NUMERIC JUDGMENTS AND DECISIONS

Joowon Kim

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Supervisor of Dissertation

____

Deborah A. Small,

Laura and John J. Pomerantz Professor of

Marketing and Professor of Psychology

Co-Supervisor of Dissertation

____

Joseph P. Simmons,

Professor of Operations, Information, and

Decisions

Graduate Group Chairperson

____

Nancy R. Zhang,

Professor of Statistics

Dissertation Committee

Joseph Kable, Baird Term Professor of Psychology

Marissa Sharif, Assistant Professor of Marketing

DEDICATION

I dedicate this dissertation to:

my parents, Jongwook Kim and Jieun Park;

my spouse, Jason Klusowski;

my friend, Priscilla Lee; and

my committee members, Deborah Small, Joseph Simmons, Joseph Kable, and Marissa Sharif.

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ABSTRACT

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Deborah A. Small and Joseph P. Simmons

This dissertation investigates people's numeric judgments and decisions (e.g., probability estimation and quantity selection). The first chapter examines whether having a choice increases people's subjective probability of success. Previous research suggests that choice makes people feel more likely to achieve preferable outcomes, even when they are selecting among options that are functionally identical (i.e., choice causes an illusion of control). This notion has been widely accepted as evidence that choice can have significant welfare effects, even when it confers no actual control. However, a series of studies in this chapter shows that choice rarely makes people feel more likely to achieve preferable outcomes—unless it makes the preferable outcomes actually more likely—and when it does, it is not because choice causes an illusion, but because choice reflects some participants' pre-existing (illusory) beliefs that the functionally identical options are not identical. The second chapter examines whether people have the tendency to choose a certain class of numbers more frequently in quantity decisions (e.g., choosing how many units of an item to acquire or consume). Previous research suggests that people often choose one or multiples of five and ten as focal numbers when selecting quantities. Studies in this chapter show that even numbers constitute another class of focal numbers, i.e., people are more likely to choose even numbers than odd numbers across a variety of quantity decisions, even excluding multiples of ten. This tendency attenuates when people can fluently retrieve an odd focal number (e.g., one unit per person) or fluently process an odd number (e.g., nine units organized in a three-by-three array). Overall, this dissertation aims to improve an understanding of people's numeric judgments and decisions.

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CHAPTER 1: Does Choice Cause an Illusion of Control?

Joowon Klusowski, Deborah A. Small, and Joseph P. Simmons

Introduction

Choice confers obvious benefits: It allows people to acquire either objectively better or subjectively more preferred options, rather than worse, less preferred options. In addition, research suggests that choice confers non-obvious benefits as well. Decades of evidence suggest that even when all options are functionally identical (e.g., lottery tickets with an identical chance of winning), having a choice imbues people with an illusory sense of control, a feeling that they are more likely to achieve preferable outcomes (e.g., winning a lottery; Langer, 1975; Nichols, Stich, Leslie, & Klein, 1996; Wohl & Enzle, 2002; Wortman, 1975). While such an illusory sense of control can distort people's judgments or decisions, it has also been hypothesized to provide numerous psychological and physiological benefits (Plous, 1993; Taylor & Brown, 1988). Accordingly, this research has been taken as evidence that choice can have significant welfare effects, even when it is trivial, incidental, or illusory and does not necessarily allow people to acquire better, more preferred options (Botti & Iyengar, 2004; Huang, Wang, & Shi, 2009; Iyengar & Lepper, 2000; Leotti & Delgardo, 2011; Patall, 2019).

The claim that choice causes an illusion of control has its roots in studies investigating lotteries, in which all options have an identical chance to win. Langer (1975) famously reported that people who chose their own lottery ticket were more reluctant to sell or exchange their ticket than people who were assigned a ticket, suggesting that choice made people feel more likely to win the lottery. This finding has been highly influential, as reflected in its high citation count (i.e., > 5,000 on Google Scholar) and its acceptance among many scholars as an empirical fact. For example, the seminal paper by Iyengar and Lepper (2000) references this work and says "many important theories in social psychology . . . all presume that even purely illusory perceptions of choice will have powerful effects" (p. 995). The influential textbook by Aronson (2012) also states that “the illusion of control . . . is a powerful one. It is small wonder that most state lotteries allow us to select our own numbers” (p. 169). Likewise, when we started this research, we had every expectation that the effect would be robust.

However, our investigation has led us to a different conclusion. In this article, we suggest that (1) some of the most-cited evidence for this notion is susceptible to alternative explanations, (2) the phenomenon rarely occurs in well-controlled experiments, and (3) when it does, it is not because choice *causes* an illusion of control, but rather because choice *reflects* some participants' pre-existing beliefs that functionally identical options are not actually identical.

Past Research

Although Langer (1975) is widely cited as showing that choice causes an illusion of control, those findings on reluctance to sell or exchange one's lottery ticket are susceptible to alternative explanations. First, since the lottery tickets in these studies featured different football players, letters, or symbols, participants who chose their ticket may have simply liked their ticket more for featuring their preferred player/letter/symbol. Second, given that active decisions tend to trigger greater anticipated regret, participants who actively chose their ticket may have anticipated greater regret from forgoing their ticket and seeing it win (Kahneman & Miller, 1986; Risen & Gilovich, 2007; van de Ven & Zeelenberg, 2011). Thus, participants who chose their ticket may have been more reluctant to sell or exchange their ticket without necessarily feeling that their ticket was more likely to win. Similarly, other researchers have suggested that some patterns that appear consistent with a choice-driven illusion of control could also result from alternative factors (e.g., other forms of active involvement, enjoyment associated with “special numbers,” or regressive estimates of one's control) or do not always replicate (Filippin & Crosetto, 2016; Gino, Sharek, & Moore, 2011; Goodman & Irwin, 2006; Kühberger, Perner, Schulte, & Leingruber, 1995; Martinez, Bonnefon, & Hoskens, 2009).

There is also a separate, more subtle problem with research on the choice-driven illusion of control: Some participants who are faced with functionally identical options may not believe that the options are functionally identical. To illustrate, imagine that people are asked to choose among three lottery tickets and that they are told that all three are equally likely to win. Also imagine that, despite that instruction, some participants incorrectly believe that the ticket presented in the middle is more likely to win. If given a choice, those participants will choose the middle ticket and, consistent with their prior beliefs, will indicate that it is more likely to win. However, if instead they are randomly assigned a ticket, the majority of those participants will not be assigned the middle ticket and thus will not indicate that their ticket is more likely to win. Overall, then, participants who choose their tickets will judge their ticket to be more likely to win than those who are assigned their ticket. However, this is not because choice *causes* an illusion of control, but rather because choice *reflects* a pre-existing belief that some options are more likely to win than the others, despite instructions to the contrary.

Thus, to establish evidence that choice causes an illusion of control, research needs to demonstrate two things, in a context in which all options are functionally identical: (1) choosers feel more likely to achieve preferable outcomes than do non-choosers and (2) this is caused by the choice rather than reflective of pre-existing beliefs.

Present Research

In this article, we report the results of 17 highly powered pre-registered experiments (N = 10,825) that examined whether choice causes an illusion of control. Specifically, these studies tested whether people faced with a choice among functionally identical options feel—or act as if they feel—more likely to achieve preferable outcomes than those without such a choice, and, if they do, whether choice causes this illusion. All of our study materials, pre-registrations, data, and code are available at the links provided in the Appendix.

Studies 1-9

Methods

Participants. We conducted Studies 1-7 on Amazon Mechanical Turk (MTurk), using lotteries as stimuli. We requested 800 participants per study for Studies 1-2, 400 per study for Studies 3-4, 800 for Studies 5 and 6, and 400 for Study 7. In this research, we selected these large samples of up to 200 participants per condition to achieve better statistical power and reliability. In Studies 1-7, we excluded responses from participants who did not complete the entire survey or who did not submit their work on MTurk with the correct completion code. In case any participant completed the survey more than once, we excluded responses with later start times. Across Studies 1-7, we excluded 138 incomplete and 14 complete responses, and achieved sample sizes that closely approximated our plans (Table 1). In Studies 1-7, the average age ranged from 36 to 40, and the proportion of females ranged from 41% to 60%.

