

# Numerical Nudging: Using an Accelerating Score to Enhance Performance

Psychological Science  
2017, Vol. 28(8) 1077–1086  
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sagepub.com/journalsPermissions.nav  
DOI: 10.1177/0956797617700497  
www.psychologicalscience.org/PS  


Luxi Shen<sup>1</sup> and Christopher K. Hsee<sup>2</sup>

<sup>1</sup>CUHK Business School, Chinese University of Hong Kong, and <sup>2</sup>Booth School of Business, University of Chicago

## Abstract

People often encounter inherently meaningless numbers, such as scores in health apps or video games, that increase as they take actions. This research explored how the pattern of change in such numbers influences performance. We found that the key factor is acceleration—namely, whether the number increases at an increasing velocity. Six experiments in both the lab and the field showed that people performed better on an ongoing task if they were presented with a number that increased at an increasing velocity than if they were not presented with such a number or if they were presented with a number that increased at a decreasing or constant velocity. This acceleration effect occurred regardless of the absolute magnitude or the absolute velocity of the number, and even when the number was not tied to any specific rewards. This research shows the potential of *numerical nudging*—using inherently meaningless numbers to strategically alter behaviors—and is especially relevant in the present age of digital devices.

## Keywords

motivation, performance, gamification, game, number comprehension, evaluability, acceleration, velocity, score, token economy, medium maximization, nudge

Received 7/18/16; Revision accepted 2/27/17

The modern world is a world of changing numbers. The burned-calories count displayed on a treadmill rises as one exercises, the points in a loyalty program accrue as one makes purchases, and the score in a video game increases as one plays.

Much prior research in psychology, economics, marketing, and management has studied how people react to numbers. However, the focus of the prior research has been on numbers that are static (e.g., De Langhe & Puntoni, 2016; Hastings & Shapiro, 2013; Schley & DeKay, 2015; Schley & Peters, 2014; van Osselaer, Alba, & Manchanda, 2004) or carry useful information (e.g., Etkin, 2016; Huang, Zhang, & Broniarczyk, 2012; Kivetz & Simonson, 2003; Koo & Fishbach, 2008; Larrick & Soll, 2008)—for example, the burned-calorie count displayed on an exercise machine that indicates the health benefit of a workout.

Our research extends prior research in two directions. First, instead of studying static numbers, we focused on dynamic numbers—in particular, on how characteristics such as the velocity and the acceleration with which a number increases influence behavior. Second, instead of

studying meaningful numbers, we focused on numbers that carried no inherently meaningful information. Studying such numbers has unique advantages. Theoretically, it can shed light on how mere numbers influence behavior. Practically, it can help practitioners, from game designers to marketers, better utilize numerical feedback (e.g., scores and points) in displays to influence behavior without altering substantive information.

## Theory

Consider two different models of a step machine (e.g., a StairMaster in a gym) that are identical in all respects except for the information shown on their digital panels. One model—the standard model—displays information such as the number of steps taken by the user. The other model displays all the same information as the standard

## Corresponding Author:

Luxi Shen, CUHK Business School, Chinese University of Hong Kong, 12 Chak Cheung St., Shatin, New Territories, Hong Kong  
E-mail: luxi.shen@cuhk.edu.hk

model plus an extra, add-on number. This extra number, which we refer to as the *X number* (though it might be referred to as a “score” in real life), increases according to a preprogrammed algorithm as the step count increases. Notably, this number carries no independent information. From a purely informational perspective, the difference between the two models should not lead to differential performance. But, as we will explain later, we predicted otherwise.

We propose that the presence of an *X number* can potentially increase motivation. Decision makers are known for being insufficiently sensitive to what information is meaningful and what is not (Thaler, 2015; Tversky & Kahneman, 1974), and they often treat information they know to be meaningless as if it were meaningful (e.g., Arkes & Ayton, 1999; Epley & Gilovich, 2006; Hsee, Yu, Zhang, & Zhang, 2003; Klayman & Brown, 1993; Risen, 2016; Shen & Urminsky, 2013). In the case of the *X number*, even if people are told that it conveys no independent information, they still treat it as if it were a score that reflects their progress, and it therefore influences their motivation.

We further propose that everything else being equal, the *X number* will lead to greater motivation if it increases in an accelerating pattern than if it increases in a decelerating pattern, regardless of its position (i.e., how large the *X number* is) or its velocity (i.e., how fast it increases). In other words, acceleration matters, whereas position and velocity do not. We refer to this effect as the *acceleration effect*. (We use the term *acceleration* throughout to refer to whether the *X number* accelerates or decelerates, and not to how fast it accelerates or how fast it decelerates.)

This proposition stems from general-evaluability theory (Hsee, 1996; Hsee, Loewenstein, Blount, & Bazerman, 1999; Hsee, Yang, Li, & Shen, 2009; Hsee & Zhang, 2010; Shen, Hsee, Wu, & Tsai, 2012; Zhang, 2016). According to this theory, when the value of a low-evaluability attribute appears in isolation (i.e., in the single-evaluation mode), people are sensitive to its *sign* (whether the value is positive or negative) but insensitive to its *size* (how large the value is), because sign is easy to evaluate independently, but size is hard to evaluate independently. For example, in a single evaluation, people who contemplate how much to pay for a cup of ice cream are sensitive to whether the cup is over- or underfilled, but they are insensitive to how much ice cream the serving actually contains (Hsee, 1998, Study 2).

