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A Randomized Controlled Field Experiment

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A Randomized Controlled Field Experiment

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Abstract

In this paper, we discuss a field experiment for encouraging behavioral changes that could result in engagement in physical activity using two types of "nudges": private information and social comparison information. In our experiment, the information provision group was notified solely about their own average step number. The social comparison group received information about their own average steps and a frequency distribution table describing both the relative ranking of each person and the distribution of steps in the group. Our findings are summarized as follows. First, we found the positive effects by private information and social comparison information. Second, we found the effect of social comparison in addition to information provision treatment was larger than the private information treatment only. Finally, we found the effects of treatments do not decrease or vanish during our experiment.

JEL classification: C93, D91, I1.

Keywords: Randomized Controlled Trial (RCT), Physical Activity (PA), Information Provision, Social Comparison.

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1. **Introduction**

Cancer, heart disease, and cerebrovascular disease are the three leading causes of death, having contributed to about 50% of the lifetime health risk in Japan (Ikeda et al. 2012). These non-communicable diseases (NCDs) are closely related to unhealthy lifestyle. Therefore, lifestyle changes that may prevent NCDs have attracted public attention. Some incentivized methods for behavioral change in lifestyle are advocated by governments or researchers. A group of experimental studies used monetary incentives to change behavior (Acland and Levy 2013; Charness and Gneezy 2009; Royer, Stehr, and Sydnor 2015). However, improper use of monetary incentives, such as using insufficiently low monetary amounts, appeared to have the risk of inhibiting behavioral change by undermining endogenous motives (Heyman and Ariely 2004; Acland and Levy 2013).

Meanwhile, some researchers used a non-monetary incentive known as a "nudge" (Thaler and Sunstein 2008). For example, an empirical analysis of electric power usage used a person's own information or social comparison as a nudge (Festinger 1954).[5] Other studies used different types of nudges, such as personal activity results, others' information, and social norms. Some studies evaluated the treatment effects of a nudge in the healthcare. Burke et al. (2012) reported that body weight decreases by self-management using a self-directed diary as a nudge. Moreover, Morgan et al. (2012) showed that weight reduced by taking a diet program via a website. A study of nudges in regulating alcohol intake by Bewick et al. (2008) reported that they informed each participant the amount of alcohol consumed and the associated health risk. In addition, they reported that the amount of alcohol intake decreased by introducing a nudge., Zhang et al. (2016) conducted a social comparison experiment in online exercise program attendance. In the study, participants were assigned to receive social comparison information that they could compare and refer to other peoples' achievement levels by ranking online information. The study concluded that participation rates of online exercise programs is improved significantly in the social comparison condition. Chapman et al. (2016) provided social comparison information on physical activity (PA), which resulted in an increase of the average number of steps by 1,100 steps per day. However,

[5] For example, Allcott (2011) uses social comparison treatment for behavioral change in power saving. The effect was about 2% by giving the own electricity usage information and the average usage of other people. Chen et al. (2010) conducted a field experiment concerning online movie evaluation by conducting social comparison treatment. It was shown that, by presenting the median evaluation values, the user who performed the evaluation equal to or less than the median value increased, and the user who was evaluating more than the median value did not necessarily decrease.

the experimental period was as short as three weeks (one week of which was the baseline), and the number of the participants was relatively small at only 64 people. Moreover, the authors highlighted the limited effect of the short-term impact of social comparison treatment. Therefore, we tried to examine the effect of information provision and the effect of social comparison treatment simultaneously.

In our paper, we conducted a field experiment at Keihanna-Gakken City in Kyoto Prefecture. We examined the average treatment effects of nudges on PA and verified the longer-term effects of treatments and heterogeneity. We used step counts as a PA outcome and examined two types of nudges: information provision and social comparison.

2. Method

2.1 Experimental Design

We conducted a randomized controlled experiment at Seika Town, a region of Keihanna-Gakken city in Kyoto Japan. The recruitment process is shown in Figure 1. We started by conducting a mail survey about health-related issues for all households in Seika Town (13,190 households and 37,490 residents) from August to September 2015. As remuneration for the response, we gave a gift token (equivalent to 2,000 JPY) or a pedometer (equivalent to 3,500 JPY) to respondents (n=3,407) based on their choice. We selected people who chose to the pedometer (n=2,125) and sent a recruitment letter including an agreement form for this experiment. The number of people who agreed to participate in the experiment was 1,099. Participants were randomly assigned to one of three groups: an information provision group (T1: n=301), a social comparison group (T 2: n=514), and a control group (C: n=284) with no intervention.

