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Incentivized personal carbon scores lower the carbon intensity of urban mobility and spill over to pro-science climate attitudes

Research team:

NUS (including Research Assistants)

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Land Transport Authority

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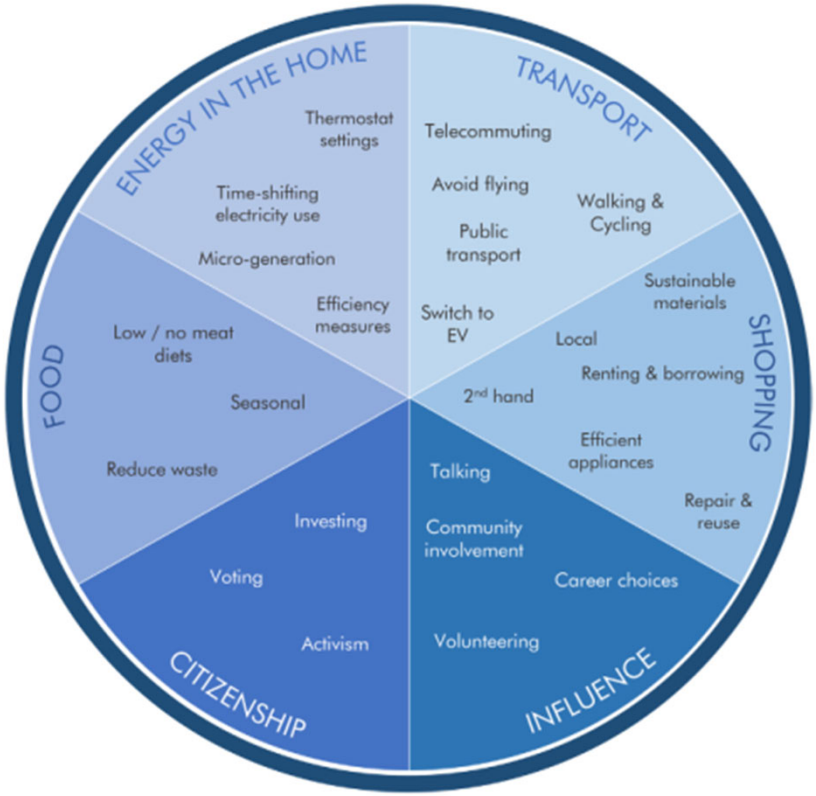
Funding: IPUR Seed Grant, FASS Dean's Chair Award, Economics Untied Academic Grant

Motivation

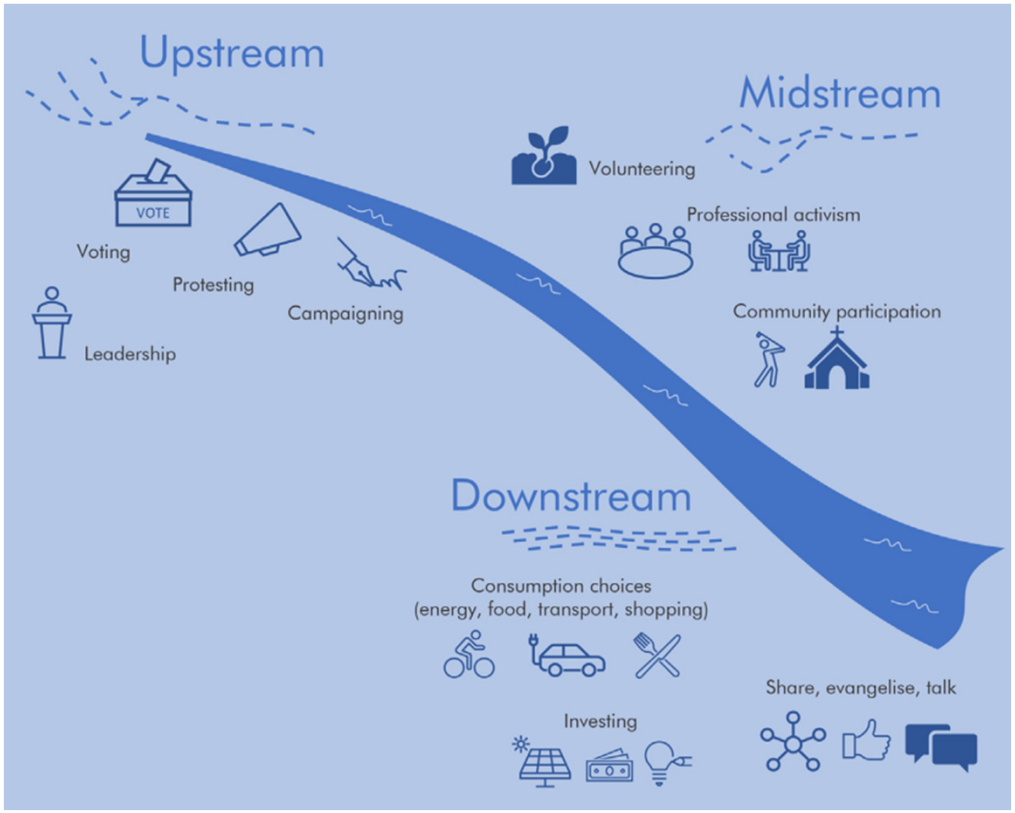


- How to raise the public's engagement with the climate crisis?
- Globally, some political leaders seem timid given the scale of the problem: Public acceptance matters
- Nations and businesses are trying to move away from BAU
- Very little (open) talk of individuals moving away from BAU
- Can positive & hopeful messaging and rewards in one specific consumption domain spill over to climate change attitudes?
- Are individuals accepting of personal carbon scoring (privately)?
  - Atmospheric carbon is the new currency in town

“A review of the multiple roles individuals play”



“The six domains of choice for climate action” (Hampton and Whitmarsh, 2023)



“The riverine ecology of choice for climate action. A combination of upstream, midstream, and downstream interventions is needed to enable and scale choices for climate action.” (Hampton and Whitmarsh, 2023)

Source: *The Business Times Weekend*, p29
Date: 16 September 2023

Keywords: Personal carbon scores, environmental messaging, gamification, low-carbon rewards, individual agency over climate, open data, fintech, SimplyGo platform

"With this fintech innovation, we would be educating consumers on the carbon footprint of how we choose to get around, and rewarding those who are greening their lifestyles."



Open data could allow for the provision of an "urban travel carbon score" to commuters, who can then adjust their behaviour accordingly. PHOTO: CHERYL ONG, BT

How open data and gamification can make Singapore's urban travel greener

Providing data on the carbon footprint of transport choices can help change commuter behaviour. **By Alberto Salvo and Leonard Lee**

Building blocks in our RCT

- Carbon labeling
- Personal carbon scoring
- Environmental messaging: Multiple co-benefits, from global to local
- Testimonials by peers
- Individual agency: Climate leadership
- Low-carbon rewards