We conducted Study 8 on MTurk and Study 9 in the Wharton Behavioral Lab at the University of Pennsylvania, using chocolates as stimuli. We requested 400 participants in Study 8 and at least 450 in Study 9. In Study 8, we applied the same exclusion criteria as in Studies 1-7, and accordingly excluded one incomplete and two complete responses. In Study 9, we excluded 15 incomplete and no complete responses. In both studies, we achieved sample sizes that closely approximated our plans (see Table 1). In Study 8, the average age was 36, and the proportion of females was 47%. In Study 9, the average age was 23, and the proportion of females was 68%.

Procedures. In Studies 1 and 2, participants played a lottery, following common paradigms in previous research (Charness & Gneezy, 2010; Dixon, 2000; Dunn & Wilson, 1990; Fellner, 2009; Koehler, Gibbs, & Hogarth, 1994; Langer, 1975; Nichols, Stich, Leslie, & Klein, 1996). In these studies, participants were randomly assigned to one of four conditions in a 2 x 2 design: Choice (Choice vs. No-choice) x Timing of Choice (Choice-first vs. Choice-last). Participants in the Choice condition chose three different integers from one to six, while participants in the No-choice condition were assigned three different randomly selected integers from one to six. In addition to this choice manipulation, we also varied the timing of choice. Specifically, participants in the Choice-first condition chose or were assigned the numbers before the lottery's winning number was determined, while participants in the Choice-last condition did so after the winning number had already been determined but before it was revealed. Motivated by research showing that people tend to believe that they have more control over future than past outcomes (Williams & LeBoeuf, 2020), our goal was to examine whether the timing of choice moderates the effects of choice on the illusion of control. The winning number in these studies was randomly selected by the computer for each participant. If a participant's three numbers included the winning number, then the participant would win the lottery and receive a $.20 bonus. We used this small bonus amount because past studies suggested that the illusion of control was more likely to be in evidence for smaller stakes than larger stakes (e.g., $0.50 vs. $5.00; Dunn & Wilson, 1990).

After participants' numbers were chosen or assigned, we assessed participants' subjective likelihood of winning. In Study 1, we asked participants, "How likely do you feel you are to win this lottery?" on a nine-point scale ranging from 1 (*extremely unlikely*) to 9 (*extremely likely*). In Study 2, we used a more feeling-based measure of subjective likelihood. First, we asked participants, "How do you feel about your numbers?" on a seven-point scale ranging from 1 (*I feel like my numbers have a very poor chance of winning*) to 7 (*I feel like my numbers have a very good chance of winning*). Then, we asked them, "How confident/unconfident do you feel that you will win this lottery?" on a seven-point scale ranging from 1 (*extremely unconfident*) to 7 (*extremely confident*). The two measures were highly correlated, $r(798) = .77$; $p < .001$, and we averaged them to create a measure of subjective confidence.

In Study 3, participants played a similar lottery, but the key dependent variable was incentive-compatible: the amount wagered on the outcome of the lottery (Dunn & Wilson, 1990). In this study, participants were randomly assigned to either the Choice or the No-choice condition. Participants in the Choice condition chose an integer from one to six, whereas participants in the No-choice condition were randomly assigned one of the six numbers. Then participants received a $0.50 bonus and decided how much of it to bet on their number. If their number matched the winning number—which the computer randomly selected from one to six for each participant—they would receive six times the amount they wagered. Otherwise, they would simply lose the amount they wagered.

In Study 4, we gave participants the same lottery as in Study 3, but in a different format. In particular, we replaced the six numbers with six different colors on a roulette wheel: red, orange, yellow, green, blue, and purple. We also showed participants an example of the roulette wheel spinning and stopping before the choice manipulation. In this study, participants completed all outcome measures from Studies 1-3.

In Studies 5-7, we tried to see whether choice would induce an illusion of control when participants could not easily compute the probability of winning (Study 5) or when the probability of winning was truly ambiguous (Studies 6 and 7). In these three studies, we used wager amount as our primary dependent variable, and we also measured subjective confidence (using 7-point scales in Studies 5 and 6, and a 10-point scale in Study 7). In Study 5, the lottery involved harder-to-compute compound risk, such that participants had to have two "winning numbers" to win. Specifically, participants were presented with six numbers, and they were told that half of them would be "winning numbers" and half would be "losing numbers." They either chose or were randomly assigned two numbers out of the six. If both of their numbers were "winning numbers," they would win the lottery and receive six times the amount they wagered. In Studies 6 and 7, the lottery offered truly ambiguous odds of winning. In Study 6, participants either chose or were randomly assigned a number from one to six, and they were told that "at least one and at most five of them" were "winning numbers." If their number was selected to be a "winning number," they received six times the amount that they wagered. In Study 7, participants either chose or were randomly assigned a number from 1 to 10, and they were told that "some" of these numbers were "winning numbers." If their number was selected to be a "winning number," they received twice the amount that they wagered.

In Studies 8 and 9, we used chocolates as stimuli, in an attempt to test whether the hypothesized effect might manifest for more subjective, preference-based stimuli (Botti & McGill, 2006). In Study 8, participants saw a picture of six identical-looking chocolates on their computer screen. Participants were told that while the chocolates looked identical on the outside, they were different flavors. In this hypothetical task, participants in the Choice condition imagined choosing one of the chocolates themselves, whereas participants in the No-choice condition imagined receiving a randomly selected chocolate. Participants then responded to two questions: "How happy do you think you will be with the chocolate you chose/were given?" and "How tasty do you think the chocolate will be?" on nine-point scales from 1 (*not at all*) to 9 (*extremely*).

In Study 9, we replicated Study 8 in the laboratory, using real chocolates. Participants were presented with four identical-looking chocolates in small clear cups with lids in front of them. They were told that the chocolates may contain different flavors, although, in reality, all chocolates had the same flavor (i.e., plain dark chocolate). In this study, participants were randomly assigned to the Choice or No-choice condition. Participants in the Choice condition chose a chocolate to eat themselves, while those in the No-choice condition were randomly assigned a chocolate. After choosing or being assigned a chocolate, participants rated their predicted satisfaction with their chocolate: an average of how satisfied they would be with their chocolate and how much they would enjoy their chocolate, on nine-point scales ranging from 1 (*not at all*) to 9 (*extremely*). In addition, participants rated their actual satisfaction with the chocolate after tasting it, using identical scales. In order to increase statistical power, we pre-registered to ask participants how much they like/dislike dark chocolate in general at the very beginning of the survey, on a scale ranging from 1 (*dislike extremely*) to 7 (*like extremely*) and to include this variable as a covariate after mean-centering it. In this study, there was also a third, "Choosing-To-Choose" condition. In this condition, participants could decide between choosing a chocolate themselves and having one randomly selected for them.

Results

We analyzed participants' responses using either ordinary least squares (OLS) regressions (+.5: Choice vs. -.5: No-choice; +.5: Choice-first vs. -.5: Choice-last) or independent sample t-tests, following our pre-registered analyses plans. Table 1 displays the results. In Studies 1-7, participants who chose their own lottery options did not feel more likely to win than participants who were assigned lottery options. In Studies 8 and 9, participants who were given a choice among chocolates neither predicted nor experienced greater satisfaction with their chocolate than did participants who were given no choice. In summary, we did not find evidence that participants who had a choice felt more likely to achieve preferable outcomes than participants who had no choice. In addition, the "Choosing-To-Choose" condition in Study 9 indicated that 31% of the participants decided to choose themselves, whereas 69% decided to have one randomly selected, which significantly differed from proportions expected by chance ($p < .001$). In other words, at least in this study, participants did not even prefer choice over random selection.