<Figure 1: Recruitment flow chart of the experiment>

We collected daily steps with a three-axis pedometer (model: Omron HJ-326F). The data were collected through Omron Healthcare's website via a computer-connected Near Field Communication device. Because the pedometer could not automatically upload the step data, each participant was asked to put the pedometer periodically on the tray and upload her data. We sent a guidance booklet to instruct participants how to upload the data.

The experiment ran from February 1 to March 31, 2016. We held three interventions during the experiment (February 10, March 2, and March 16). As interventions were done by postcard, we assumed that each participant received on the day after the mailing date.

The information provision group was notified only about their own average step number (Figure 2), which was considered using the average number of steps in each of the three intervention periods until the participants mailed their postcards at the end of each period. The information on the card contained the average number of steps per day during the period and encouraging messages.

<Figure 2: Postcard text example for information provision treatment>

We defined *social comparison treatment* as a relative ranking information. The social comparison group received information of their own average steps and a histogram describing the relative ranking of each person and the distribution of steps in the group. A person assigned to the social comparison condition can compare their own activity with the achievement levels of others through an online-based ranking information. A message contained the average number of steps per day during the period, ranking information, the number of total participants and encouraging message (Figure 3).

<Figure 3: Postcard Text Example for Social Comparison Treatment>

2.2 Hypothesis

We first draw from Burke et al. (2012) concerning information provision. They showed that weight was reduced by self-management including such methods as using diaries. Also, Bewick et al. (2008) showed that alcohol intake decreases by providing participants with their past consumption amounts. Therefore, we expect that presenting participants with their own past PA results will lead to behavioral change.

Next, concerning social comparison, Alcott (2011) shows that power-saving behavior is promoted by presenting the average electricity usage of others. A study by Chen et al. (2010) also provides useful information about social comparison in evaluating movies online; it was shown that the evaluation rating given by a participant at equal to or less than the median value rose by presenting the median value. Furthermore, Zhang et al. (2016) showed that the participation rate in a program improves by presenting the achievement status of others. Therefore, we expect that a behavioral change will be triggered by giving information comparing their own achievement status with that of others.

Finally, when we provided social comparison treatment in addition to information provision treatment, we predict that the effect of treatment of the social comparison

condition is greater than that of only information provision. Chapman et al. (2016) showed that the average number of steps increases when the information of others is compared with that of their own from the level resulting from being presented solely with their own information. Thus, we predict that giving additional information will result in an increase in the number of steps of the social comparison condition that is larger than that for information provision only.

Therefore, we adopt the following hypothesis: Providing one with information about one's own activity level along with information about the level of others will promote changes in behavior.

2.3 Analysis

We explain the estimation model for conducting econometric analysis. In order to estimate the overall effect by intervention, using the data before interventions (data from February 1 to February 10) and the data after interventions (data from February 11 to March 31), taking a fixed effect on individuals and time, we conduct the panel estimation with the following equation:

$$y_{it} = \alpha_i + \beta \cdot post + \sum_{g=1,2} \beta_g \cdot treatment_g \cdot post + \theta_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where *i* represents an individual, and *t* represents a particular day between February 1 and March 31. In addition, the explained variable y_{it} represents the daily steps of *i* at *t*. α_i represents a constant term that we interpret as the average outcome of the control group. Further, when g = 1, g indicates the information provision group, and when g = 2, it indicates the social comparison group. The explanatory variable $treatment_g$ is a dummy variable indicating when $treatment_g = 1$ for each g that each treatment is received. Also, the variable $post$ is a dummy variable indicating before treatment ($post = 0$) and after treatment ($post = 1$). Finally, θ_i is a fixed effect that shows that the effect on the steps does not change through the experiment period by each individual. In addition, λ_t represents a time dummy that controls the influence of daily weather and temperature. To avoid multicollinearity, we removed λ_1 from our analysis. Furthermore, ε_{it} represents an error term that includes the influence of unobservable variables; we assume that the expected value of the error term is zero.

