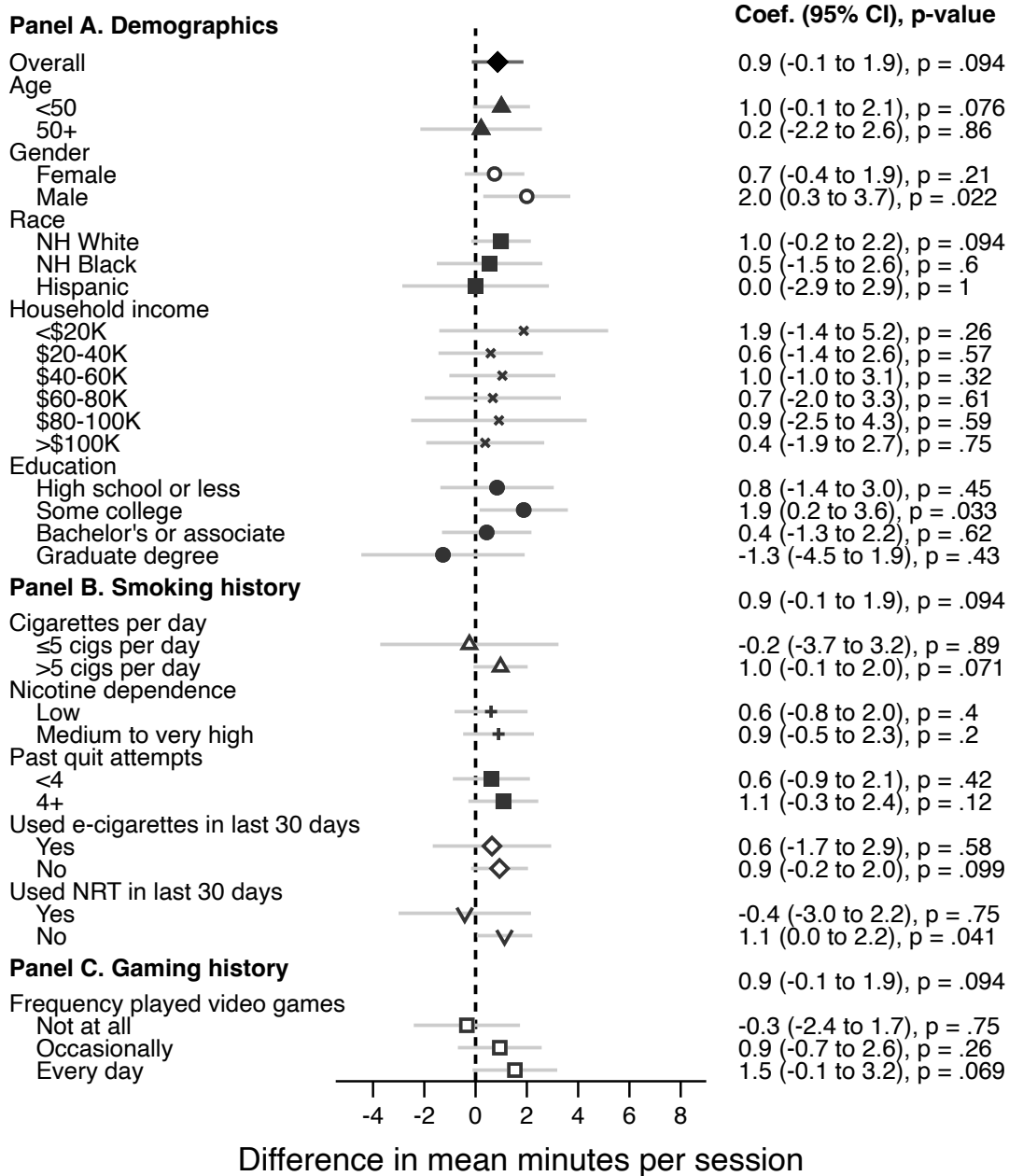
Note: This figure shows a heatmap of the pairwise correlation matrix between total number of app sessions (the primary user engagement outcome), inscribed in the blue box, and selected features of the Inner Dragon game module. The figure shows a moderate (correlation 0.4 to 0.6) or strong (0.6 to 0.8) positive association between most game features and total number of app sessions, as well as a strong or very strong (0.8 to 1.0) positive association between the features with each other. All correlation coefficients are statistically significant at the 0.01 level.

Figure S6. Subgroup estimates of differences in primary outcomes by study group

A. Difference in sessions per user by study group



B. Difference in mean minutes per session by study group



Note: Each figure is based on a series of unadjusted stratified regressions in which each row shows the treatment effect from a single regression. The row with the “overall” estimates corresponds to the estimate for the full sample.

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