In these studies, we found no effects of choice on participants' subjective likelihood of achieving preferable outcomes. However, perhaps our outcome measures were not sensitive enough to pick up any difference that exists in reality. This seems unlikely, since (1) many of these outcome measures mirrored those used in past research on the illusion of control and (2) the estimated coefficients did not consistently have a positive sign. Nevertheless, to investigate this possibility, Studies 10-11 examined whether our outcome measures responded to choice when it *actually* made preferable outcomes more likely.

					Results					
					Choice	No-choice	Statistical Test			Effect Size
Study	*N*	Stimuli	DV(s)	Condition	*M* (*SE*)	*M* (*SE*)	*t*	*df*	*p*	*d* [95% CI]
1[a]	794	Lottery: Die-roll	Likelihood	Aggregate	5.49 (0.08)	5.45 (0.09)	0.34	792	.738	0.02 [-0.12, 0.16]
				Choice-first	5.60 (0.11)	5.52 (0.12)	0.51	396	.610	0.05 [-0.15, 0.25]
				Choice-last	5.38 (0.12)	5.39 (0.12)	-0.04	394	.971	-0.00 [-0.20, 0.19]
2[a]	800	Lottery: Die-roll	Confidence	Aggregate	4.54 (0.06)	4.54 (0.06)	0.05	798	.957	0.00 [-0.13, 0.14]
				Choice-first	4.49 (0.09)	4.48 (0.08)	0.09	397	.931	0.01 [-0.19, 0.21]
				Choice-last	4.59 (0.09)	4.59 (0.09)	0.00	399	.997	0.00 [-0.20, 0.20]
3	399	Lottery: Die-roll	Wager		0.21 (0.01)	0.21 (0.01)	0.05	397	.963	0.00 [-0.19, 0.20]
			Confidence[c]		2.78 (0.10)	3.01 (0.11)	-1.57	397	.117	-0.16 [-0.35, 0.04]
4	400	Lottery: Roulette	Wager		0.12 (0.01)	0.11 (0.01)	1.28	398	.202	0.13 [-0.07, 0.32]
			Likelihood		3.29 (0.17)	2.95 (0.15)	1.50	398	.134	0.15 [-0.05, 0.35]
			Confidence		3.15 (0.18)	2.91 (0.16)	0.99	398	.322	0.10 [-0.10, 0.30]
5	399	Lottery: Compound Risk	Wager		0.26 (0.01)	0.28 (0.01)	-1.25	397	.214	-0.12 [-0.32, 0.07]
			Confidence[c]		3.52 (0.10)	3.72 (0.10)	-1.38	397	.168	-0.14 [-0.34, 0.06]
6	399	Lottery: Ambiguity	Wager		0.27 (0.01)	0.26 (0.01)	0.26	397	.798	0.03 [-0.17, 0.22]
			Confidence[c]		3.45 (0.10)	3.47 (0.11)	-0.15	397	.885	-0.01 [-0.21, 0.18]
7	400	Lottery: Ambiguity	Wager		0.27 (0.02)	0.28 (0.02)	-0.19	398	.847	-0.02 [-0.22, 0.18]
			Confidence[c]		3.02 (0.17)	3.24 (0.19)	-0.84	398	.401	-0.08 [-0.28, 0.11]
8	398	Chocolates: Images	Predicted happiness		5.90 (0.13)	6.19 (0.12)	-1.63	396	.103	-0.16 [-0.36, 0.03]
			Predicted taste		6.38 (0.12)	6.46 (0.12)	-0.45	396	.655	-0.04 [-0.24, 0.15]
9[b]	301	Chocolates	Predicted satisfaction		6.03 (0.15)	5.94 (0.19)	0.37	299	.709	0.04 [-0.18, 0.27]
			Actual satisfaction		7.11 (0.15)	7.00 (0.17)	0.51	299	.611	0.06 [-0.17, 0.29]

[a]There was no significant interaction effect between Choice and Timing of Choice either in Study 1, b = 0.09; $t(790)$ = 0.39, p = .700, or Study 2, b = 0.01, $t(796)$ = 0.06, p = .953.

[b]There was a significant interaction effect between Choice and Baseline Liking for dark chocolates (mean-centered) on Predicted Satisfaction, b = -0.23, $t(297)$ = -2.85, p = .005, indicating that the effect of Baseline Liking on Predicted Satisfaction was smaller in the Choice condition than in the No-choice condition. There was no significant interaction effect between Choice and Baseline Liking on Actual Satisfaction, b = -0.10, $t(297)$ = -0.98, p = .327. Including or excluding Baseline Liking did not substantively change the effects of choice on either Predicted or Actual Satisfaction.

[c]These dependent variables were not pre-registered.

Table 1. Summary of the results from Studies 1-9.

Studies 10-11

Methods

Participants. We conducted Studies 10-11 on MTurk. We requested 800 participants per study. In these studies, we applied the same exclusion criteria as in Studies 1-7. Across these two studies, we excluded 17 incomplete and 11 complete responses, and achieved sample sizes that closely approximated our plans. The final sample size was 796 in Study 10 and 794 in Study 11. The average age was 39 in both samples, and the proportion of females was 53% in Study 10 and 55% in Study 11.

Procedures. In Study 10, participants played a lottery, similar to those in Studies 1-7. In this study, we not only manipulated choice, but also whether the choice actually made preferable outcomes more likely. Specifically, participants were randomly assigned to one of four conditions in a 2 x 2 design: Choice (Choice vs. No-choice) x Control (Illusory-control vs. Actual-control). As in Studies 1-7, participants in the Choice condition could choose one of six numbers, whereas those in the No-choice condition were randomly assigned a number. In the Illusory-control condition, all six numbers had an identical 35% chance of winning. Once participants either chose or received their number, the computer randomly determined whether their number won, such that all participants independently had a 35% chance of winning. As a result, participants who had a choice could not increase their chance of winning. However, in the Actual-control condition, the six numbers had different probabilities of winning: Each number from one to six independently had a 10%, 20%, 30%, 40%, 50%, and 60% chance of winning, respectively. Once participants either chose or received their number, the computer randomly determined whether their number won, such that those with number one had a 10% chance of winning, those with number two had a 20% chance of winning, and so on. Therefore, participants who had a choice could select the numbers that were more likely to win and increase their chance of winning. Before these outcomes were revealed, participants received a $0.50 bonus, and decided how much of it to bet on their number. If their number won, they would receive three times the amount they wagered. Otherwise, they would lose the amount they wagered.

If this incentive-compatible measure showed no difference between the Choice and the No-choice conditions in both the Illusory-control and the Actual-control conditions, it would suggest that our outcome measure was simply not sensitive enough to pick up any real difference. In contrast, if this outcome measure showed no difference in the Illusory-control condition but showed a significant difference in the Actual-control condition, it would indicate that the null effects in earlier studies did not simply result from the insensitivity of our outcome measures.

In Study 11, we tested the same hypothesis, but using pictures of chocolates as stimuli, following similar procedures as in Study 8. Participants were randomly assigned to one of four conditions in a 2 x 2 design: Choice (Choice vs. No-choice) x Control (Illusory-control vs. Actual-control). Participants in the Choice condition imagined choosing a chocolate themselves, whereas those in the No-choice condition imaged receiving a randomly selected chocolate. In the Illusory-control condition, participants saw a picture of six identical-looking chocolates that were unlabeled. Therefore, even though these participants were told which flavors were present in the set, having a choice would not make them more likely to select the preferable flavors. In the Actual-control condition, participants saw the identical picture, but the chocolates were labeled with their flavors. As a result, having a choice would allow them to select their preferred flavor. We assessed participants' predicted satisfaction with their chocolate, by asking and averaging how happy they thought they would be with their chocolate and how tasty they thought their chocolate would be, on nine-point scales ranging from 1 (*not at all*) to 9 (*extremely*). Again, if this measure showed no difference between the Choice and the No-choice participants in both the Illusory-control and the Actual-control conditions, it would indicate that our outcome measure was not sensitive enough. In contrast, if this measure showed no difference in the Illusory-control condition but showed a significant difference in the Actual-control condition, it would indicate that null effects did not simply arise from insensitive measures.