Next, we estimate a model that controls covariates of individuals as represented in the

following equation:

$$y_{it} = \alpha_i + \beta \cdot post + \sum_{g=1,2} \beta_g \cdot treatment_g \cdot post + \sum_g \sum_k \gamma_{gk} \cdot treatment_g \cdot post \cdot (x_{ki} - \bar{x}_k) + \theta_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where the variable x_{ki} represents each covariate of i. $\bar{x}_k$ represents the average of covariate k. By subtracting the average value of each covariate from the covariate value of each individual, the relationship between the parameter of equation (1) and the parameter of equation (2) becomes clear (Imbens and Rubin 2015). All variables used as covariates (gender, marriage, and educational background) are dummy variables. In the case of gender, 0 represents men and 1 represents women. In the case of marriage, 0 represents unmarried status (including divorce or bereavement) and 1 represents married status. In addition, when the academic background is 0, it indicates that a participant has less than a college degree, whereas 1 represents that a participant is at least a university graduate. The estimate equation (2) is defined as including two treatments, and those that crossed each covariate with each treatment dummy and post dummy. In addition to the two treatments mentioned above, the interaction term of the covariates, each treatment, and the post dummy, the estimated expression (2)' includes the interaction term of the result of the questionnaire on health consciousness survey, each treatment, and the post dummy.

To analyze the treatment effect of each term, we use the following equation:

$$y_{it} = \alpha_i + \sum_{j=1,2,3} \beta_j \cdot event_j + \sum_{g=1,2} \sum_{j=1,2,3} \beta_{gj} \cdot treatment_g \cdot event_j + \theta_i + \lambda_t + \varepsilon_{it} \quad (3)$$

where index j takes values 1, 2, and 3, and indicates that it is a period of receiving the first, second, and third treatment, respectively. In addition, the variable $event_j$ is a dummy variable indicating that it is receiving the j-th treatment when coding each j as 1 for each j.

3. Results

3.1 Balance Check

To ensure the randomization, we ran a robustness check among three groups, as shown in Table 1. We could not find any differences, allowing us to assess the randomization as successful.

<Table 1 Balance check of the participants' attributions>

3.2 Descriptive graphical analysis

We examined the variation of the number of steps during the experiment using graphical charts. In the control group, the average number of steps before the experiment was 2,382.6 (s.d.= 3,852.1). The average number of steps after the intervention started was 2,042.8 (s.d.=3,725.1). Figure 4 shows the differences between the average daily steps for each treatment group. The vertical line (D11, D31, D45) in the figure represents the day on which each intervention was done. We calculated the difference-in-difference (DID) of the number of steps by following procedure. We took the difference in the average daily steps before (to February 10th) and after intervention (from February 11th) by each group. After that, we took the difference of each treatment group and the control group. Figure 4 shows the effect of each intervention is almost greater than zero and the effect is maintained during the experiment. Furthermore, for many days, the value for the social comparison group is higher than that of the information provision group.

<Figure 4 Average daily steps (DID): C v.s.T1, T2>

Figure 5 shows the difference between the social comparison and information provision groups after taking the difference before and after the intervention shown in Figure 4. This graph shows that intervention by social comparison plus information provision is more effective than intervention by information provision only. Despite some fluctuation during the experimental period, social comparison intervention is more effective than intervention by information provision only. Moreover, the effect appears continuously for the duration of the experiment.

<Figure 5 Average steps per day (DID): T1 vs. T2>

We found that the hypothesis tends to be supported. In the following section, we will examine this hypothesis by using regression analysis.

3.3 Estimation Results

Table 2 shows the results of estimation equation (1), (2) and (2’). We first see that equation (1). Average number of steps of control group is 2,884 steps before the interventions started. Also, after the experiment began, this number decreased by about 858 steps. Next, we see that the information provision treatment led to an increase in the average number of steps by about 406 steps (treatment1). The social comparison treatment caused the average number of steps to increase by about 608 steps (treatment2). Furthermore, the difference between the social comparison and the information provision treatment was about 202 steps and statistically significant at the 1% level (t=8.76). This result shows that the average number of steps significantly increases by providing information not only about each participant’s activity but also additionally for social comparison.

<Table 2 Estimation results: Equations (1), (2), (2’)>

In equation (2), when the social comparison treatment was given, there was an average decrease of about 495 steps in women from the level of men. Regarding age, the number of steps increased significantly even when giving either information provision treatment or social comparison treatment. Furthermore, concerning participants’ annual income, an average number of steps significantly increased only when information was provided. Finally, concerning education level, the average number of steps increased by about 609 when information provision treatment was done, but decreased by about 269 steps when social comparison treatment was given. In addition, similar to the result obtained by equation (1), about 315 steps in the information provision and a 601 step increase in the social comparison treatment are respectively shown.