The preceding account extends to the *X number*. The *X number* is an unfamiliar, low-evaluability attribute, and each person encounters one *X number* only—in other words, it appears only in the single-evaluation mode. Because the magnitude and velocity of the *X number* are matters of size (and therefore are hard to evaluate independently), neither should influence people’s behavior. By contrast, whether the *X number* accelerates or

decelerates is a matter of sign (and therefore is easy to evaluate independently), and consequently it should make a difference. Acceleration is a positive change in velocity, and deceleration is a negative change in velocity, so although the original velocity is hard to evaluate, a positively changed (i.e., accelerated) velocity should seem fast (relative to the original velocity), make people feel good about their progress, and motivate them, whereas a negatively changed (i.e., decelerated) velocity should produce the opposite effects.

Our proposition that acceleration matters is consistent with results from Hsee and Abelson (1991), who found that the size of velocity matters in a within-subjects design. Manipulating the size of velocity within participants is equivalent to manipulating the direction of acceleration—slow to fast or fast to slow.

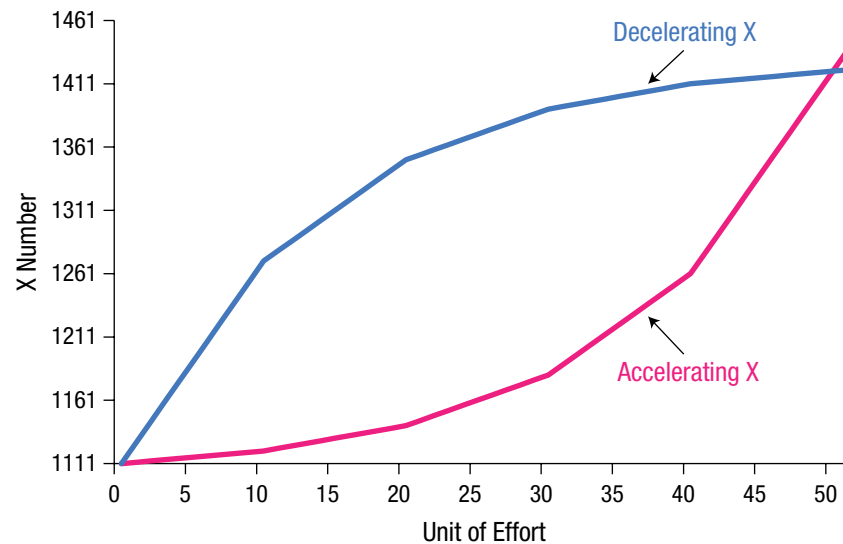
Next, we report six experiments that tested our theory. Experiments 1, 2, and 3 demonstrated the acceleration effect while controlling position and velocity. Experiment 4 tested the evaluability account. Experiments 5 and 6 replicated the acceleration effect in contexts in which performance lasted longer and had greater consequences.

For all lab experiments in this research (Experiments 1, 2, 3, and 5), we determined the sample size in advance as follows. We stopped data collection at the end of the day on which we had data from at least 20 participants in each cell; this sample size was recommended in the literature at the time the experiments were conducted (Simmons, Nelson, & Simonsohn, 2011). For the experiment conducted using Amazon’s Mechanical Turk (Experiment 4), we preset a sample size of 50 participants per cell during recruitment. For the field experiment (Experiment 6), it was impossible for us to determine the sample size in advance, so we simply included everyone who responded to our recruitment advertisement. For all experiments, additional experimental details and analysis results are reported in Section 1 of the Supplemental Material available online.

## Experiments 1 Through 3

### Method

This set of three experiments was designed to test our prediction in a well-controlled lab setting. In all of these experiments, there were at least two conditions: accelerating *X* and decelerating *X*. In each experiment, we predicted that participants in the accelerating-*X* condition would be more motivated than those in the decelerating-*X* condition. However, not only acceleration but also position and velocity varied between these conditions, because it is impossible to manipulate acceleration without also varying position and velocity. Across experiments, we manipulated acceleration by controlling position and



**Fig. 1.** Patterns of change in the X number in the accelerating-X and decelerating-X conditions of Experiments 1, 5, and 6. In Experiment 1, 1 unit of effort was equivalent to one entry of the target word (“applepie”). In Experiment 5, 1 unit of effort was equivalent to eight steps on a step machine (in this experiment, the same pattern was repeated in each of the four rounds in the two X-number conditions). In Experiment 6, 1 unit of effort was equivalent to the completion of one survey.

velocity at some points during the process and varying position and velocity at other points. We predicted that no matter how the position and the velocity of an X number were varied, the X number would always be more motivating if it accelerated than if it decelerated.