First present these blocks, then show how they come together

(Warm up) Carbon labeling & education

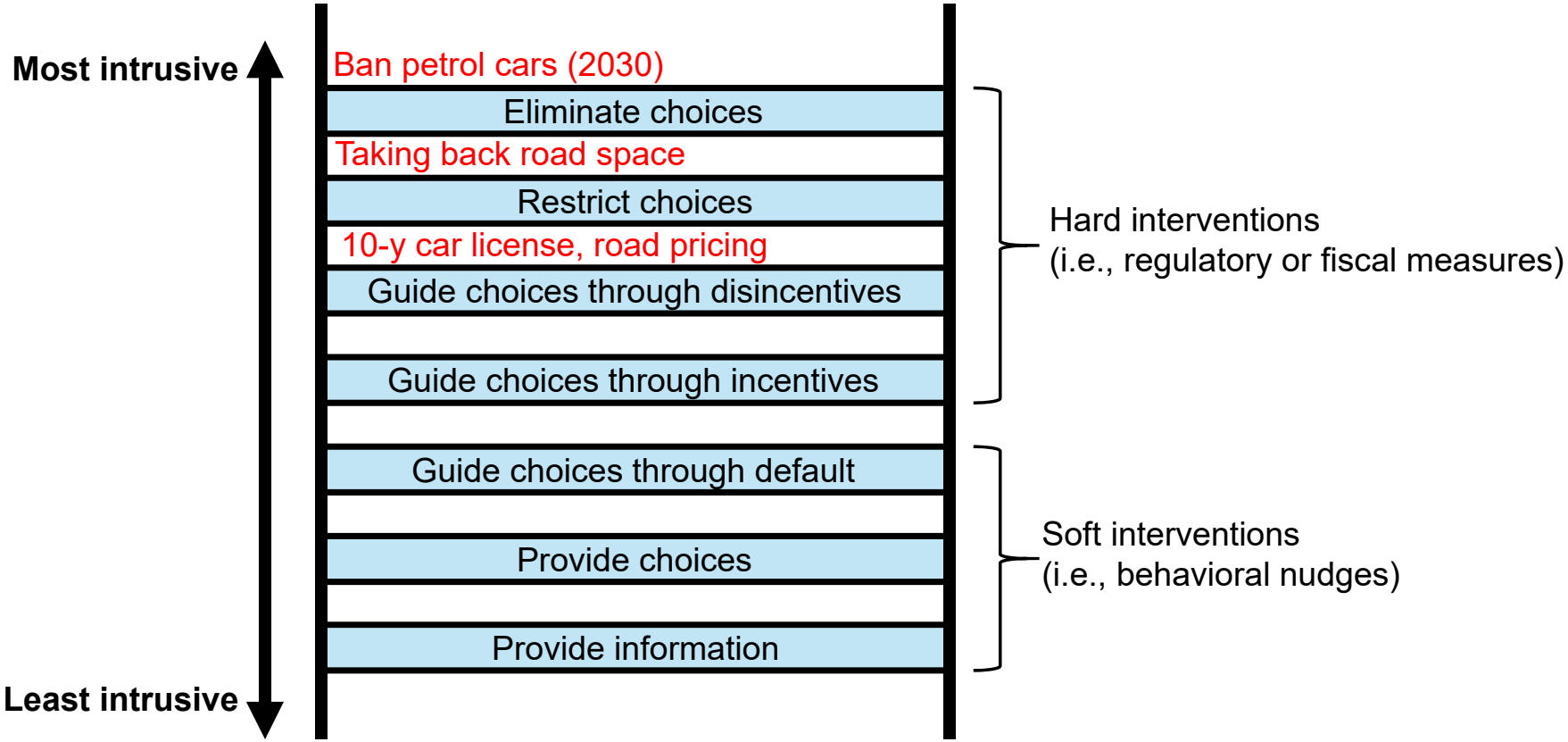
- Examples of personal carbon emissions (lifecycle)
  - Urban travel: A 10-km ride in a mid-size petrol car (Saudi oil)
    - 2 kg CO_2e ¥2.8 = $0.4 climate damage @ Social Cost of Carbon of ~$200/t$CO_2e$)
  - Residential utilities: 10 kWh (a 3-room flat's daily use) (Indonesian gas)
    - 5 kg CO_2e ¥6.4 = $0.9 climate damage
  - Animal protein: 1 kg bone-free beef **(the edible version of coal)**
    - 25 kg CO_2e ¥35 = $5 climate damage
  - Air travel: Economy-class roundtrip Singapore to Beijing **(now in tons!)**
    - 1,200 kg CO_2e ¥1,700 = $240 climate damage
  - And in the business cabin?
    - 3,600 kg CO_2e ¥5,100 = $720 climate damage



The glamour of a high-carbon consumption lifestyle:
Penelope Cruz, Brand Ambassador for Emirates Business Class

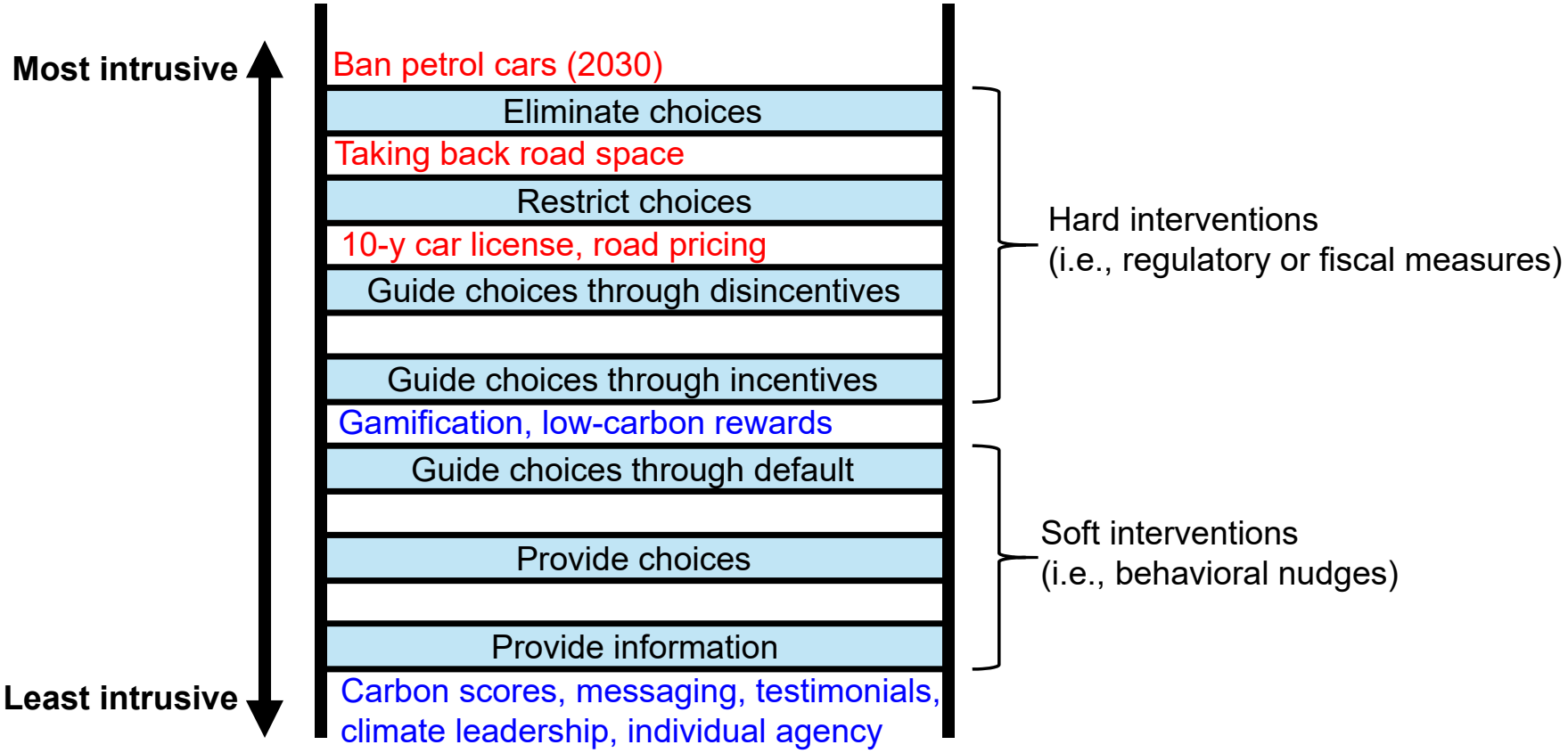
Using carbon scoring and incentives to raise/preserve public transport modal share

Intervention ladder (Nuffield Council on Bioethics, 2007)



Using carbon scoring and incentives to raise/preserve public transport modal share

Intervention ladder (Nuffield Council on Bioethics, 2007)