Subsequently, as equation (2’), regarding "actual feeling of lack of exercise," the average number increased by 124 steps when information provision treatment was given, whereas when social comparison treatment was given, the average number of steps increased by about 168 steps. Regarding the "implementation of exercise," the average number of steps increased by about 98 steps when giving the information provision treatment, and the number of steps increased about 123 steps when the social comparison treatment was given. As in the result obtained by the estimation equation (1), the number of steps increased about 338 steps in the information provision treatment and increased about 611 steps by the social comparison treatment increase the number of steps.

Next, estimation results for equation (3) are shown in Table 3. When giving the information provision treatment, the average number of steps increased by about 365 for

the first treatment, about 413 steps for the second treatment, and about 450 steps for the third treatment. Also, in the case of social comparison treatment, we observed that the number of steps increased about 492 steps by the first treatment, 638 steps by the second treatment and about 740 steps by the third treatment.

<Table 3 Estimation result: Equation (3)>

Table 4 carries the results of t-test based on the results of equation (3) comparing each intervention period by two treatments. The effect of the information provision treatment did not vary through the intervention periods. The effect gradually became larger when social comparison treatment was given in the first, second, and third intervention periods. From these results, the effect of each treatment was observed at all intervention points, and it was understood that the effect of the treatment did not disappear by the repetition of interventions.

<Table 4 Results of the t-test based on the results of equation (3) comparing each intervention period by two treatments>

4. Discussion

We show that it is possible to induce an active behavior change via PA by giving one item of information about one's own behavioral results. Our result was similar to those of previous studies by Burke et al. (2012) and Bewick et al. (2008). Moreover, we found that social comparison treatment also positively affected PA. Allcott (2011) and Zhang et al. (2016) also gave information resulting from comparing individuals with other people and found that this led to a larger behavioral change.

In our study, we show that the effect of social comparison in addition to information provision was greater than the effect of information provision. Our result of the difference of the number of steps by information treatment and social comparison is about 200 steps per day. However, by the result of previous research (Chapman et al., 2016), the difference between giving private information and social comparison information was about 1,120 steps (95% CI, 538, 1703) per day. The effect obtained in our study was smaller than the previous study. The reason for this owes to the fact that in Chapman et al. (2016) the researchers gave participants information about others every day over the course of the experiment. In our study, we only provided information once every two weeks. Overall, our research shows that simply presenting individual activity results can result in an

increase in the average amount of daily activity. Also, presenting the relative information of other people promoted stronger behavior changes and improved the amount of activity**.** Thus, if we could provide information frequently, we would have successfully promote PA.

Next, our findings show that providing the results of an activity to an individual who realizes that he or she is not getting enough exercise every day improves the level of activity. Additionally, presenting the information of others so that one may draw comparison between oneself and other people strengthens this change. Furthermore, both interventions are effective for those who actually do exercise every day. These interventions are also effective both for those who do not habitually exercise and for those who are beginning to put an exercise routine into practice.

Finally, we observed that the effect of any treatment was not attenuated and did not disappear during our experiment. The effect was confirmed throughout the experiment for both interventions. Furthermore, no significant difference was found between treatments for each intervention in each group, except that the effect increased more for the first intervention than for the second intervention. It was also found that the effect of the treatment did not decay throughout the experiment. Burke et al. (2012) found the influence on habit formation of medium- and long-term interventions, such as six months and 24 months; we confirm this effect. However, our experimental period was only about two months. We conducted our study over a much shorter period than Burke et al. did, and there was no follow up at all after any of these interventions; thus, we could not observe habit formation over the medium and long term. Although we ran a short experiment, the effects of these interventions were sustained and effective without attenuation and disappearance throughout the experimental period. Also, whereas there are a few other previous studies that examined the long-term effect of information provision on healthcare activity, there is no other study that examines the long-term effect of information provision on PA, especially concerning walking activity. Therefore, our study is the first study to examine the longer-term effect of information provision on PA. We show that by repeating interventions, sustainable effects upon PA can be expected with the integration of information provision and social comparison.

5. **Conclusion**

In the present study, we used a randomized controlled trial on PA to investigate whether information provision and social comparison treatments affect average step number. Information provision and social comparison significantly improved the level of PA. In

comparing the difference between effect of social comparison plus information provision treatment and effect of information provision only, the effect of social comparison plus information provision treatment was more pronounced. This result indicates that merely presenting the results of activities of individuals improves the average daily activity; moreover, it indicates that the promotion of behavioral change is stronger with the presentation of relative information. Throughout our experiment, the effect of social comparison and individual information on PA was sustained without attenuation, which suggests that “nudges” will lead to good PA habit formation for the long term.