All three experiments used similar procedures. Participants took part individually using a computer. Participants were asked to enter a target “word” (“applepie” with no space in Experiment 1 and “type” in Experiments 2 and 3) as many times as possible in a 3-min period. During the experiment, all participants could see the number of times they had entered the target word and the time that had elapsed.

Participants in the conditions with an X number saw a number displayed at the center of their computer screen, and were told the number did not represent anything about their performance but that it would increase according to a predetermined pattern every time they entered the target word. To further minimize the likelihood that participants would associate the X number with specific meanings, we invited participants in each experiment to draw lots to randomly assign themselves to one of the patterns of change.

Experiment 1 involved 95 participants and comprised three conditions (accelerating X, decelerating X, and a no-X control condition), Experiment 2 involved 42 participants and comprised two conditions (accelerating X and decelerating X), and Experiment 3 involved 83 participants and comprised four conditions (accelerating X,

decelerating X, constantly fast X, and constantly slow X). All participants were recruited from a large private university in Chicago, Illinois. Figures 1 through 3 show how the X number changed in these three experiments.

## Results

**Experiment 1.** A one-way analysis of variance (ANOVA) revealed a significant effect of condition,  $F(2, 94) = 3.92$ ,  $p = .02$ ,  $\eta_p^2 = .08$ . Specifically, participants exerted more effort (i.e., they entered the target word more times) when seeing an accelerating X number ( $M = 83.13$ ,  $SD = 27.18$ ) than when seeing a decelerating X number ( $M = 68.87$ ,  $SD = 12.59$ ),  $t(59) = 2.64$ ,  $p = .01$ ,  $d = 0.69$ , 95% confidence interval (CI) for the mean difference =  $[-0.28, 24.84]$ , or seeing no X number at all ( $M = 70.85$ ,  $SD = 22.47$ ),  $t(62) = 1.98$ ,  $p = .05$ ,  $d = 0.50$ , 95% CI for the mean difference =  $[3.35, 25.17]$ . There was no significant difference between the decelerating-X condition and the no-X condition,  $t < 1$ ,  $p > .5$ . At first glance, the last result seems at odds with our theory, which would predict deceleration to be demotivating. However, comparing responses to the decelerating X number with responses to no X number was not a clean test of whether deceleration is demotivating, because the mere presence of an X number might have been interesting and motivating (Hsee et al., 2003). To better test whether deceleration is demotivating, we compared a decelerating X number with a constant-velocity X number in Experiment 3.

**Experiment 2.** Replicating our findings from Experiment 1, results in Experiment 2 showed that participants in the accelerating-X condition ( $M = 167.73$ ,  $SD = 41.01$ ) exerted more effort (i.e., they entered the target word more times) than did those in the decelerating-X condition ( $M = 133.40$ ,  $SD = 34.89$ ),  $t(40) = 2.91$ ,  $p < .01$ ,  $d = 0.90$ , 95% CI for the mean difference =  $[-10.64, 58.01]$ .

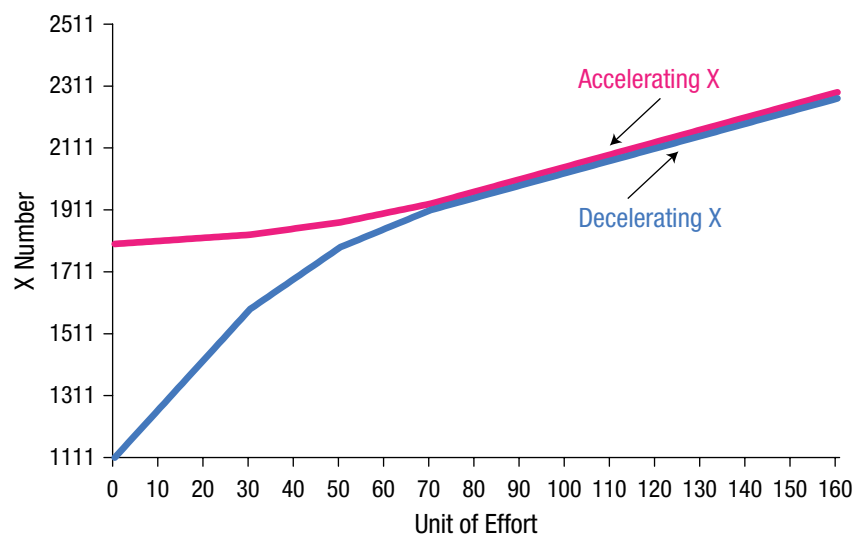
**Experiment 3.** For Experiment 3, a one-way ANOVA revealed a significant effect of the pattern of change in the X number,  $F(3, 82) = 7.53$ ,  $p < .001$ ,  $\eta_p^2 = .22$ . The accelerating-X condition ( $M = 167.10$ ,  $SD = 42.08$ ) induced more effort than did any of the other three conditions—the constantly-fast-X condition ( $M = 135.90$ ,  $SD = 27.31$ ),  $t(39) = 2.80$ ,  $p < .01$ ,  $d = 0.87$ , 95% CI for the mean difference =  $[8.89, 53.50]$ ; the constantly-slow-X condition ( $M = 141.33$ ,  $SD = 31.18$ ),  $t(40) = 2.25$ ,  $p = .03$ ,  $d = 0.70$ , 95% CI for the mean difference =  $[2.66, 48.86]$ ; and the decelerating-X condition ( $M = 118.81$ ,  $SD = 30.74$ ),  $t(40) = 4.25$ ,  $p < .001$ ,  $d = 1.31$ , 95% CI for the mean difference =  $[25.30, 71.27]$ . The constantly-fast-X condition did not induce more effort than the constantly-slow-X condition, even though the X number increased 10 times faster in the former condition than in the latter condition,  $t(70) = 1.12$ ,  $p = .27$ ,  $d = 0.19$ , 95% CI for the mean difference =  $[-23.93, 13.06]$ . Both of the constant-velocity conditions generated more effort than the decelerating condition—constantly-fast X versus decelerating X:  $t(39) = 1.88$ ,  $p = .07$ ,  $d = 0.59$ , 95% CI for the mean difference =  $[-35.44, 1.26]$ ; constantly-slow X versus decelerating X:  $t(40) = 2.36$ ,  $p = .02$ ,  $d = 0.73$ , 95% CI for the mean difference =  $[3.21, 41.84]$ .