Results

In Study 10, we analyzed participants' wagers using an OLS regression with the Choice condition (+.5: Choice vs. -.5: No-choice), Control condition (+.5: Actual-control vs. -.5: Illusory-control), and their two-way interaction. We found a significant interaction between the Choice and the Control conditions, $t(792) = 2.04$, $p = .042$. Specifically, choice did not increase participants' wagers when the lottery numbers had an identical probability of winning (M_{choice} = .18, SE_{choice} = .01; $M_{no\text{-}choice}$ = .18, $SE_{no\text{-}choice}$ = .01), $t(395) = 0.35$, $p = .724$, $d = 0.04$ [-0.16, 0.23]. However, it did increase wagers when the numbers had different probabilities of winning (M_{choice} = .25, SE_{choice} = .01; $M_{no\text{-}choice}$ = .20, $SE_{no\text{-}choice}$ = .01), $t(397) = 3.15$, $p = .002$, $d = 0.31$ [0.12, 0.51].

In Study 11, we analyzed participants' predicted satisfaction with their chocolate using an OLS regression with the Choice condition (+.5: Choice vs. -.5: No-choice), Control condition (+.5: Actual-control vs. -.5: Illusory-control), and their two-way interaction. Again, we found a significant interaction between the Choice and the Control conditions, $t(790) = 6.38$, $p < .001$. Choice did not increase participants' predicted satisfaction with their chocolate when the chocolates were unlabeled (M_{choice} = 6.37, SE_{choice} = .12; $M_{no\text{-}choice}$ = 6.19, $SE_{no\text{-}choice}$ = .12), $t(396) = 1.02$, $p = .308$, $d = 0.10$ [-0.09, 0.30], but it did when the chocolates were clearly labeled (M_{choice} = 7.84, SE_{choice} = .08; $M_{no\text{-}choice}$ = 6.04, $SE_{no\text{-}choice}$ = .17), $t(394) = 9.42$, $p < .001$, $d = 0.95$ [0.74, 1.15].

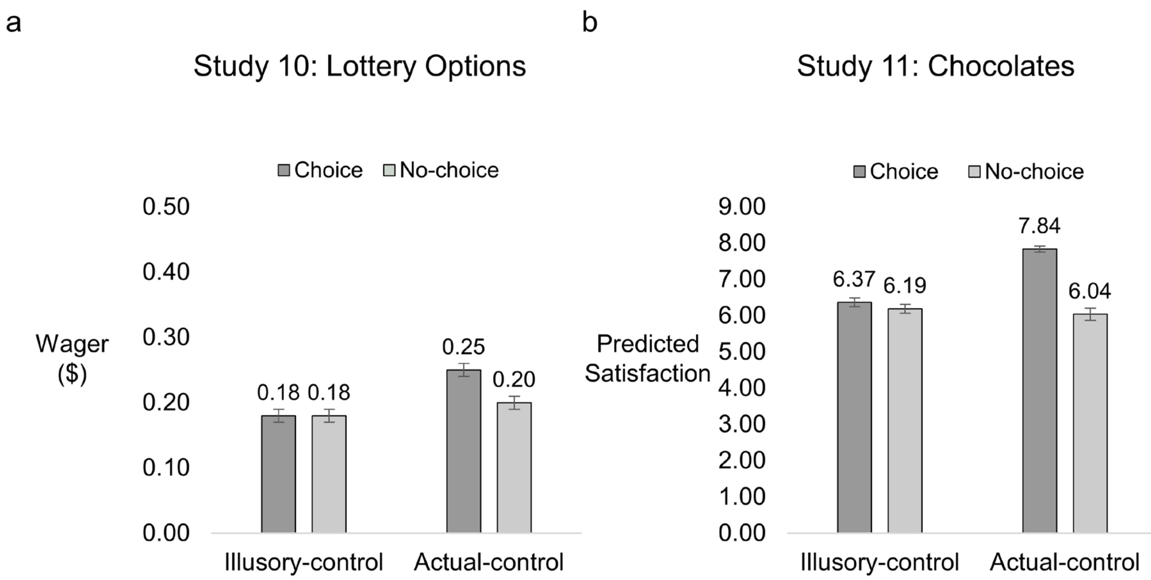

Figure 1. Summary of the results from Studies 10-11. Error bars indicate standard errors.

Together, these results indicate that choice does not make people feel more likely to achieve preferable outcomes if all options are functionally identical. Yet it does confer such an advantage when the options are meaningfully differentiated, making choosers actually more likely to achieve the preferable outcomes. These findings rule out the alternative explanation that the null effects obtained across the 11 studies simply result from insensitive outcome measures.

While we did not find evidence consistent with a choice-driven illusion of control across these contexts, there was at least one outcome measure we had not yet tried. We had not yet asked participants to estimate their probability of winning (Sloof & von Siemens, 2017). We had not used this measure because we thought that participants would feel compelled to report the true, objective probability of winning, causing the measure to be too insensitive to capture a choice-driven illusion of control. Nevertheless, after eleven failed attempts, we decided to try it.

Studies 12-15

Methods

Participants. We conducted Studies 12-15 on MTurk. We requested 800 participants per study in Studies 12-14 and 1,200 in Study 15. In these studies, we excluded responses from participants who did not complete the entire survey or did not submit their work on MTurk to receive compensation. In case any participant completed the survey more than once, we excluded responses with later start times. Across Studies 12-15, we excluded 62 incomplete and 9 complete responses, and achieve sample sizes that closely approximated our plans (Table 2). In these studies, the average age ranged from 37 to 40, and the proportion of females ranged from 53% to 55%.

Procedures. In Studies 12, 13, and 14, participants played a lottery with two, three, and four identical-looking boxes, respectively (Sloof & von Siemens, 2017). In these studies, participants were randomly assigned to one of four conditions in a 2 x 2 design: Choice (Choice vs. No-choice) x Number of Evaluated Options (One-option vs. All-options). Participants saw a picture of identical-looking boxes, and learned that one of the boxes contains a $1.00 bonus. Participants in the Choice condition chose one of the boxes, while participants in the No-choice condition were randomly assigned one of the boxes. If their box contained the bonus, they would receive the bonus. In addition to the choice manipulation, we also varied the number of the options evaluated by participants (i.e., one vs. all), to see whether this might moderate the effects of choice. Specifically, participants in the One-option condition saw a picture of the identical-looking boxes, with their chosen or assigned box highlighted, and read the following: “Please let us know how likely it seems to you that this box contains the $1.00 bonus.” They responded to this question by entering a probability estimate for their box, which could range from 0% to 100%. Participants in the All-options condition saw a picture of the identical-looking boxes, with their chosen or assigned box highlighted, and read the following: "Please let us know how likely it seems to you that each of these boxes contains the $1.00 bonus." They responded to this question by entering a probability estimate for each of the boxes, which could individually range from 0% to 100% but collectively had to add up to 100%. The dependent variable in these studies was the probability estimate for one's own box, representing one's subjective probability of winning the lottery.