Today: Our first RCT, with students

Participants: NUS undergraduate students

- Advertised on NUS Student Work Scheme platform, NUS email lists, NUS Telegram channels
  - “Research on consumption patterns of different demographic groups in Singapore”
  - 16-week study from Jan to May 2024 (~120 minutes of participation)
  - Earn between $100-$110

- Maintain an 11-week **personal travel diary**, share transactions from transportation platforms, stay tuned by Telegram/email

- **1017 students expressed interest** in joining the study; we targeted 350 (power calculation)

- We **oversampled among those without cars** in the family
  - The project kicked off in briefing sessions, 340 students attended
  - 59% female, mean age 21y, 57% living off campus, 81% no family car
  - After the briefing, we randomized attendees into a control group and two treatment conditions (balancing tests)

Daily travel diary (barebones)

Week 6: Monday 26 February to Sunday 3 March **Participant:** Yuen Wei Lun

Day of the week	Date	Trip No.	Origin Description	Postal code, address, landmark description	Destination Description	Postal code, address, landmark description	Travel Mode	(For private car rides only) Size of traveling party	Distance on Googlemaps
Monday	26/2/2024	1	Home	688646	School	NUS Kent Ridge campus	Public transport (e.g., M...		17.8 km
		2	School	NUS Kent Ridge campus	Lunch	West Coast Plaza	Walking		3.4 km
		3	Lunch	West Coast Plaza	Shopping	Ion shopping mall	Private car (e.g., taxi, rid...	2	14.3 km
		4	Shopping	Ion shopping mall	Home	488D Choa Chu Kang Avenue 5	Private car (e.g., taxi, rid...	1	20.0 km
		5					(Please select an option)		

Powered by Google Sheets with a Google Maps interface
Trips subsequently verified with transaction reports (transport platforms)

Subjects in control and two treatment groups, weeks 0-11

Building block: Carbon labels

- Our carbon labels: A hierarchy accounting for limited bandwidth
  - (1/1) Car, single rider: 200 g of CO_2 per km
  - (1/2) Car, shared rider: 100 g of CO_2 per km
  - (1/5) Public transport: 40 g of CO_2 per km
- Lifecycle emissions
  - Cars are mainly midsize gasoline
- Average over differences within public transport
  - Train (electric) vs. bus (mostly diesel), varying occupancy
- Focus on motorized mobility
  - In this RCT, we cannot verify walking & cycling transactions from platforms

Building block: Personal carbon scores

Week 6: Monday 26 February to Sunday 3 March **Participant:** Yuen Wei Lun

Friendly note: Remember that fewer car rides are choices that you can take to protect our climate, our rainfall, and our sea level.

Your average carbon score from Wks 6-8 (g of CO2 per km)	Total motorized distance traveled from Wks 6-8 (km)
118	52

Day of the week	Date	Trip No.	Origin Description	Postal code, address, landmark description	Destination Description	Postal code, address, landmark description	Travel Mode	(For private car rides only) Size of traveling party	Average CO2 emissions (g/km) since Week 6 to this trip	Distance on Googlemaps
Monday	26/2/2024	1	Home	688646	School	NUS Kent Ridge campus	Public transport (e.g., M...		40	17.8 km
		2	School	NUS Kent Ridge campus	Lunch	West Coast Plaza	Walking		NA	3.4 km
		3	Lunch	West Coast Plaza	Shopping	Ion shopping mall	Private car (e.g., taxi, rid...	2	67	14.3 km
		4	Shopping	Ion shopping mall	Home	488D Choa Chu Kang Avenue 5	Private car (e.g., taxi, rid...	1	118	20.0 km
		5					(Please select an option)			

Individual choices & carbon labels → Personal carbon scores averaged over 3-week periods
Repeated exposure to carbon quantities

Treatment group 1, weeks 6-8, reset weeks 9-11
Treatment group 2, weeks 3-5, reset weeks 6-8, reset weeks 9-11

Building block: Environmental messaging

- 3 periods × 3 weeks/period × 3 messages/week, cycling over:
- Climate benefits *More car rides, more carbon emissions, a hotter climate, a higher sea level. From one ride to the next, it adds up.*
- Air quality co-benefits *Elevate Your Eco-Game: Swap the car ride for public transport and be a hero in fighting urban pollution.*
- Accident externality *Worried about accidents? Bus and train rides are safer than car rides.*
- Land use *Roads take 12% of Singapore's land, and are mostly taken up by cars. Less car rides means more land for other uses such as housing and parks.*
- Motivation and social influence *Remember that protecting our climate is in our hands. Set the example by taking fewer car rides!*
- Value of time *Riding public transport can be part of an active and busy lifestyle: Walk to transport and catch up with others while riding!*
- Pro-social behavior and sustainability *Show love to others and to the environment. Skip that car ride and take the bus.*
- Government policy *Singapore Green Plan 2030 calls for a car-lite society.*

Treatment groups 1 and 2, weeks 3-11

Building block: Personal goals

- Goal repeated by 3-week period
  - *Let's play! Try to keep your travel carbon score close to 40 grams of CO2 per km and, if not, as low as possible.*
  - *Took too many car rides? That's OK, try harder next time.*

Building block: Testimonials by peers

From: C
Sent: Thursday, 21 March 2024 8:20 pm
To: Salvo, Alberto E Brugarolas <albertosalvo@nus.edu.sg>
Subject: Re: My most recent testimonial and urban mobility carbon score

hi alberto

thank you for letting me participate in this research.

initially i had always been someone who took grab to school, but participating in this programme has made me change my habits, and i now try my best to take public transport. this active change has actually lifted my mood, and i really do enjoy walking and taking the bus now. i believe it is little choices like this that help reinforce a sense of hope that we have some agency over the outcomes of climate change. these emails as well as the little encouraging messages on the google sheets are very appreciated.

A subject in treatment group 2 (with financial incentives from week 6), personal carbon scores of 116 gCO2 per km in week 5 → 56 gCO2 per km in week 8 → 47 gCO2 per km in week 11

Building block: Low-carbon rewards

Week 6: Monday 26 February to Sunday 3 March **Participant:** Yuen Wei Lun

Friendly note: **Remember that fewer car rides are choices that you can take to protect our climate, our rainfall, and our sea level.**

Your average carbon score from Wks 6-8 (g of CO2 per km)	Total motorized distance traveled from Wks 6-8 (km)	To preserve the validity of our research, please do not share details until May. Thank you.
118	52	**Over Wks 6-8, $5 for up to 60 g/km plus $5 for up to 45 g/km**

Day of the week	Date	Trip No.	Origin Description	Postal code, address, landmark description	Destination Description	Postal code, address, landmark description	Travel Mode	(For private car rides only) Size of traveling party	Average CO2 emissions (g/km) since Week 6 to this trip	Distance on Googlemaps
Monday	26/2/2024	1	Home	688646	School	NUS Kent Ridge campus	Public transport (e.g., M...		40	17.8 km
		2	School	NUS Kent Ridge campus	Lunch	West Coast Plaza	Walking		NA	3.4 km
		3	Lunch	West Coast Plaza	Shopping	Ion shopping mall	Private car (e.g., taxi, rid...	2	67	14.3 km
		4	Shopping	Ion shopping mall	Home	488D Choa Chu Kang Avenue 5	Private car (e.g., taxi, rid...	1	118	20.0 km
		5					(Please select an option)			

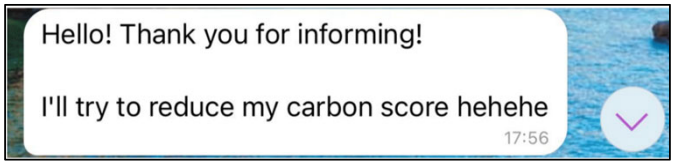
Low-carbon rewards by 3-week period:

$5 for average carbon score ≤ 60 g of CO_2 per km

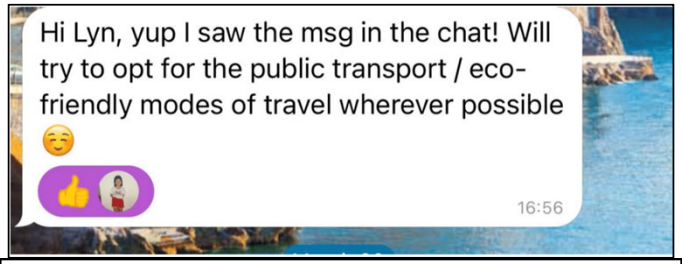
Another $5 for average carbon score ≤ 45 g of CO_2 per km

Treatment group 2, weeks 6-8 & 9-11

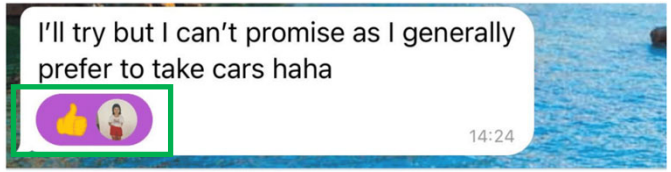
More testimonials from subjects



Lives on campus, family does not own a car
Weeks 3-5: 50 gCO2 per km
Weeks 6-8: 43 gCO2 per km (earned $10 reward)



Lives off campus, family owns a car
Weeks 3-5: 71 gCO2 per km
Weeks 6-8: 65 gCO2 per km (earned no reward)



Lives on campus, family does not own a car
Weeks 3-5: 62 gCO2 per km
Weeks 6-8: 53 gCO2 per km (earned $5 reward)

From: K
Sent: Wednesday, 20 March 2024 8:43 pm

Like you, I would play games when I am journeying or would catch up on some sleep, especially in the morning. I grew up taking public transport often, and I like how convenient our public transport system is, connecting us from places to places without much of a hassle. I believe that I would continue to take more public transport in future!

I sincerely feel that this study has been very interesting, and I think it is interesting to find out how our small steps is able to make a difference. With that, I would like to say thank you very much for allowing me to be part of this study.

Combining the blocks: Study design

Subjects in 3 groups maintain a travel diary, verified through platform transactions

Timeline

- Aug 2023 to Jan 2024: Baseline ($N = 327$)
- Weeks 0-2: Pre-intervention (familiarization)
- Weeks 3-5: Intervention
- Weeks 6-8: Continue intervention
- Weeks 9-11: Continue intervention
- Weeks 12-15: Post-intervention

→ Early feedback survey ($N = 267$)
(confirms subjects are not environmentally minded)

→ Post-intervention survey ($N = 265$)
(PCS and LCR significantly more environmentally minded)

→ Closing survey ($N = 299$)

Group:	Control: Only travel diary	(1) PCS = Environmental messages + personal carbon scores	(2) LCR = Environ. messages + personal carbon scores + low-carbon rewards
Intervention, weeks 3-5	No mention of carbon, climate, social or environmental behavior, etc.	Environmental messaging	Environmental messaging & carbon scores (no rewards yet)
Intervention, weeks 6-8, weeks 9-11		Environmental messaging & personal carbon scores (without rewards)	Environmental messaging & personal carbon scores with low-carbon rewards

Verifiable trips (except family car & NUS shuttle)



Subjects submitted their travel transactions reports from all five public transport and taxi/car-hail platforms when joining and again when completing the study.

Externally compiled ride data.

Subjects were reminded that their travel diaries would be audited.

Also reminded subjects to abide by their NUS Student Honor Code when logging their daily travel.

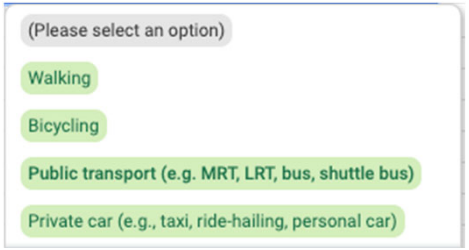
Pre-intervention and control travel diary

B	C	D	E	F	G	H	I	J	K
Pre-Week 1: Monday 1 January to Sunday 7 January			**Research Participant:**						
Day of the week	**Date**	**Trip No.**	**Origin Description**	**Postal code, address, landmark description**	**Destination Description**	**Postal code, address, landmark description**	**Travel Mode**	**(For private car rides only) Size of traveling party**	**Distance on Googlemaps**
Neverday	31/01/2099	1	Home	684488	Uni	NUS Kent Ridge campus	Public transport (e.g., …		16.3 km
		2	Uni	NUS Kent Ridge campus	Mall	Takashimaya	Bicycling		10.4 km
		3	Mall	Takashimaya	Badminton	Yishun sports hall	Private car (e.g., taxi, ri…	3	18.1 km
		4	Badminton	Yishun sports hall	Home	684488	Walking		20.3 km
Monday	1/1/2024	1					(Please select an option)		
		2					(Please select an option)		
		3					(Please select an option)		
		4					(Please select an option)		

Briefly describe your location

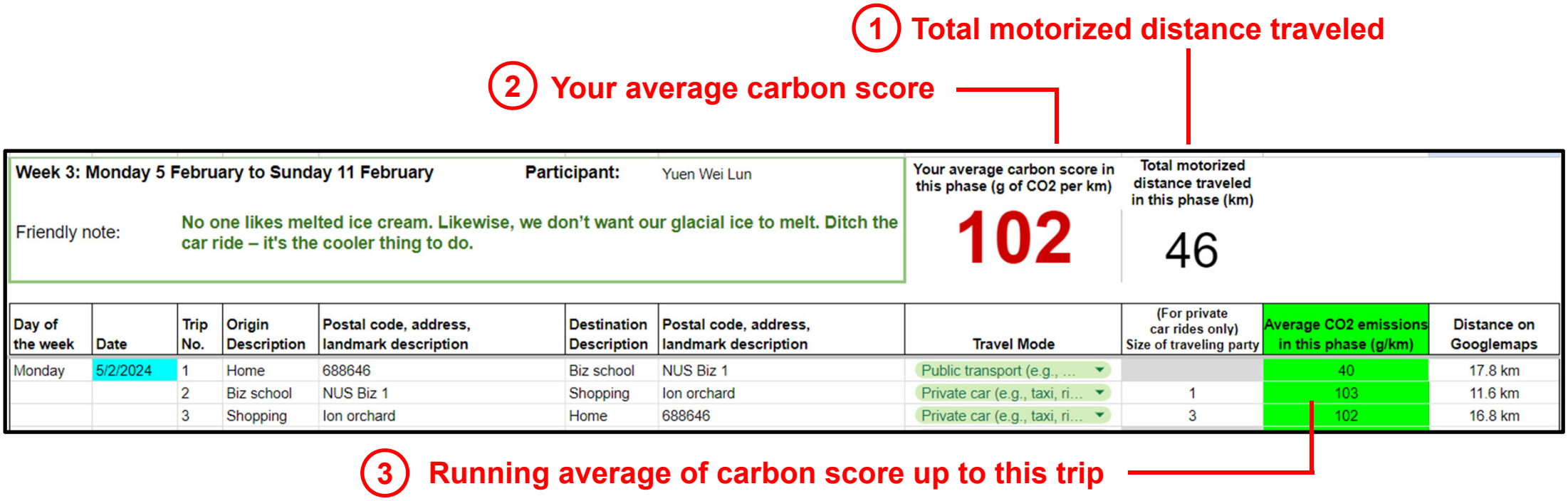
Location postal code

Select your travel mode



Include the no. of people traveling with you to the same destination

Total distance traveled will be reflected here automatically. It may take a short while to load.