The design of Experiment 3 also allowed us to distinguish the effect of velocity from the effect of acceleration. Note that the patterns of change in the constantly-slow and the accelerating-X conditions shared the same initial velocity, those in the constantly-fast and the decelerating-X conditions shared the same initial velocity, those in the constantly-slow and the decelerating-X conditions shared the same final velocity, and those in the constantly-fast and the accelerating-X conditions shared the same final velocity. Therefore, these four conditions can be construed as constituting a 2 (initial velocity: slow, fast)  $\times$  2 (final velocity: slow, fast) factorial design.

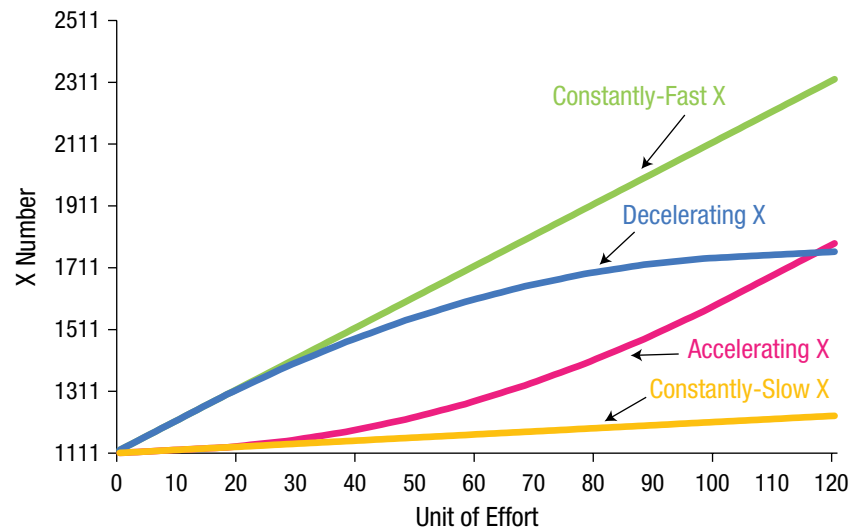
Accordingly, we conducted a two-way ANOVA and found a significant main effect of initial velocity,  $F(1, 82) = 13.44$ ,  $p < .001$ ,  $\eta_p^2 = .15$ , 95% CI for the mean difference =  $[0.03, 0.28]$ ; a significant main effect of final velocity,  $F(1, 82) = 8.55$ ,  $p < .01$ ,  $\eta_p^2 = .10$ , 95% CI for the mean difference =  $[0.01, 0.22]$ ; and no interaction between the two factors,  $F < 1$ ,  $p > .5$ . This result indicates that when the initial velocity was held constant, a faster final velocity yielded better performance, and when the final velocity was held constant, a slower initial velocity yielded better performance. Both are, by definition, the acceleration effect.

## Discussion

Together, Experiments 1 through 3 showed that the presence of an X number bolstered motivation, and that the X number was more motivating if it accelerated than if it decelerated. This result held true regardless of what other properties of the X number were controlled—overall



**Fig. 2.** Patterns of change in the X number in the accelerating-X and decelerating-X conditions of Experiment 2. One unit of effort was equivalent to one entry of the target word ("type").



**Fig. 3.** Patterns of change in the X number in the accelerating-X, decelerating-X, constantly-fast-X, and constantly-slow-X conditions of Experiments 3 and 4. In Experiment 3, 1 unit of effort was equivalent to one entry of the target word (“type”). In Experiment 4, participants watched the X number automatically increase in one of the four patterns.

velocity (Experiment 1), final velocity (Experiment 2), or both initial and final velocity (Experiment 3).