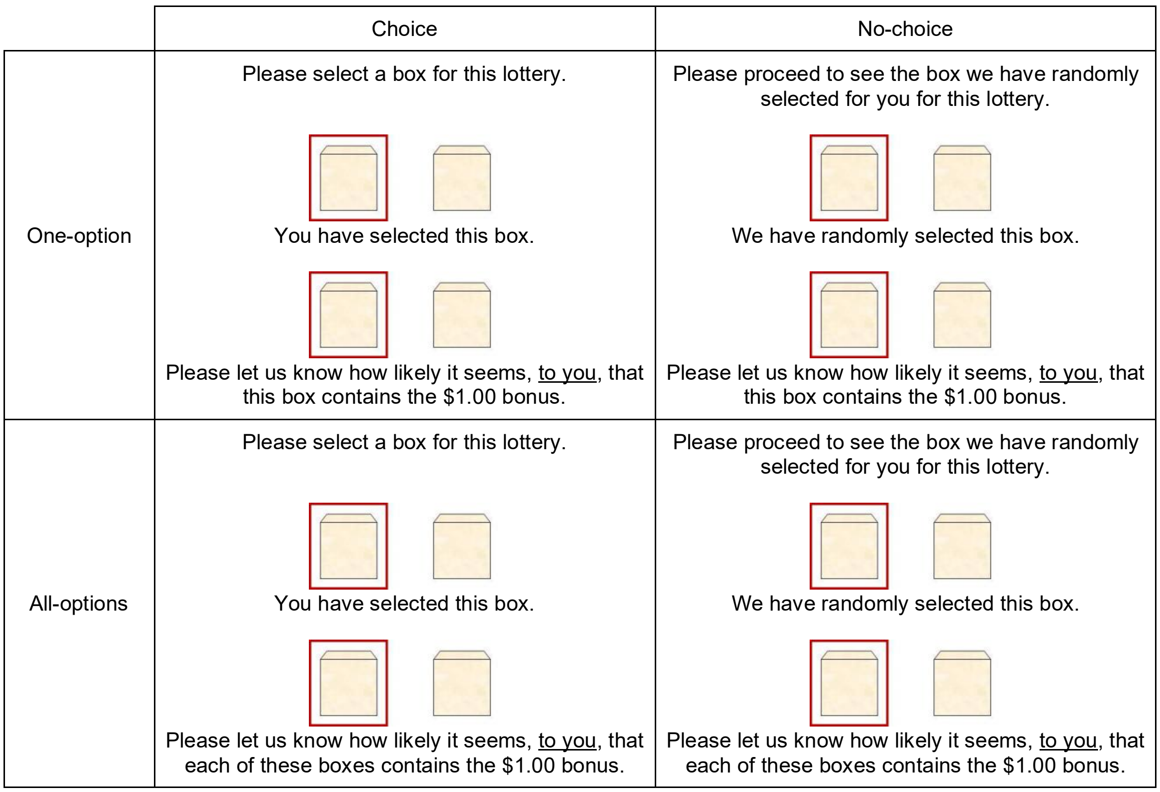

Figure 2. Summary of the experimental manipulations in Study 12.

In Study 15, we used a similar lottery with three boxes, but with two changes. First, we emphasized the randomness of the lottery by explicitly informing participants that "the computer will randomly select the winning box" and that "each box will have an equal chance of being selected as the winning box." Second, we formatted the response options in two ways. Specifically, participants in this study were randomly assigned to one of four conditions in a Choice (Choice vs. No-choice) x Outcome Measure (Probability-estimates vs. Multiple-choice) design. Participants in the Choice and No-choice conditions received the same choice manipulation as in Studies 12-14. Participants in the Probability-estimates condition saw a picture of the three boxes, with their box highlighted, and read the following: “How likely does it seem to you that each of these boxes will be randomly selected as the winning box?” They answered this question by entering a probability estimate for each of the three boxes, which could individually range from 0% to 100% but collectively had to add up to 100%. Participants in the Multiple-choice condition saw a picture of the three boxes, with their box highlighted, and read the following: “How likely does it seem to you that this box will be randomly selected as the winning box?” They answered this question by choosing one of three options: “Compared to the other boxes, more likely, equally likely, or less likely to be selected as the winning box.” In this study, we pre-registered to analyze the dependent variables in three different ways. First, to compare the Choice and the No-choice conditions within the Probability-estimates condition, we analyzed participants’ probability estimate for their selected box. Second, to compare the Choice and the No-choice conditions within the Multiple-choice condition, we analyzed the proportion of participants who indicated that their box was more likely to be selected than the other boxes. Third, to analyze the data altogether under one measure, we transformed the probability estimates such that any estimate greater than 34% was recorded as “more likely to be selected as the winning box”. Then we analyzed the proportion of participants who indicated that their box was more likely to be selected across all four conditions.

Results

Table 2 summarizes the results across Studies 12-15. We analyzed participants’ responses using OLS regressions (+.5: Choice vs. -.5: No-choice; +.5: One-option vs. -.5: All-options; +.5: Probability-estimates vs. -.5: Multiple-choice), following our pre-registered analyses plans. Across Studies 12-15, we find that participants who chose their own box estimated a higher probability of winning for their box than participants who were randomly assigned a box, which appears consistent with a choice-driven illusion of control. This pattern occurred more consistently when participants evaluated all options than a single option (Studies 12-14) and only with a probability estimate measure and not with an equivalent multiple-choice measure (Study 15).

Study	*N*	Stimuli	DV(s)	Condition	Results: Choice *M* (*SE*)	No-choice *M* (*SE*)	Statistical Test *t*	*df*	*p*	Effect Size *d* [95% CI]
12[a]	799	Lottery: Two Boxes	Probability (%)	Aggregate	50.91 (0.52)	48.98 (0.67)	2.26	797	.024	0.16 [0.02, 0.30]
				One-option	50.32 (0.63)	49.59 (0.97)	0.63	399	.527	0.06 [-0.13, 0.26]
				All-options	51.50 (0.83)	48.38 (0.92)	2.51	396	.012	0.25 [0.05, 0.45]
13[a]	800	Lottery: Three Boxes	Probability (%)	Aggregate	35.63 (0.58)	32.10 (0.64)	4.10	798	<.001	0.29 [0.15, 0.43]
				One-option	34.78 (0.81)	33.81 (0.77)	0.87	398	.385	0.09 [-0.11, 0.28]
				All-options	36.49 (0.82)	30.40 (1.01)	4.70	398	<.001	0.47 [0.27, 0.67]
14[a]	800	Lottery: Four Boxes	Probability (%)	Aggregate	28.06 (0.67)	25.71 (0.61)	2.60	798	.010	0.18 [0.04, 0.32]
				One-option	28.26 (1.01)	25.88 (0.82)	1.83	398	.068	0.18 [-0.01, 0.38]
				All-options	27.86 (0.87)	25.54 (0.91)	1.85	398	.066	0.18 [-0.01, 0.38]
15[b]	1,197	Lottery: Three Boxes	Probability (%)	Probability-estimates	35.67 (0.57)	33.70 (0.60)	2.39	598	.017	0.19 [0.03, 0.36]
			Proportion feeling more likely to win (%)	Aggregate	10.91 (1.28)	8.65 (1.15)	1.31	1,195	.190	0.08 [-0.04, 0.20]
				Probability-estimates	16.67 (2.16)	10.33 (1.76)	2.28	598	.023	0.19 [0.03, 0.35]
				Multiple-choice[c]	5.07 (1.28)	6.98 (1.47)	-0.98	595	.328	-0.08 [-0.24, 0.08]

[a]There was a significant interaction effect between Choice and Number of Evaluated Options in Study 13, b = -5.11, $t(796)$ = -2.98, p = .003, but not in Study 12, b =-2.39; $t(795)$ = -1.41, p = .160, or Study 14, b = 0.05; $t(796)$ = 0.03, p = .978).
[b]There was a significant interaction effect between Choice and Outcome Measure, b = 0.08, $t(1,193)$ = 2.42, p = .016.
[c]A pre-registered chi-squared test also showed that there was no significant difference between the Choice and the No-choice conditions in the proportion of participants who felt more likely to win, $\chi^2(1, N = 597) = 0.65$, p = .419.

Table 2. Summary of the results from Studies 12-15.

It is worth noting that, while these effects appear significant in aggregate, they do not represent the majority of the participants' beliefs. In fact, 85%, 76%, 85%, and 80% of all participants in Studies 12-15 responded that their selected box was no more or less likely to win than expected by chance. In addition, 84%, 73%, 82%, and 77% of participants who estimated the probability for each and every box in the All-options or the Probability-estimates condition in Studies 12-15 indicated that all boxes were equally likely to win. In other words, these effects were driven by a small subset of the participants who believed that some boxes were more or less likely to win than expected by chance.