1. Total motorized distance travelled on public transport and private car (in km)
2. Carbon score: Average lifecycle emissions calculated as total grams of CO_2 / total motorized distance (km)
   - [Low] Public transport incurs 40 grams of CO_2 per km traveled
   - [Medium] Shared private car (size of travel party > 1) incurs 100 grams of CO_2 per km traveled
   - [High] Solo private car (size of travel party = 1) incurs 200 grams of CO_2 per km traveled
3. Running average of carbon score up to that trip

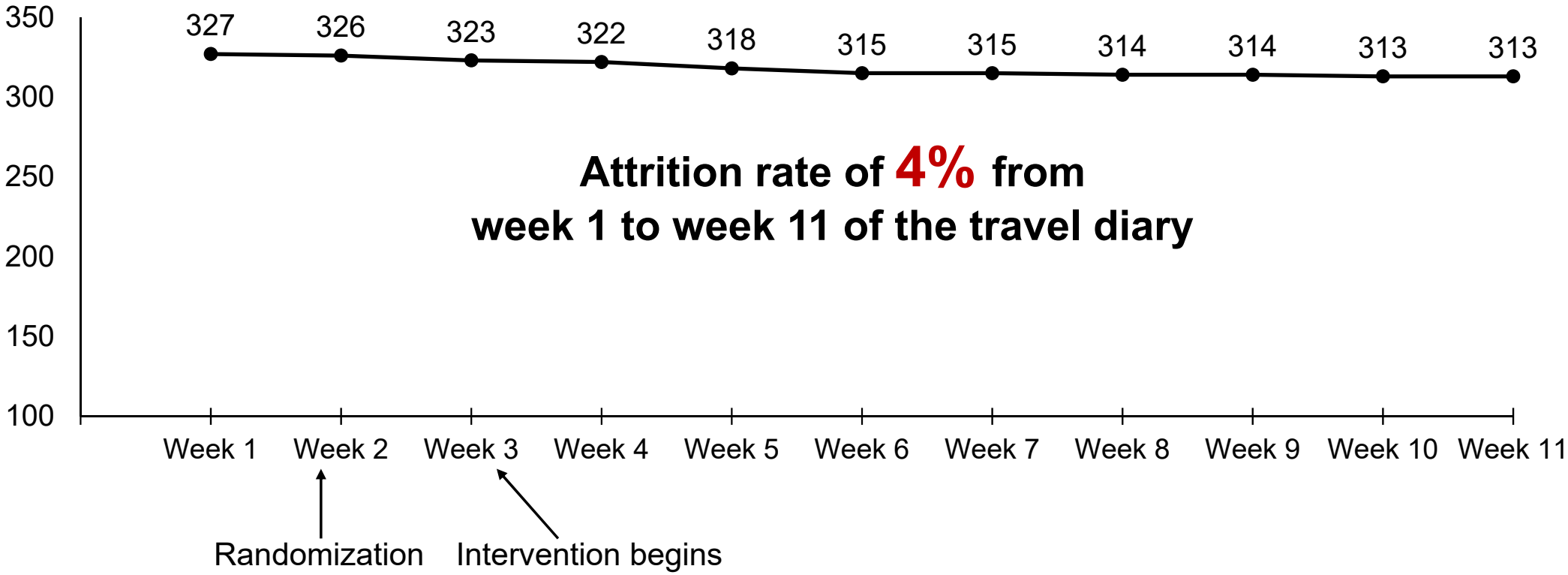
Summary of design

Phase	A Pre-Intervention	B Intervention	C Intervention	D Intervention	E Post-intervention
Timeline	Weeks 0-2	Weeks 3-5	Weeks 6-8	Weeks 9-11	Weeks 12-15
Control group	• Briefing • Familiarization with travel diary • Submission of baseline transactions 	Travel diary	Travel diary	Travel diary	Submission of transactions up to May 5, 2024 
Personal carbon scoring group		Environmental messages	Environmental messages + Carbon scoring	Environmental messages + Carbon scoring	
Low-carbon rewards group		Environmental messages + Carbon scoring	Environmental messages + Carbon scoring + **Low-carbon rewards**	Environmental messages + Carbon scoring + **Low-carbon rewards**	

Results (omit heterogeneity & persistence today)