## Experiment 4

### Method

According to the evaluability account, the acceleration effect occurs because acceleration is easy to evaluate, whereas velocity is hard to evaluate. In other words, a constantly fast velocity would not feel faster than a constantly slow velocity, but a positively changed (accelerated) velocity would feel faster than a negatively changed (decelerated) velocity. Experiment 4 tested these predictions.

Participants recruited through Amazon’s Mechanical Turk ( $N = 167$ ) watched a video clip in which an X number automatically increased in one of the four patterns used in Experiment 3 (see Fig. 3)—namely, accelerating, decelerating, constantly fast, or constantly slow. At the end of the video clip, participants were asked, “How fast is the number increasing?” and indicated their answer using a scale from 1 (*extremely slowly*) to 9 (*extremely fast*).

### Results

A one-way ANOVA revealed a significant effect of the pattern of change in the X number,  $F(3, 167) = 85.48$ ,  $p < .001$ ,  $\eta_p^2 = .61$ . Participants rated the number’s change as faster in the accelerating-X condition ( $M = 7.48$ ,  $SD = 1.32$ ) than in any of the other three conditions—the constantly-fast-X condition ( $M = 4.88$ ,  $SD = 1.07$ ),  $t(82) = 9.87$ ,  $p < .001$ ,  $d = 2.18$ , 95% CI for the mean difference = [2.08, 3.12]; the constantly-slow-X condition ( $M = 4.55$ ,

$SD = 1.50$ ),  $t(82) = 9.51$ ,  $p < .001$ ,  $d = 2.10$ , 95% CI for the mean difference = [2.31, 3.54]; and the decelerating-X condition ( $M = 2.44$ ,  $SD = 1.87$ ),  $t(85) = 14.54$ ,  $p < .001$ ,  $d = 3.16$ , 95% CI for the mean difference = [4.33, 5.74]. Furthermore, participants rated the number’s change as not significantly faster (or slower) in the constantly-fast-X condition than in the constantly-slow-X condition,  $t(78) = 1.12$ ,  $p = .27$ ,  $d = 0.25$ , 95% CI for the mean difference = [−0.25, 0.90]. Finally, participants rated the number’s change in both the constantly-fast-X condition and the decelerating-X condition—constantly-fast X versus decelerating X:  $t(81) = 7.21$ ,  $p < .001$ ,  $d = 1.60$ , 95% CI for the mean difference = [1.77, 3.09]; constantly-slow X versus decelerating X:  $t(81) = 5.64$ ,  $p < .001$ ,  $d = 1.25$ , 95% CI for the mean difference = [−1.37, 2.85].

Notably, the number in the accelerating condition had the same final velocity as the number in the constantly-fast-X condition, yet participants rated the former as increasing faster than the latter. Conversely, the number in the decelerating-X condition had the same final velocity as the number in the constantly-slow-X condition, yet participants rated the former as increasing slower than the latter. Moreover, even though the number in the constantly-fast-X condition was increasing 10 times as fast as the number in the constantly-slow-X condition, participants did not rate the former as increasing at a different velocity than the latter. Together, these results suggest that what influenced the subjective perception of velocity was acceleration rather than velocity. These findings are consistent with the evaluability account, according to which acceleration is easy to evaluate (and thus influences performance), whereas velocity is not.

## Experiment 5

### Method

Like the first three experiments, Experiment 5 focused on behavior. In this experiment, we sought to extend the preceding findings on the acceleration effect in several ways. First, Experiment 5 involved a more tiring task: physical exercise. Second, we had participants go through four rounds of an X-number manipulation to test whether the acceleration effect was sustained over time. Finally, we measured not only participants' overall performance but also their moment-to-moment performance.

The experiment was run in a private gym room in Shanghai, China. Participants took part individually. They were asked to exercise as hard as possible on a step machine (i.e., to climb as many steps as they could). Each participant underwent four total rounds of such exercise. Each round lasted 2 min and was followed by a brief break.

To encourage participants to perform well in all rounds, we told them in advance that at the end of the experiment, the top performer in each round would receive 100 Chinese yuan (approximately US\$16) in cash. Thus, a participant could receive as much as 400 Chinese yuan (approximately US\$64).

As did Experiment 1, Experiment 5 included three between-subjects conditions: accelerating X, decelerating X, and no X (control; see Fig. 1). In all the conditions, the step machine was connected to an LCD screen. While exercising, each participant saw at least two numbers: the time elapsed (in seconds, presented on the left side of the screen) and a unit count reflecting performance (presented on the right side of the screen). Participants knew in advance that 1 unit was equivalent to eight steps. (We used eight steps rather than one step as a unit because if 1 unit were one step, the unit number in any condition would change too fast for participants to notice its pattern of change.) In addition, participants in the two X-number conditions saw an extra number in the middle of the screen. In each round, the number started from the beginning position, "1111," and followed the pattern shown in Figure 1.

Seventy-four male college students from multiple large public universities in Shanghai, China, participated in this experiment for a nominal payment plus an opportunity to earn the cash prize described earlier.