Reference

[1] Acland, D., & Levy, M.R. (2015). Naiveté, projection bias, and habit formation in gym attendance. *Management Science*, 61(1), 146-160.

[2] Allcott, H. (2011). Social norms and energy conservation. *Journal of public Economics*, 95(9-10), 1082-1095.

[3] Bewick, B.M., Trusler, K., Mulhern, B., Barkham, M., & Hill, A.J. (2008). The feasibility and effectiveness of a web-based personalised feedback and social norms alcohol intervention in UK university students: a randomised control trial. *Addictive behaviors*, 33(9), 1192-1198.

[4] Burke, L.E., Styn, M.A., Sereika, S.M., Conroy, M.B., Ye, L., Glanz, K., & Ewing, L.J. (2012). Using mHealth technology to enhance self-monitoring for weight loss: a randomized trial. *American journal of preventive medicine*, 43(1), 20-26.

[5] Collins, C.E., Morgan, P.J., Jones, P., Fletcher, K., Martin, J., Aguiar, E.J., Lucas, A., Neve, M.J., & Callister, R. (2012). A 12-week commercial web-based weight-loss program for overweight and obese adults: randomized controlled trial comparing basic versus enhanced features. *Journal of medical Internet research*, 14(2), e57.

[6] Chapman, G.B., Colby, H., Convery, K., & Coups, E.J. (2016). Goals and social comparisons promote walking behavior. *Medical Decision Making*, 36(4), 472-478.

[7] Charness, G., & Gneezy, U. (2009). Incentives to exercise. *Econometrica*, 77(3), 909-931.

[8] Chen, Y., Harper, F.M., Konstan, J., & Li, S.X. (2010). Social comparisons and contributions to online communities: A field experiment on movielens. *American Economic Review*, 100(4), 1358-98.

[9] Festinger, L. (1954). A theory of social comparison processes. *Human relations*, 7(2), 117-140.

[10] Halpern, S.D., French, B., Small, D.S., Saulsgiver, K., Harhay, M.O., Audrain-McGovern, J., Loewenstein, G., Brennan, T.A., Asch, D.A., & Volpp, K.G. (2015). Randomized trial of four financial-incentive programs for smoking cessation. *New England Journal of Medicine*, 372(22), 2108-2117.

[11] Heyman, J., & Ariely, D. (2004). Effort for payment: A tale of two markets. *Psychological science*, 15(11), 787-793.

[12] Ikeda, N., Inoue, M., Iso, H., Ikeda, S., Satoh, T., Noda, M., Mizoue, T., Imano, H., Saito, E., Katanoda, K., Sobue, T., Tsugane, S., Naghavi, M., & Shibuya, K. (2012). Adult mortality attributable to preventable risk factors for non-communicable diseases and injuries in Japan: a comparative risk assessment. *PLoS medicine*, 9(1), e1001160.

[13] Imbens, G.W., & Rubin, D.B. (2015). Causal inference for statistics, social, and biomedical sciences: An introduction. *Cambridge University Press*.

[14] Royer, H., Stehr, M., & Sydnor, J. (2015). Incentives, commitments, and habit formation in exercise: evidence from a field experiment with workers at a fortune-500 company. *American Economic Journal: Applied Economics*, 7(3), 51-84.

[15] Thaler, R.H., & Sunstein, C.R. (2009). Nudge: Improving decisions about health, wealth, and happiness. *Penguin*.

[16] Volpp, K.G., Troxel, A.B., Pauly, M.V., Glick, H.A., Puig, A., Asch, D.A., Galvin, R., Zhu, J., Wan, F., DeGuzman, J., Corbett, E., Weiner, J., & McGovern, J.A. (2009). A randomized, controlled trial of financial incentives for smoking cessation. *New England Journal of Medicine*, 360(7), 699-709.

[17] Zhang, J., Brackbill, D., Yang, S., & Centola, D. (2015). Efficacy and causal mechanism of an online social media intervention to increase physical activity: results of a randomized controlled trial. *Preventive medicine reports*, 2, 651-657.