Nevertheless, since we found evidence that those who had a choice estimated a higher probability of winning than those who did not have a choice in aggregate, we next sought to determine whether choice caused this illusion or simply reflected participants' pre-existing beliefs. To understand the difference, consider the two possible cases in Figure 3. If participants initially believe that all options are equally likely to win, but later come to believe that their selected option is more likely to win after choosing, then one could argue that choice causes an illusion of control (Figure 3, Panel a). Alternatively, if participants incorrectly believe from the beginning that some options are more likely to win, and hence feel more likely to win after choosing—because they get to select the option they consider more likely to win—then choice would be merely reflecting pre-existing beliefs (Figure 3, Panel b).

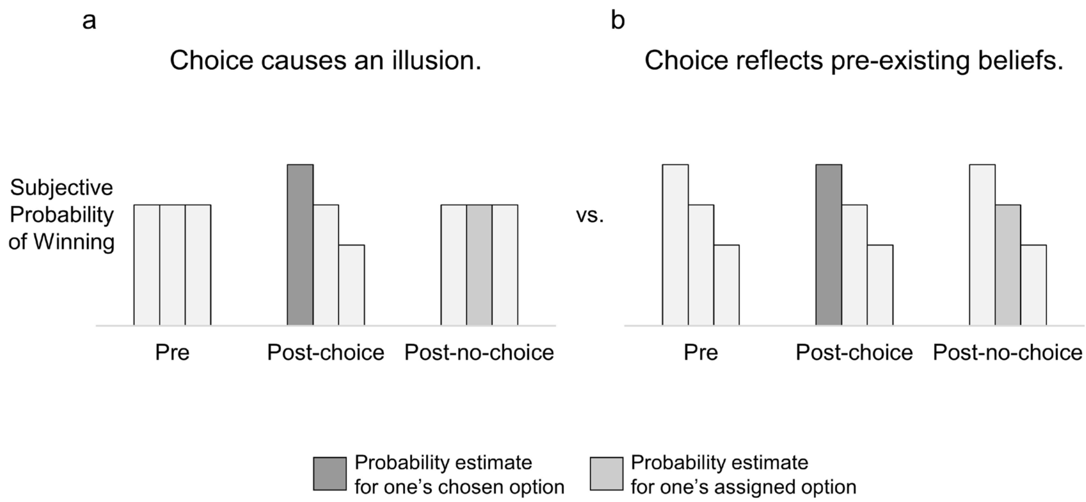

Figure 3. Two possible effects of choice. The bars in each group represent the probability estimates for the options that one considers most likely, second most likely, and least likely to win among three lottery options, in succession from left to right.

As shown in Figure 3, we cannot distinguish these two cases by simply comparing the probability estimates for participants' chosen vs. assigned options, as they can lead to the exact same patterns. Instead, we need to compare the probability estimate for the option that each participant considers most likely to win in the Pre, Post-choice, and Post-no-choice conditions (i.e., the leftmost bar in each group). If choice causes an illusion of control, this probability should be higher in the Post-choice condition than in the other two conditions. If choice merely reflects a pre-existing illusion, this probability will not be higher than in the other two conditions.

In Studies 12-15, participants assigned to the All-options condition or the Probability-estimates condition estimated the winning probability for each and every box. This allowed us to explore whether the average probability estimate for the box that each participant considered most likely to win was higher in the Choice condition than in the No-choice condition. As shown in Figure 4, we found no evidence for this: In none of these studies was this probability higher in the Choice condition than in the No-choice condition ($t(396) = -1.00$, $p = .320$, $d = -0.10$ [-0.30, 0.10] in Study 12; $t(398) = -2.44$, $p = .015$, $d = -0.24$ [-0.44, -0.05] in Study 13; $t(398) = -1.20$, $p = .230$, $d = -0.12$ [-0.32, 0.08] in Study 14; and $t(598) = 0.19$, $p = .850$, $d = 0.02$ [-0.14, 0.18] in Study 15). In Study 13, the opposite was true, though it did not replicate in other studies. These exploratory analyses suggest that choice is reflective of some participants' pre-existing beliefs rather than a cause of an illusion of control.

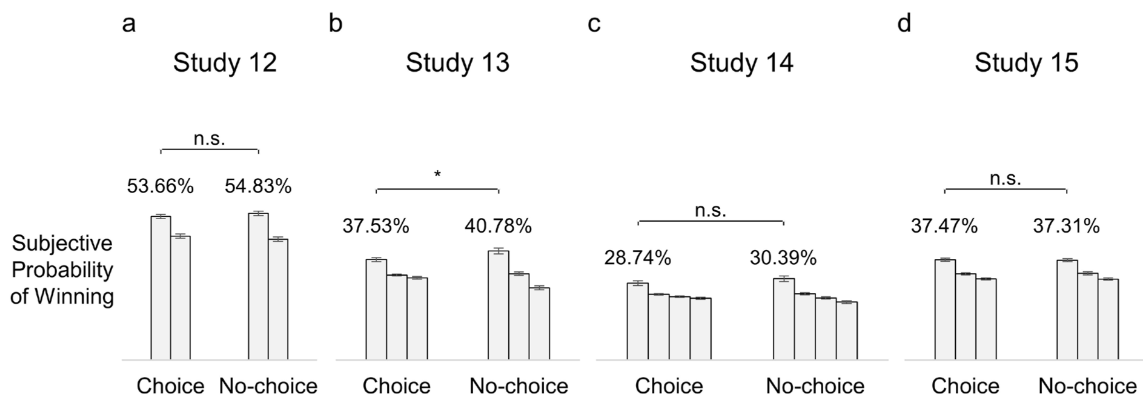

Figure 4. Summary of the exploratory analyses from Studies 12-15. The bars in each group represent the average probability estimates (across individuals) for the boxes that were considered most likely to least likely to win, in succession from left to right. The average probability estimate for the box that each participant considered most likely to win (i.e. the leftmost bar in each group) was not higher in the Choice condition than in the No-choice condition, consistent with the notion that choice did not cause an illusion of control. Error bars indicate standard errors.

To examine this more thoroughly, we next sought to determine, with a pre-registered analysis plan, whether this probability differed before and after choosing, as well as after choosing and after being assigned an option. If choice causes an illusion of control, this probability should be higher after choosing. We tested this in Studies 16 and 17.

Studies 16-17

Methods

Participants. We conducted Studies 16 and 17 on MTurk. We requested 600 participants per study. We applied the same exclusion criteria as in Studies 12-15. Across these two studies, we excluded 29 incomplete and 3 complete responses. The final sample size was 599 in Study 16 and 598 in Study 17. The average age was 36 and 39, and the proportion of females was 52% and 54% in Studies 16 and 17, respectively.

Procedures. In Studies 16 and 17, we again used a lottery with three boxes. The procedure was nearly identical to Study 15, except that participants in these studies were randomly assigned to one of three conditions: Pre, Post-choice, and Post-no-choice. All participants learned that they would play a lottery in which one of the boxes would be theirs and they would receive a bonus if their box was selected as the winning box. Participants in the Pre condition estimated the probabilities for the boxes *before* choosing or being randomly assigned a box. Participants in the Post-choice condition did so after choosing a box, and participants in the Post-no-choice condition after being randomly assigned a box. The only difference between Studies 16 and 17 was in the image of the boxes that participants saw when estimating the probabilities. In Study 16, all participants saw an identical image of the boxes, which did not highlight participants' chosen or assigned box, to prevent any potential confounds across conditions. In Study 17, participants in the Post-choice and the Post-no-choice conditions saw an image that highlighted their chosen or assigned box, consistent with Studies 12-15. We pre-registered to analyze two outcome measures in these studies: the probability estimate for the box that each participant considered most likely to win (comparing all three conditions) and the probability estimate for each participant's selected box (comparing the Post-choice and the Post-no-choice conditions only).