### Results

**Overall performance.** A  $3$  (condition: accelerating X, decelerating X, no X)  $\times 4$  (round: 1, 2, 3, 4) mixed-design ANOVA yielded a significant effect of condition,  $F(2, 213) = 19.15$ ,  $p < .001$ , with no significant effect of round and no significant interaction. In all rounds, the participants in the accelerating-X condition expended more effort than did the participants in either the decelerating-X condition or the

no-X condition, and this acceleration effect did not dwindle across rounds (Table 1).

**Moment-to-moment performance.** To further probe how participants reacted to the different patterns of change in the X number, we explored their moment-to-moment performance by using linear regression models with clustered observations to account for repeated measures. The analysis yielded the following findings (see Fig. 4). First, there was no interaction between round and condition, which again indicated that the acceleration effect did not fade over time. Second, within a round, the performance of the participants in the decelerating-X and no-X conditions weakened over time, probably as a result of fatigue—decelerating X:  $b = -0.05$ ,  $SE = -0.01$ ,  $p < .001$ , 95% CI for the mean difference =  $[-0.07, -0.04]$ ; no X:  $b = -0.03$ ,  $SE = 0.01$ ,  $p < .001$ , 95% CI for the mean difference =  $[-0.05, -0.01]$ . By contrast, the performance of the participants in the accelerating-X condition remained strong,  $b = -0.01$ ,  $SE = 0.01$ ,  $t < 0.05$ ,  $p > .6$ . It thus appears that seeing an accelerating X number can keep people going despite their fatigue.

### Discussion

Presenting participants with an accelerating X number significantly increased their performance in a physically exhausting activity, and this effect showed no sign of waning over repeated trials. The analysis of moment-to-moment performance confirmed that the effect was sustained within rounds. These results suggest that to motivate the users of an exercise machine, the designer of the machine could add an X number as a score on its display and program the number so that it accelerates as the user exercises.

## Experiment 6

### Method

Experiment 6 further extended the previous experiments. First, it was conducted in the field rather than in the lab. Second, whereas the other experiments lasted only a few minutes, this experiment lasted 8 hr. Third, to test the generality of the acceleration effect, we adopted a different method in this experiment than in the others: In the other experiments, the focal activity was a continuous task (e.g., continuous exercise on a step machine), the X number was displayed continuously as participants worked on the task, and the dependent variable was the speed at which the participants worked. In this experiment, the focal activity was a series of discrete tasks, the X number (operationalized as "points," which were symbolic tokens that could not be exchanged for any rewards) appeared only once every time a participant completed a

**Table 1.** Performance Results for Each Round in Experiment 5

| Round   | Condition <sup>a</sup> |                |              | Comparison of conditions <sup>b</sup>                               |                                                                     |                                                                    |
|---------|------------------------|----------------|--------------|---------------------------------------------------------------------|---------------------------------------------------------------------|--------------------------------------------------------------------|
|         | Accelerating X         | Decelerating X | No X         | Accelerating X vs. decelerating X                                   | Accelerating X vs. no X                                             | Decelerating X vs. no X                                            |
| Round 1 | 47.23 (8.89)           | 39.29 (9.36)   | 37.88 (6.37) | $t(48) = 3.08, p < .01, d = 0.87, 95\% \text{ CI} = [2.74, 13.14]$  | $t(48) = 4.25, p < .001, d = 1.20, 95\% \text{ CI} = [4.98, 13.73]$ | $t < 1, p > .5$                                                    |
| Round 2 | 48.85 (7.44)           | 40.42 (8.11)   | 36.13 (5.68) | $t(48) = 3.83, p < .001, d = 1.09, 95\% \text{ CI} = [3.99, 12.87]$ | $t(48) = 6.75, p < .001, d = 1.91, 95\% \text{ CI} = [8.97, 16.47]$ | $t(46) = 2.12, p = .039, d = 0.61, 95\% \text{ CI} = [0.22, 8.36]$ |
| Round 3 | 47.04 (7.78)           | 40.00 (8.61)   | 36.96 (6.17) | $t(48) = 3.04, p < .01, d = 0.86, 95\% \text{ CI} = [2.36, 11.72]$  | $t(48) = 5.05, p < .001, d = 1.43, 95\% \text{ CI} = [6.10, 14.06]$ | $t < 1.5, p > .15$                                                 |
| Round 4 | 46.69 (9.38)           | 38.42 (8.12)   | 35.63 (7.18) | $t(48) = 3.33, p < .01, d = 0.94, 95\% \text{ CI} = [3.30, 13.25]$  | $t(48) = 4.66, p < .001, d = 1.32, 95\% \text{ CI} = [6.34, 15.80]$ | $t < 1.5, p > .2$                                                  |

Note: One unit of effort was equivalent to eight steps on a step machine.

<sup>a</sup>These columns present mean values for units of effort, with standard deviations in parentheses.

<sup>b</sup>The 95% confidence intervals (CIs) in these comparisons are for the difference between means.

task, and the dependent variable was the total number of tasks the participant opted to complete during the 8-hr period.