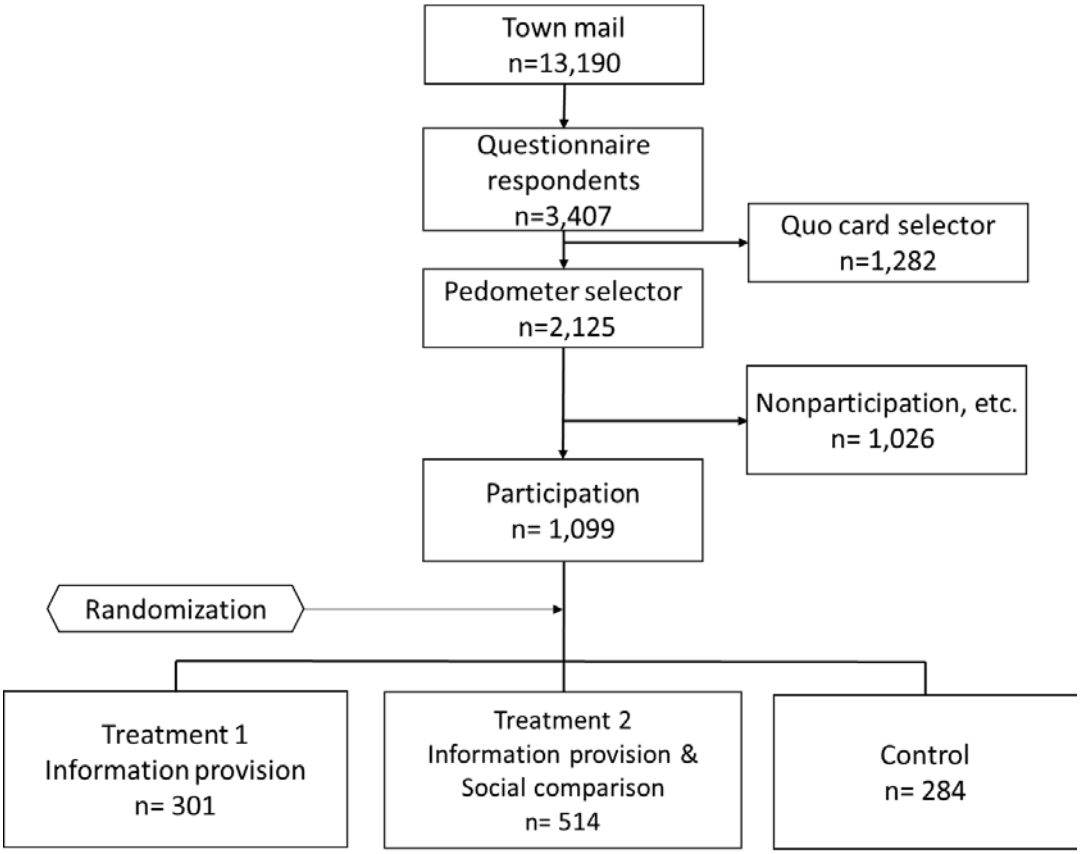

Figure 1: Recruitment flow chart of the experiment

Kyoto University Seika Smart Healthcare Project

Mr. seika008

From February 26 to March 10

Your average number of steps per day was

23,489 steps

Continue walking! Let's get healthy!

Figure 2: Postcard text example for information provision treatment

Kyoto University Seika Smart Healthcare Project

Mr. seika008

From February 26 to March 10

Your average number of steps per day was

23,489 steps

There were 252 people out of 514 people who completed the transfer of step count data.

Among them, you were

1st ／ 252 people

Continue walking and let's make your health!