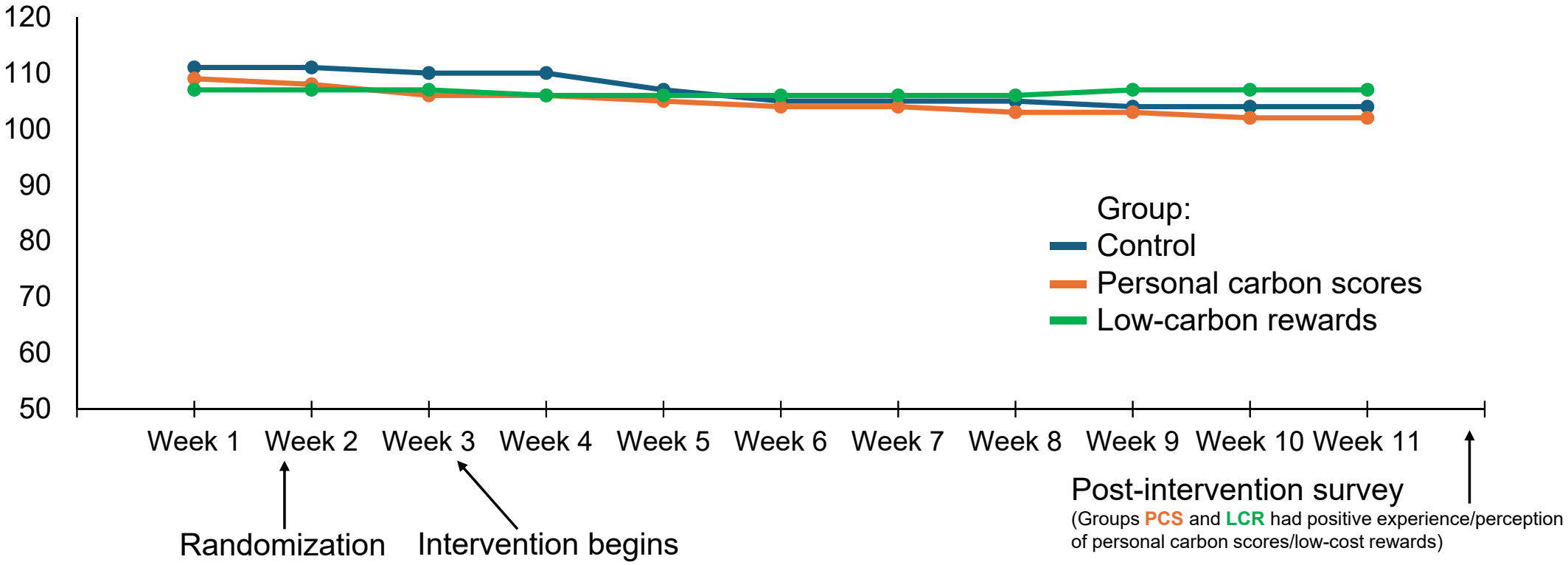
Very high engagement across 3 groups

340 students attended briefings, 327 began logging diaries



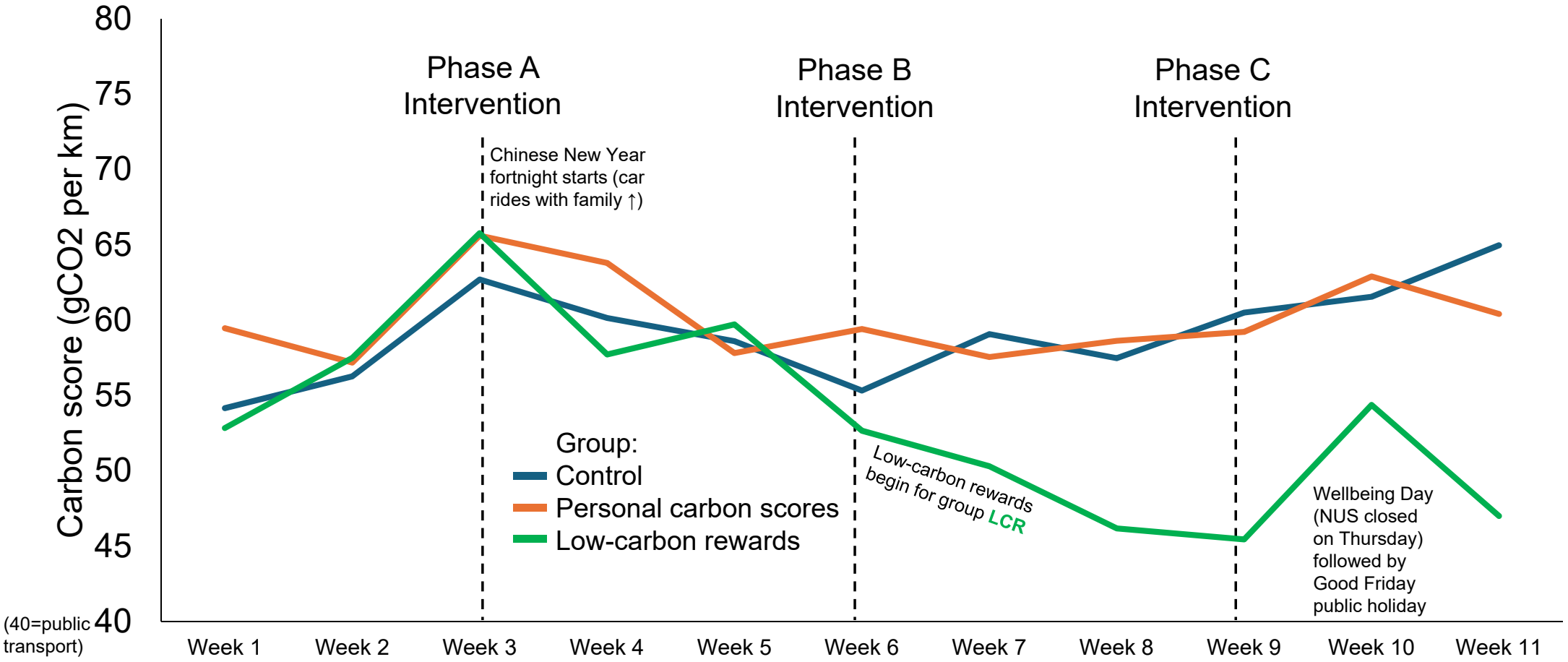
Very high engagement in group **LCR**