The experiment was conducted using an online survey platform (similar to Amazon's Mechanical Turk) affiliated with a large public university in Hong Kong. The platform's participant pool (the workers) comprised local residents openly recruited from multiple public part-time-job Web sites (e.g., [www.parttime.hk](http://www.parttime.hk)). We blocked an exclusive 8-hr session on the online survey platform to conduct this experiment (i.e., during this session, the platform offered no other surveys) and tracked workers' activity. During the 8 consecutive hours, only one survey was shown at a time; a new survey was activated every 5 min, at which point the previous survey automatically expired. A total of 96 surveys were available over the course of the session (6 were canceled because of technical issues). All the surveys concerned evaluations of print advertisements, each took about 2 min to finish, and both the platform and the surveys were mobile-device friendly. The workers could choose to take or to skip each survey as it became available.

The day before the experiment, all workers were informed via e-mail about the procedure of the experiment. The e-mail explained that the 3 workers who completed the highest number of surveys would receive a cash prize of 500 Hong Kong dollars (approximately US\$65). The e-mail also explained that for every survey a worker completed, he or she would receive some points, that the points did not indicate how likely he or she was to win the cash prize, and that the points could not be exchanged or redeemed for anything. All these guidelines were also available in workers' individual accounts

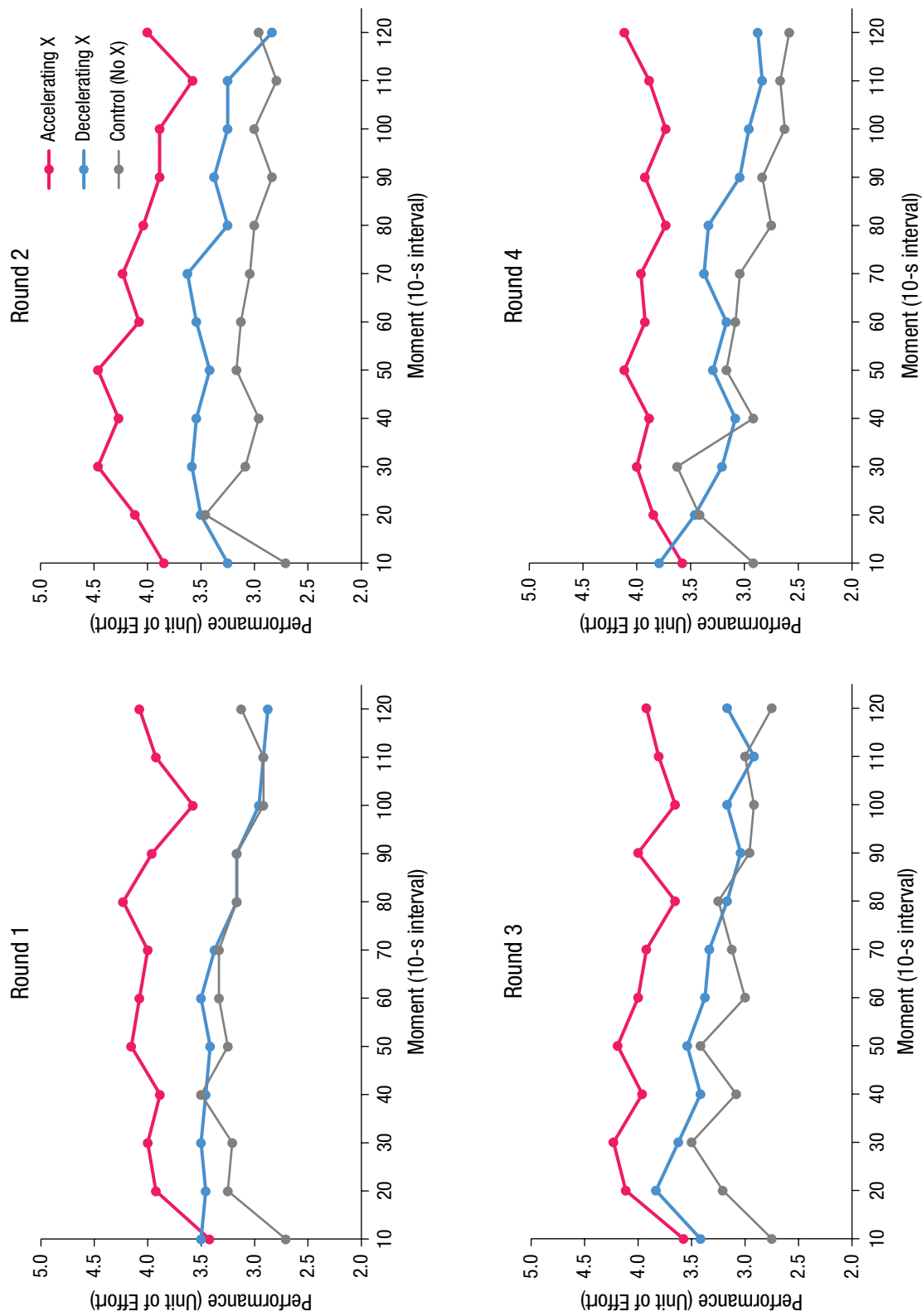
on the survey platform. All workers were required to confirm that they understood these instructions.