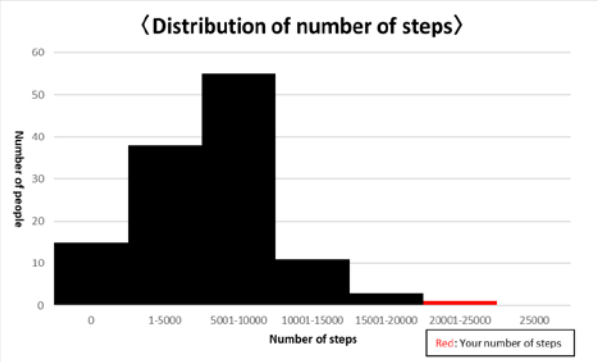

Figure 3: Postcard text example for social comparison treatment

Table 1: Balance check of participants' characteristics

	C (s.d)	T1 (s.d)	T2 (s.d)	All (F-value)
Sex	0.373	0.365	0.36	0.07
	(0.485)	(0.482)	(0.480)	
BMI	22.661	22.693	22.884	0.51
	(2.952)	(3.617)	(3.515)	
Age	59.789	59.95	60.545	0.35
	(13.748)	(13.775)	(13.164)	
Marriage	0.889	0.863	0.908	1.95
	(0.314)	(0.344)	(0.289)	
Income	521.642	541.812	510.285	0.79
<1,000 JPY>	(341.754)	(357.038)	(325.578)	
Educational qualification	0.571	0.62	0.585	0.77
	(0.496)	(0.486)	(0.493)	
Actual perception of lack of exercise	2.563	2.645	2.62	0.28
	(1.307)	(1.362)	(1.374)	
Implementation of exercise	2.772	2.622	2.68	1.02
	(1.256)	(1.335)	(1.246)	

* Regarding "actual feeling of lack of exercise," we asked in the questionnaire on health consciousness survey the question item "I feel that my daily exercise level falls short."

** "Implementation of exercise" asked the question items "I am trying to exercise /participate in sports for my health" in the questionnaire above in five stages.