Results

Figure 5 displays the distributions of participants' subjective probabilities of winning across the boxes in the Pre, Post-choice, and Post-no-choice conditions in Studies 16 and 17. First, it is worth noting that, even though we explicitly informed participants that all boxes had an identical chance of winning, a sizable minority of participants reported pre-existing illusory beliefs. Specifically, 33% of participants in Study 16 and 26% of participants in Study 17 reported an unequal subjective probability distribution (i.e., probability estimates more extreme than 33-34% per box) before even choosing or being assigned a box. Next, following our pre-registered analyses plans, we analyzed participants' responses using independent sample t-tests. In both Studies 16 and 17, the average probability estimate for the box that each participant considered most likely to win was not significantly higher in the Post-choice-condition than in the other conditions. If anything, it was either directionally or significantly lower in the Post-choice condition than in the other conditions (Post-choice vs. Pre: $t(399) = -1.32$, $p = .187$, $d = -0.13$ [-0.33, 0.06] and Post-choice vs. Post-no-choice: $t(396) = -1.11$, $p = .269$, $d = -0.11$ [-0.31, 0.09] in Study 16; Post-choice vs. Pre: $t(400) = -.60$, $p = .548$, $d = -0.06$ [-0.26, 0.14] and Post-choice vs. Post-no-choice: $t(395) = -2.47$, $p = .014$, $d = -0.25$ [-0.45, -0.05] in Study 17). Interestingly, in these studies, the probability estimate for one's selected box did not significantly differ between the Post-choice and the Post-no-choice conditions, but the effects are in the same direction as Studies 12-15 ($M_{\text{post-choice}}$ = 35.60%, $SE_{\text{post-choice}}$ = .76%, $M_{\text{post-no-choice}}$ = 34.61%, $SE_{\text{post-no-choice}}$ = .99%, $t(396) = .80$, $p = .425$, $d = 0.08$ [-0.12, 0.28] in Study 16; $M_{\text{post-choice}}$ = 36.24%, $SE_{\text{post-choice}}$ = .82%, $M_{\text{post-no-choice}}$ = 35.80%, $SE_{\text{post-no-choice}}$ = 1.10%, $t(395) = .33$, $p = .744$, $d = 0.03$ [-0.16, 0.23] in Study 17).

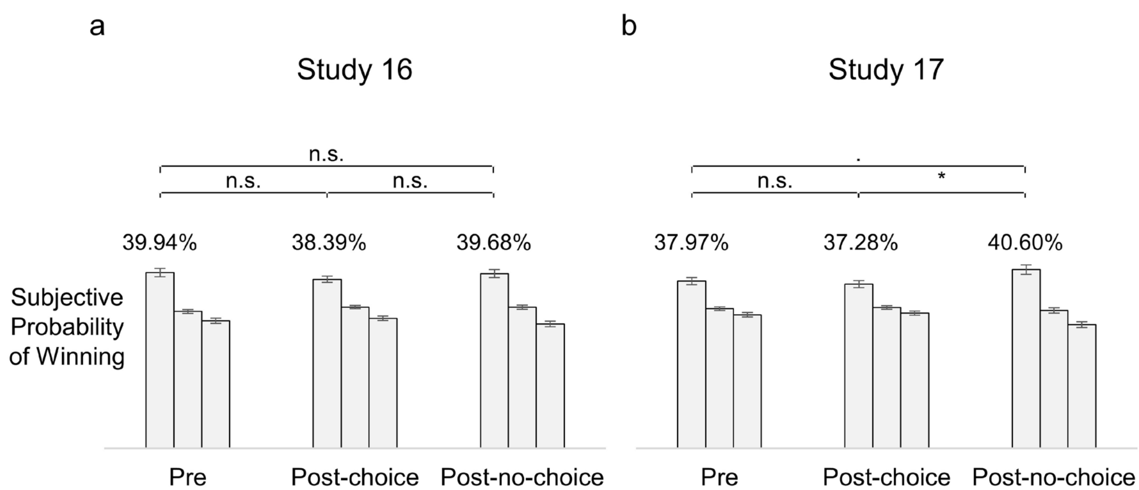

Figure 5. Summary of the results from Studies 16-17. The bars in each group represent the average probability estimates (across individuals) for boxes that were considered most likely, second most likely, and least likely to win, in succession from left to right. The average probability estimate for the box that each participant considered most likely to win (i.e. the leftmost bar in each group) was not higher in the Post-choice condition than in the Pre or the Post-no-choice condition, consistent with the notion that choice did not cause an illusion of control. Error bars indicate standard errors.

General Discussion

Across 17 studies, we found no evidence that choice causes an illusion of control. Choice rarely made people feel more likely to achieve preferable outcomes when all options were functionally identical, whether we used different outcome measures (Studies 1-3), visualized the process (Study 4), varied the levels of uncertainty (Studies 5-7), or increased the subjectivity of the outcome evaluations (Studies 8-9). Choice had such effects only when it conferred actual control (Studies 10-11). In the rare cases in which choosers felt more likely to achieve preferable outcomes (Studies 12-15), choice seemed to reflect people's pre-existing beliefs, rather than cause an illusion (Studies 16-17).

Our findings that a purported effect of choice results from an alternative account shares similarities with other re-investigations of classic findings. Specifically, Chen and Risen (2010) show that what looks like a choice-driven attitude change via cognitive dissonance reduction in fact occurs because the choice is used to select people with different attitudes in the first place. Similarly, Tong, Feiler, and Ivantsova (2017) show that what appears as choice-driven over-optimism via motivated reasoning emerges because choice reveals options that people already overestimate. Likewise, we revisit the highly influential and widely accepted phenomenon that choice causes an illusion of control. We find that such patterns rarely occur in cleanly designed experiments, and when they do, they are due to the choice reflecting people's pre-existing beliefs, rather than causing an illusion. Together, this line of work suggests that some purported effects of choice may be due to the choice acting as a selection mechanism—either among different participants or options—rather than as a cause of such effects.

Limitations

Despite our attempts to provide a comprehensive investigation, multiple questions remain.

First, our research does not address what might moderate the difference between the non-significant (Studies 1-11) and the significant (Studies 12-15) effects of choice. One possibility is that the probability estimates used in the latter studies are more sensitive than the other measures. In fact, our result from Study 15, which directly compared the probability estimates and multiple-choice measures, seems consistent with this conjecture. However, our results from

Studies 1-9 show that the non-significant coefficients in these studies do not have a consistently positive sign, which is not what one would expect if the measures were merely less sensitive. Moreover, Studies 10-11 directly show that these measures were sensitive enough to respond when the choice made the preferable outcomes actually more likely. Another possibility is that evaluating multiple options in Studies 12-15 makes people more likely to develop normatively incorrect beliefs and hence more likely to show patterns that appear consistent with a choice-driven illusion of control. When evaluating multiple options, there is a greater number of ways to express normatively incorrect beliefs (vs. only one way to express the normatively correct belief) than when evaluating a single option, which might facilitate such beliefs. However, our results from Studies 12-14 indicate that the number of evaluated options does not always moderate the effect of choice. While our research does not address these puzzling discrepancies, subsequent research could examine what may explain them.

Second, we do not know what leads a subset of participants to demonstrate pre-existing illusions, even when we explicitly inform them that all options have identical prospects (Studies 16-17). It is possible that certain individuals are prone to forming these beliefs due to past experiences, superstitious thinking, or distrust, but our research does not address what causes these beliefs or whether they are generalizable to people outside of our samples (Harris & Osman, 2012; Risen, 2016, Sharpe, Adair, & Roese, 1992). Future research could examine what individual or situational factors can lead people to develop such beliefs in the face of instructions that contradict them.

Third, our research focuses on choice and thus does not address other factors that might truly cause an illusion of control. Previous research suggests additional factors that might cause an illusion of control (e.g., competition, familiarity, active involvement; Langer, 1975; Martinez, Bonnefon, & Hoskens, 2009). While our research suggests that choice is unlikely to cause an illusion of control itself, it is possible that these other actions could.