LCR: No attrition from week 1 to week 11 of the travel diary

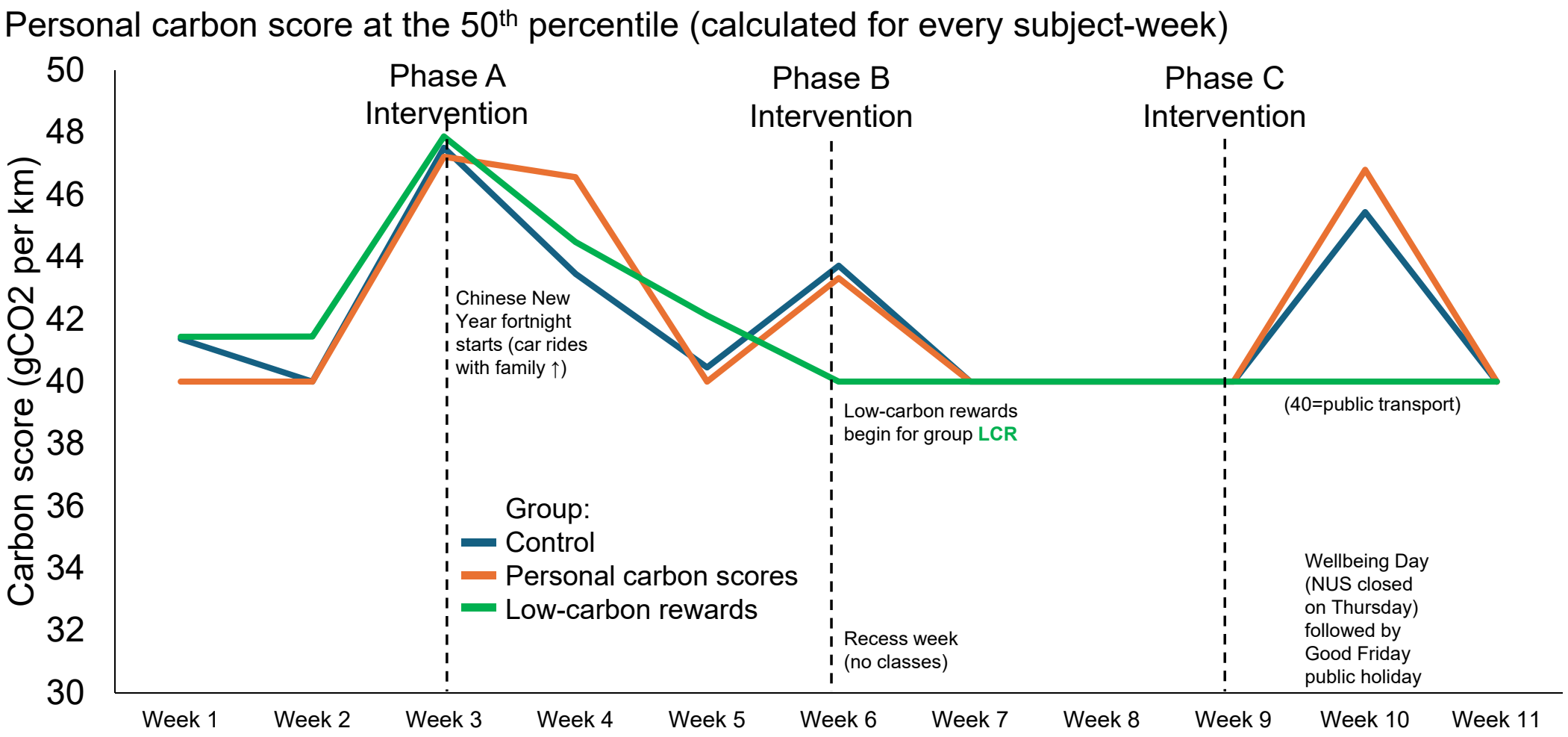


Carbon abatement through rewards

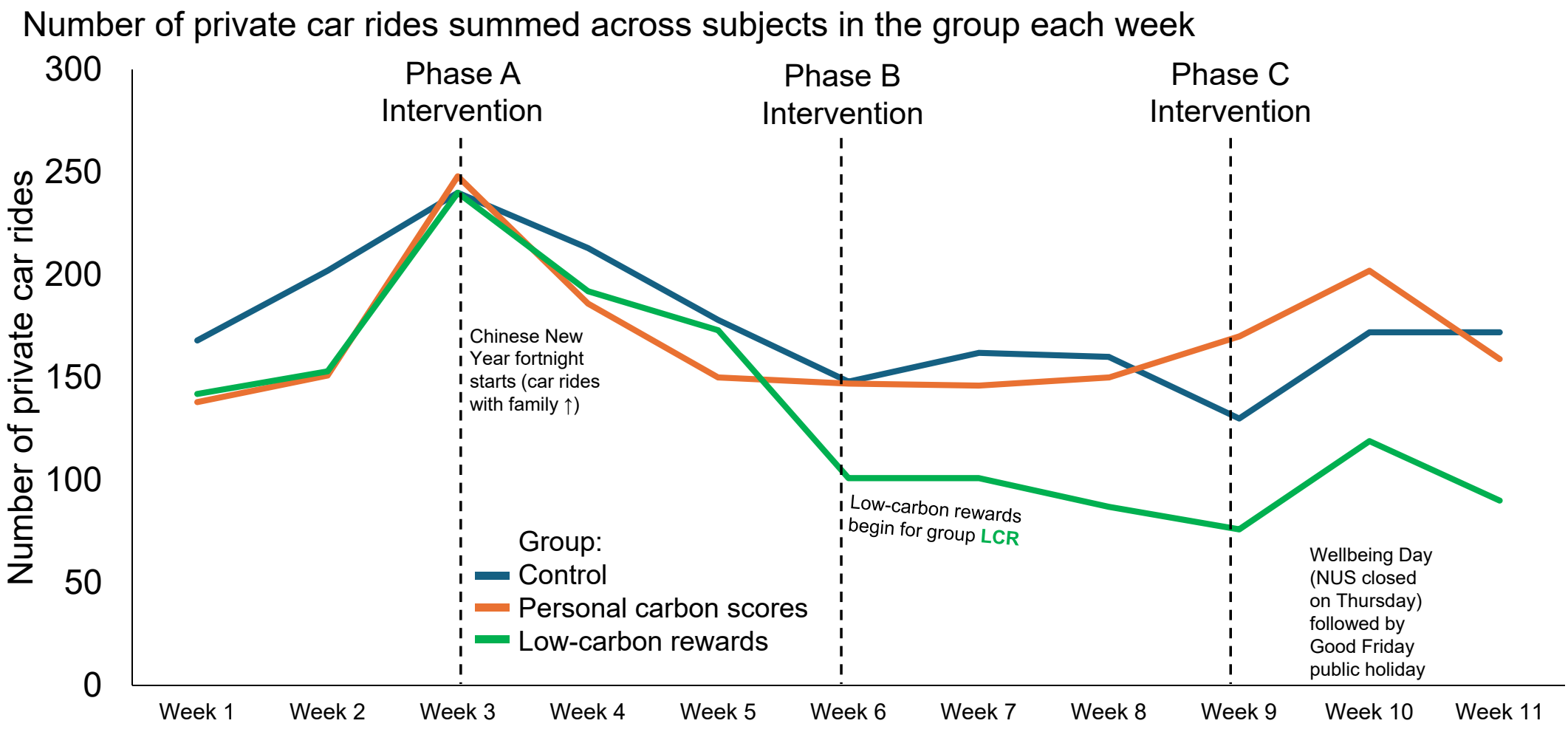
Personal carbon score at the 75th percentile (calculated for every subject-week)