On the day of the experiment, every time a worker completed a survey, his or her computer screen displayed the total number of points he or she had received, as well as the number of points he or she had received for each completed survey so far. These points served as X numbers in the experiment.

We manipulated the points' pattern of change and examined its impact on workers' motivation during the 8-hr period. Specifically, we included two between-subjects conditions—accelerating X and decelerating X—and used the same patterns of change used in Experiment 5. Our measure of workers' motivation was the total number of surveys they completed during the 8-hr period.

## Results

Again, we replicated the acceleration effect: The workers who were presented with an accelerating X number completed significantly more surveys ( $M = 54.85, SD = 22.92$ ) than did the workers who were presented with a decelerating X number ( $M = 41.82, SD = 20.45$ ),  $t(52) = 2.21, p = .0318, d = 0.60, 95\% \text{ CI for the mean difference} = [1.13, 24.92]$ . Notably, the top 3 performers were all from the accelerating-X condition. A seemingly inconsequential X number thus turned out to be consequential, in that it significantly increased workers' chances of reaping the cash reward. These findings corroborate those from the other experiments, suggesting that an accelerating X number can increase motivation not only in lab settings and over a short time span, but also in naturally occurring settings and over a longer time span.



**Fig. 4.** Moment-to-moment performance in each condition of Experiment 5, shown separately for each of the four rounds. One unit of effort was equivalent to eight steps on a step machine.

## General Discussion

In this research, we investigated how people react to numbers and found that presenting an extra, increasing number can significantly enhance performance even if it conveys no substantive information.

Although this research was specifically focused on the acceleration aspect of a dynamic number, it suggests a more general principle. The movement of any changing variable can be characterized by its position and its derivatives with respect to time, such as its velocity and acceleration. Position is the most basic property; velocity is the first time derivative of position; and acceleration is the second time derivative of position, or the first time derivative of velocity. Each of these properties may vary either in sign or in size. For example, whether a number increases or decreases is a matter of the sign of its velocity, and how fast it increases or how fast it decreases is a matter of the size of its velocity.

A general principle about how a changing number changes behaviors is that people are sensitive to the sign of the number and its time derivatives, but not to the size of the number or its time derivatives. Following from this, we could further propose that people are (a) sensitive to the sign of position (reacting more positively to positive numbers than to negative numbers) but (b) insensitive to the size of position, (c) sensitive to the sign of velocity (reacting more positively to increasing numbers than to decreasing numbers) but (d) insensitive to the size of velocity, and (e) sensitive to the sign of acceleration (reacting more positively to accelerating numbers than to decelerating numbers) but (f) insensitive to the size of acceleration. The present research tested only a subset of these propositions, primarily (d) and (e).

Several qualifications are in order. First, although the general principle theoretically applies to high-order derivatives of position with respect to time as well as to low-order derivatives, high-order derivatives are practically hard to manipulate and hard to discern, and therefore are unlikely to produce the predicted effects. Second, the principle just described is more applicable to unfamiliar numbers, such as an X number, than to familiar numbers, such as a salary. Compared with the sign and the size of unfamiliar numbers, both the sign and the size of familiar numbers are easier to evaluate independently (e.g., Hsee, Salovey, & Abelson, 1994; Huang & Zhang, 2011; Kivetz, Urminsky, & Zheng, 2006; Koo & Fishbach, 2012; Morewedge, Kassam, Hsee, & Caruso, 2009). Third, the principle applies to numbers that people believe are better as they become larger, such as scores. A pretest showed that for the X number, participants did believe larger was better (see Section 2 of the Supplemental Material). Thus, the principle applies to the X number. However, the opposite principle would likely hold for numbers that people believe are better as they become smaller.

Our findings carry practical implications. In recent years, behavioral researchers have attempted to bring theory to practice by using *nudges*, which “[alter] people’s behavior in a predictable way without forbidding any options or significantly changing their economic incentives” (Thaler & Sunstein, 2008, p. 6). We advocate a type of nudging that we have dubbed *numerical nudging*. It is the art and science of using changing numbers to change behavior. In the current digital age, it is easy to add a score to the digital panel of a device and to program the pattern of change in that score. The current research demonstrates a prime example of numerical nudging: An accelerating X number can be used to enhance people’s performance in a predictable way without significantly changing their economic incentives.

## Action Editor

Leaf Van Boven served as action editor for this article.

## Author Contributions

L. Shen and C. K. Hsee developed the study concept and contributed to the study design. L. Shen carried out the testing, supervised data collection at multiple research centers (in Chicago, Illinois; Shanghai, China; and Hong Kong), and conducted the data analyses. L. Shen and C. K. Hsee worked on the manuscript together. Both authors approved the final version of the manuscript for submission.

## Acknowledgments

We thank Oleg Urminsky for his comments on early drafts and advice on statistical analyses.

## Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

## Funding

Support for this research was provided by the Research Grants Council of Hong Kong (Grant ECS 24501215) and the John Templeton Foundation.

## Supplemental Material

Additional supporting information can be found at <http://journals.sagepub.com/doi/suppl/10.1177/0956797617700497>

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