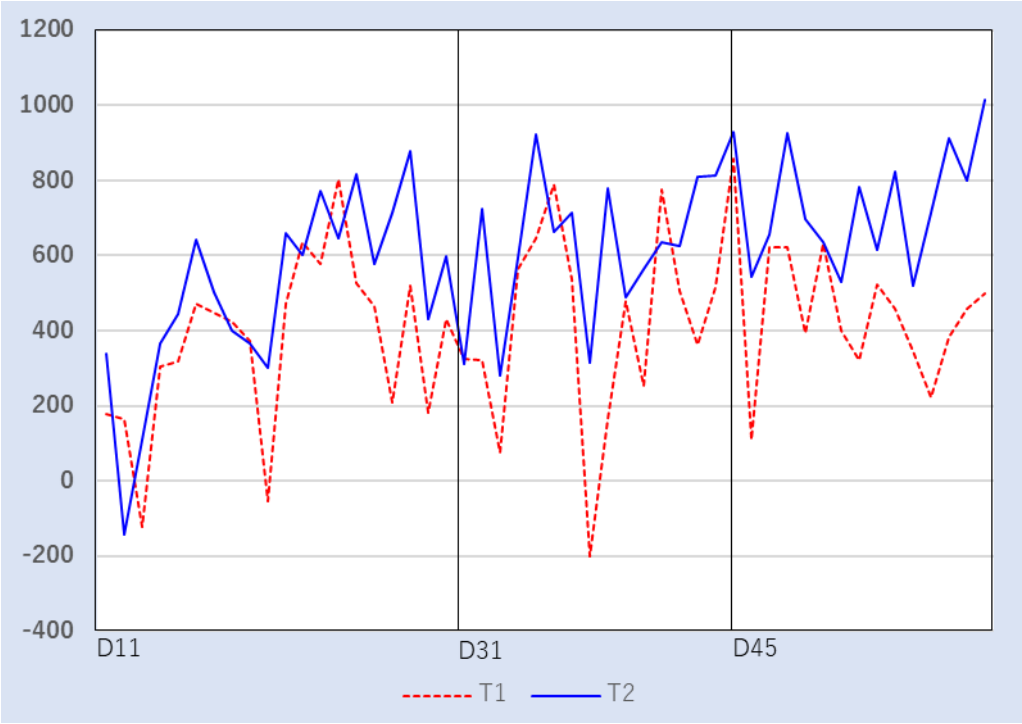

Figure 4: Average daily steps (DID): C v.s.T1, T2

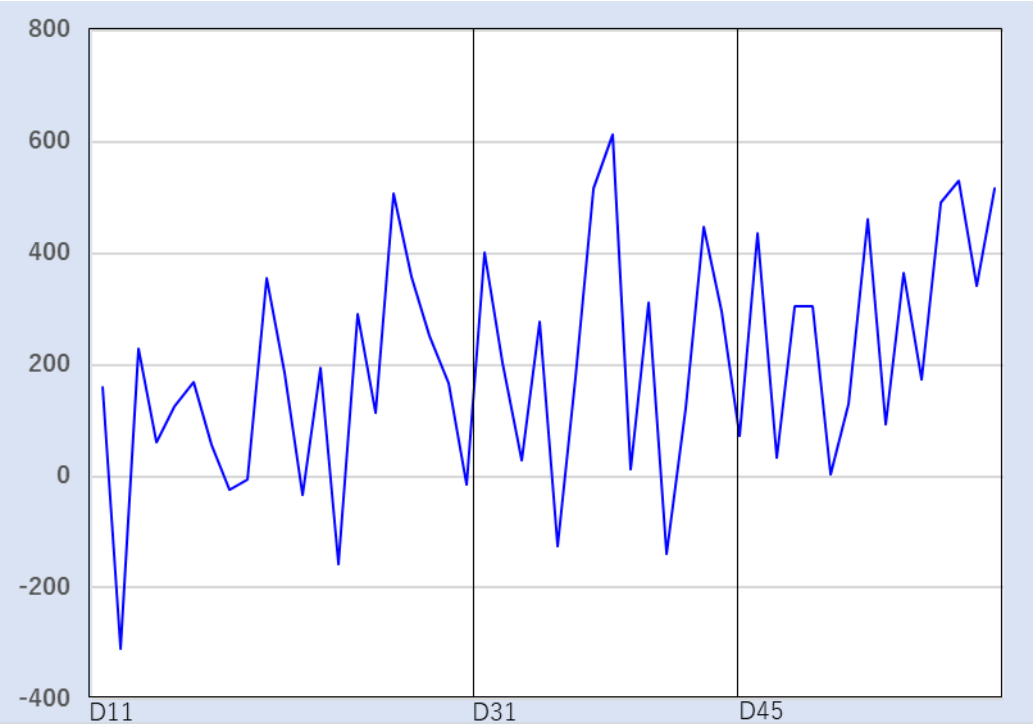

Figure 5: Average steps per day (DID): T1 vs. T2

Table 2: Estimation results: Equations (1), (2), (2')

Variables	(1)	(2)	(2)'
cons	2884.480***	2926.094***	2943.952***
	(81.756)	(84.710)	(86.529)
post	-858.170***	-160	-183.489
	(125.179)	(129.982)	(132.572)
treatment1	405.843***	315.499***	337.502***
	(77.668)	(81.116)	(82.952)
treatment2	607.549***	601.119***	610.670***
	(69.418)	(72.398)	(73.549)
treatment1· sex		3.144	-58.333
		(130.051)	(133.965)
treatment2· sex		-494.984***	-482.845***
		(101.563)	(104.224)
treatment1· BMI		-13.264	-9.588
		(15.672)	(16.117)
treatment2· BMI		-14.718	-9.641
		(12.703)	(12.963)
treatment1· age		29.002***	28.336***
		(4.510)	(4.841)
treatment2· age		16.310***	11.410***
		(3.738)	(3.989)
treatment1· marriage		7.251	-3.942
		(175.458)	(188.168)
treatment2· marriage		-120.425	36.787
		(153.596)	(157.602)
treatment1· income		0.928***	1.078***
		(0.167)	(0.175)
treatment2· income		0.034	-0.079
		(0.147)	(0.149)
treatment1· education		608.621***	688.318***
		(120.096)	(123.754)
treatment2· education		-268.638***	-334.434***
		(91.796)	(93.563)
treatment1· lack			124.119**
			(52.772)
treatment2· lack			167.618***
			(38.531)
treatment1· exer			97.643*
			(52.704)
treatment2· exer			122.685***
			(41.380)
R^2	0.679	0.68	0.678
adj R^2	0.674	0.675	0.672
obs	65,940	61,920	59,820

Standard errors are in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 3: Estimation result: Equation (3)

Variables	Coefficients
cons	2884.480***
	(81.749)
event1	-792.993***
	(127.266)
event2	131.574
	(129.048)
event3	21.226
	(128.694)
treatment1 · event1	364.650***
	(86.136)
treatment1 · event2	413.489***
	(92.823)
treatment1 · event3	456.377***
	(91.525)
treatment2 · event1	492.314***
	(76.986)
treatment2 · event2	638.054***
	(82.963)
treatment2 · event3	740.407***
	(81.802)
R^2	0.679
adj R^2	0.674
obs	65,940

Standard errors are in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 4: Results of the t-test based on the results of equation (3) comparing each intervention period by two treatments

	t-statistics
treatment1・event1 vs treatment1・event2	0.4
treatment1・event2 vs treatment2・event3	0.27
treatment2・event1 vs treatment2・event2	4.44***
treatment2・event2 vs treatment2・event3	12.51 ***

*** p < 0.01, ** p < 0.05, * p < 0.1.