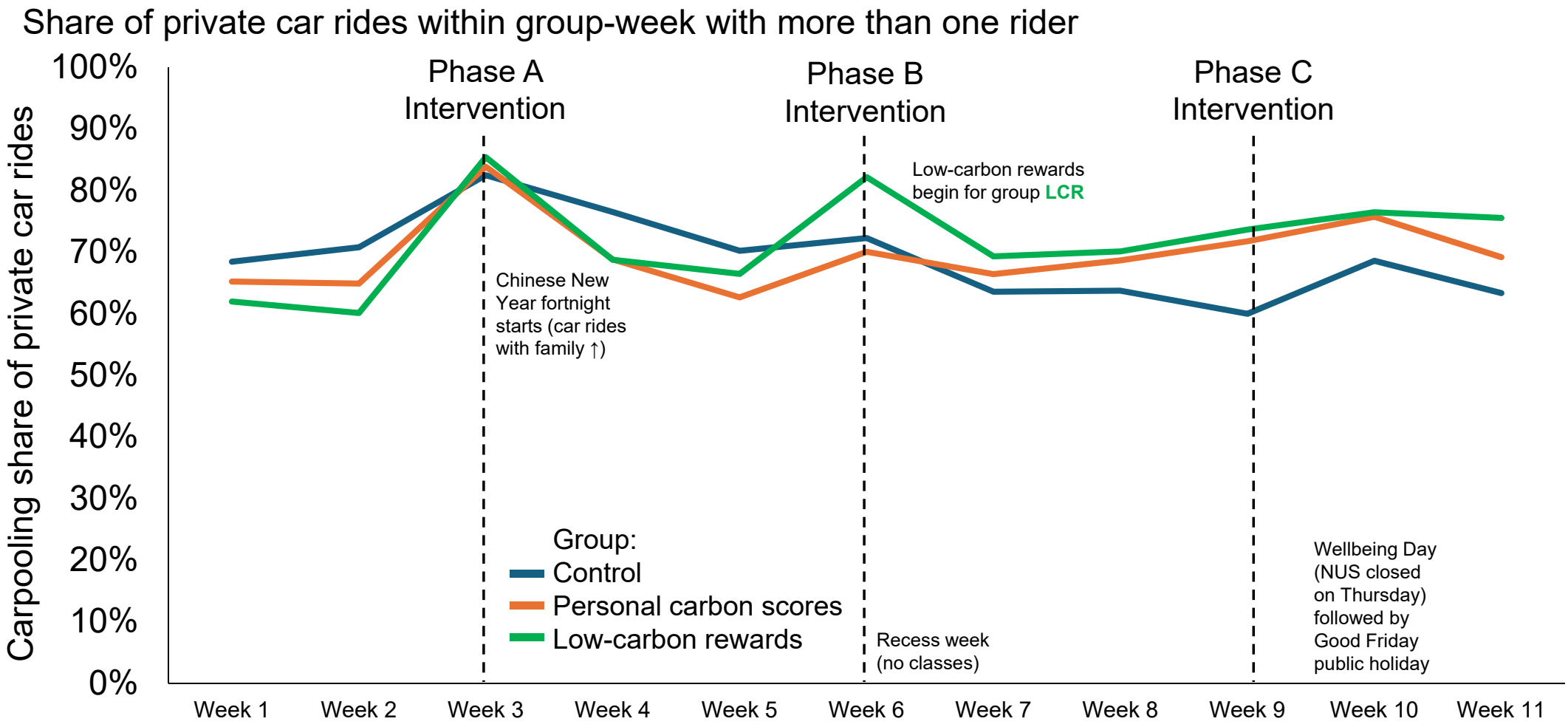
Carbon abatement through rewards



Carbon abatement through rewards

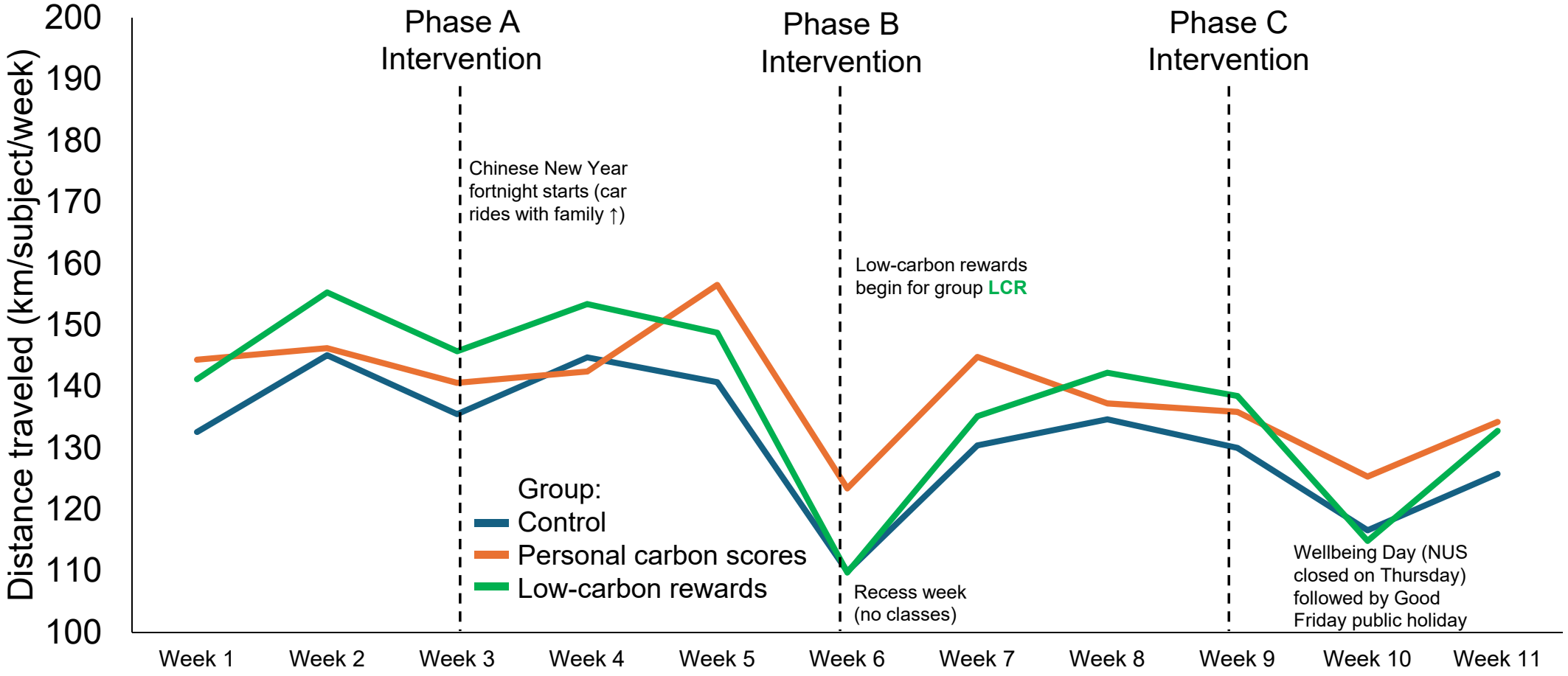


Carbon abatement through rewards



Carbon abatement through rewards

Motorized distance traveled, mean over subjects within group who submitted diary that week



Carbon abatement through rewards

Dependent variable is a subject-week's:	No. of trips (all modes) (1)	Distance traveled (km, motorized only) (2)	Carbon score (gCO_2/km, motorized only) (3)
Environmental Messaging in effect in this phase, three times per week (yes = 1)	0.39	-1.98	2.11
	(0.73)	(6.51)	(2.12)
Carbon score reported, cumulative average from the start of the 3-week period to the latest trip (yes = 1)	0.49	3.51	-1.54
	(0.50)	(4.74)	(1.55)
Low-carbon rewards on offer in this 3-week period (yes = 1)	-0.24	-4.42	-6.62***
	(0.58)	(5.36)	(1.57)
Week fixed effects	Yes	Yes	Yes
Individual fixed effects	Yes	Yes	Yes
Mean of dependent variable	16.55	136.18	53.41
Number of observations	3,495	3,495	3,459
Subjects (~uniformly distributed over LCR, PCS, Control)	327	327	327
R^2	0.70	0.71	0.63

Notes: The table reports estimates from a different two-way fixed-effects panel regression in each column.

Environmental education

- Post-intervention survey ($N = 265$, weeks 12-13) vs. early feedback survey ($N = 267$, week 3 as the intervention started)
  - Post-intervention, 74%, 46%, 50% of C, PCS, LCR subjects stated that the impact on the environment was “Not at all” or “Slightly” important (differences are statistically significant)
  - Early feedback responses are balanced across groups
  - Difference-in-differences estimates (not shown today)
- Post-intervention survey: “Over the past 11 weeks…”
  - 28%, 41%, 52% of C, PCS, LCR subjects chose “less private car rides”
  - 25%, 29%, 41% of C, PCS, LCR subjects chose “more public transport rides”
  - 19%, 32%, 37% of C, PCS, LCR subjects chose “more walking and cycling (active mobility)”—consistent with messaging

Spillovers into climate change attitudes

	Mean in Control condition **C** (S.D.)	Diff. in means **PCS** vs. Control (S.E.)	Diff. in means **LCR** vs. Control (S.E.)
Subject response coded as **0 = Strongly Disagree, 1 = Disagree, 2 = Neutral, 3 = Agree, and 4 = Strongly Agree (pro-environmental)**			
With our current lifestyles, humans are abusing the environment.	3.05 (0.64)	+0.04 (0.10)	+0.17* (0.09)
Our climate is warming, rainfall is becoming less reliable, and sea levels are rising.	3.37 (0.54)	-0.04 (0.09)	+0.14* (0.08)
Humans are responsible for global warming and climate change.	3.36 (0.59)	-0.03 (0.08)	+0.10 (0.09)
I feel anxious about what global warming and rising sea levels will do to us.	2.73 (0.913)	+0.08 (0.13)	+0.20 (0.13)
Policies to protect the environment are very important for Singapore's government to consider.	3.26 (0.63)	-0.01 (0.09)	+0.06 (0.09)
Actions to reduce environmental impact are very important for people to consider when getting around, shopping, and at home.	2.89 (0.76)	-0.04 (0.11)	+0.21** (0.10)
We should leave future Singaporeans at least as well off as we are.	2.99 (0.78)	-0.02 (0.11)	+0.10 (0.11)
My choice of travel modes have an impact on the environment.	2.91 (0.73)	+0.01 (0.10)	+0.09 (0.11)
Subject response coded as **4 = Strongly Disagree (pro-environmental), 3 = Disagree, 2 = Neutral, 1 = Agree, and 0 = Strongly Agree**			
Humans are meant to rule over the rest of nature.	2.47 (1.08)	+0.14 (0.15)	+0.11 (0.16)
The so-called "climate crisis" facing humans has been exaggerated.	2.88 (1.04)	+0.06 (0.14)	+0.23* (0.14)
We do not need to change our lifestyles to address dimate change because science and technology alone will provide solutions.	2.96 (0.90)	-0.04 (0.12)	-0.06 (0.13)
Sum of a subject's 11 responses, out of $11 \times 4 = 44$ (most pro-environmental)	32.87 (5.12)	+0.15 (0.71)	+1.36* (0.71)

+1.36/32.87 = 1.04
p-value = 0.056

Social return on investment

- Preliminary back-of-the-envelope
  - To fix ideas, consider a $10 reward over a 4-week period
  - Mean distance traveled (motorized only) = 136 km/week
  - Mean change in carbon intensity = -6.6 gCO2/km
  - Mean change in carbon emissions = -6.6 × 136 x 4 = 3.6 kgCO2/month
- Viewed narrowly as a tool for abating carbon
  - Carbon abatement cost = 10 / (3.6/1000) = $2,800 per tonCO2
  - An order of magnitude higher than the social cost of carbon
- Viewed broadly as a tool for engaging the public, including climate
  - Car-lite society: Many more co-benefits than carbon abatement

Reward/subsidy vs. punishment/tax

- Consider rewarding the public transport rider
  - To fix ideas, consider a $10 reward over a 4-week period
  - Mean distance traveled (motorized only) = 136 km/week
  - Subsidy per km is $10 / (4 x 136/100) = $1.84 per 100 km
- Cf. SG public transport subsidy: $1 per trip = $10 per 100 km
  - Not salient
- Cf. 10-y license (COE) 'punishing' the car driver
  - To fix ideas, consider $100,000 over 10 years
  - VKT per car = 18,000 km/year
  - Tax per km is $100,000 / (10 x 18,000/100) = $55.56 per 100 km
- Model citizen, rides public transport, is a climate leader

General policy opportunity



- Demand for a FinTech platform to track one's travel choices
  - Opt-in + open-data regulations (UK): Need to safeguard privacy
  - Design to be revenue neutral (white knight/carbon mkts to help fund?)
  - Cover all mobility transactions incl. certified step, bike, scooter trackers
  - Add personal health (10,000 steps), planetary health (CO_2), monetary cost
- Building blocks can be built into urban mobility platform
  - Phone app based, e.g., NREL OpenPath
- Tool for public engagement, manage eco-anxiety (on the rise)
  - Until energy transition is well underway (2040?)
  - C., voluntarily "*it is little choices like this that help reinforce a sense of hope that we have some agency over the outcomes of climate change*"