In conclusion, past research suggests that choice can be powerful even without conferring actual control because it creates an illusion of control. Our research suggests a more sober perspective on the value of choice: Choice simply enables people to get what they want.

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CHAPTER 2: Even Number Prevalence in Quantity Decisions

Joowon Klusowski, Deborah A. Small, and Jacob Goldenberg

Introduction

When people are deciding the quantity of a particular product to acquire or consume, multiple factors may influence their decisions. For example, when they are buying apples, they may buy *seven* because they would eat an apple a day and shop once a week, or *four* because that is the number of people in their household, or *one* because they we will be walking the rest of the day and do not want to carry extra. Yet, aside from such idiosyncratic, deliberate reasons for choosing specific quantities, people may also have a general, arbitrary tendency to choose a certain class of numbers. In this research, we show that people choose even numbers more frequently than odd numbers when selecting quantities.

From a strictly normative perspective, people should not choose even numbers more frequently than odd numbers in quantity decisions. In the absence of any priors, it seems fair to assume that people's quantity decisions would follow a uniform distribution. According to a uniform distribution—or any other symmetric distribution—people should choose even numbers approximately the same time as odd numbers. Aside from such probabilistic perspectives, the "rule of odds" in visual arts—a principle that people find an odd number of objects more aesthetically appealing—may even suggest that people should choose odd numbers more frequently (Ensenberger, 2012).

Nevertheless, we hypothesize that people choose even quantities more frequently than odd quantities because the former are simply more fluent than the latter. We posit that even numbers are higher on both retrieval fluency and processing fluency than odd numbers, which can lead people to choose the former more frequently than the latter when selecting quantities.

First, even numbers may be associated with higher retrieval fluency than odd numbers. Previous research on the prominence of certain numbers suggests that halving and doubling are two of the simplest multiplicative operations and that such factors increase the accessibility or the retrieval fluency some numbers in peoples mind (e.g., 5, 10 20; Converse & Dennis, 2018). If so, even numbers, which often constitute easy inputs or outputs of such operations, may also be more accessible and retrievable when people are selecting quantities. In addition, previous research also suggests that even numbers are often more likely to result from common arithmetic operations than odd numbers (e.g., more than twice as likely to appear in a nine-by-nine multiplication table; Lochy, Seron, Delazer, & Butterworth, 2000). Such frequency in common arithmetic operations may also increase the accessibility or the retrieval fluency of even numbers (Converse & Dennis, 2018) and lead people to choose even numbers more frequently.

Second, even numbers may also be associated with higher processing fluency. Previous research suggest that people process numbers that result from common additions and multiplications more fluently than other numbers (King & Janiszewski, 2011). Given that even numbers inherently comprise multiples of two, whereas odd numbers consist of many prime numbers, we postulate that people find the former easier to process than the latter. In fact, studies have shown that people are usually better at processing arithmetic operations involving even numbers than odd numbers (Chang & Gibson, 2011; Hines, 1990). Furthermore, the fact that even numbers are inherently more symmetric (i.e., being multiples of two) or considered more complete (Gunasti & Ozcan, 2016) can also increase their processing fluency (Attneave, 1954; Garner, 1974; Mishra & Mishra, & Nayakankuppam, 2006; Northey & Chan, 2020). Such high processing fluency can lead people to choose even numbers more frequently—since people prefer numeric stimuli that they can fluently process (King & Janiszewski, 2011).

Importantly, these hypotheses suggest that the prevalence of even numbers would decrease when the fluency of odd numbers increases. First, consider contexts in which the retrieval fluency of odd numbers is relatively high. For example, imagine that people are deciding how many free samples of a food item to take. Given the common implicit social norm to take only one free sample per person, many people will fluently retrieve and choose one as the desired quantity, which will attenuate the prevalence of even numbers. Second, consider contexts in which the processing fluency of an odd number is relatively high. For example, suppose that eight and nine units of a food item are each organized in a three-by-three array. This organization will make the odd quantity more symmetric, complete, and easier to process, which will lead people to choose the odd quantity and diminish the prevalence of the even quantity. Likewise, we conjecture that the prevalence of even numbers depends on the relative fluency—both retrieval and processing fluency—of even vs odd numbers.

This research contributes to the literature on the prevalence of certain classes of numbers as focal numbers. Previous research suggests that people often use certain focal points or salient decision labels when making decisions (e.g., choosing Grand Central Terminal as the meeting location in a coordination game; Crawford, Gneezy, & Rottenstreich, 2008; Schelling, 1960) and numeric decisions are no exception. For example, previous research has shown that, among many possible choices of numbers, people frequently choose one (Geier, Rozin, & Doros, 2006), "round numbers" that include multiples of ten (Baird, Lewis, & Romer, 1970; Lynn, Flynn, & Helion, 2013; Pope & Simonsohn, 2011), or "prominent numbers" that include powers of ten as well as their doubles and halves (Converse & Dennis, 2018). However, this line of work has primarily focused on the prevalence of numbers that are multiples of five and ten. It has also often focused on contexts that may warrant the use of such round numbers for approximation (e.g., estimation of relatively more abstract and uncertain quantities, e.g., Baird, Lewis, & Romer, 1970). We propose that a much more granular class of focal numbers exists at the level of even vs. odd numbers and that this tendency manifests even when people are choosing more concrete quantities to acquire or consume.

In addition, this research extends the literature on people's interactions with numbers in an important way. Previous research in this domain has primarily focused on people's responses (e.g., perceptions, preferences) to externally generated numeric stimuli (cf., Converse & Dennis, 2018). For example, pricing studies have found that people perceive quality from round-ending prices and value from non-round-ending prices (Naipaul & Parsa, 2001; Schindler & Kirby, 1997). Branding studies have shown that people prefer brand names that include a large, round, or fluently processed number (Gunasti & Ross, 2010; Gunasti & Ozcan, 2016; King & Janiszewski, 2011). Other studies have argued that people prefer products featuring divisible numbers in some cases (e.g., preferring room 305 when feeling lonely; Yan & Sengupta, 2021). Complementing this research on people's responses to externally generated numbers, our research examines people's tendencies when they are internally generating numbers, often without prompt, as is often the case when choosing quantities to acquire or consume.

Moreover, our work contributes to the literature on even vs. odd numbers. To this date, research on even vs. odd numbers remains limited. In fact. much of the research has focused on either round vs. non-round numbers or divisible vs. indivisible numbers (Baird, Lewis, & Romer, 1970; Lynn, Flynn, & Helion, 2013; Pope & Simonsohn, 2011; Yan & Sengupta, 2021). Even the studies on even vs. odd pricing usually focus on prices that are round vs. non-round (e.g., $16.00 vs. $15.99 or $15.98; Schindler & Wiman, 1989) or prices that end in a specific even vs. odd digit only (e.g., 0 vs. 9; Coulter, 2001). Notably, some studies suggest that people have different perceptions about even vs. odd numbers (e.g., even numbers are feminine and odd numbers are masculine; Wilkie & Bodenhausen, 2012). However, these findings do not logically imply whether people will choose one class of numbers over the other when selecting quantities, especially when they are unrelated to such perceptions. Our work provides additional insights about even vs. odd numbers—some of the most commonly encountered classes of numbers in real life.

Furthermore, in addition to these theoretical contributions, our work has the potential to offer practical insights. People routinely decide not only whether to engage in certain behaviors (e.g., whether to buy) but also to what extent to engage in those behaviors (e.g., whether to buy). Therefore, if people have the general, arbitrary tendency to choose even numbers disproportionately more frequently in these decisions, it may suggest that they are selecting non-optimal quantities. One example that might reflect such tendencies can be found in medicine, in which two-unit blood transfusions have been common practice even when they are not necessary, e.g., "The 'thing we do for no reason" is giving 2-unit RBC [(red blood cell)] transfusions when 1 unit would suffice (Thakkar, Podlasek, Rotello, Ness, & Frank, 2017; p. 747)." Addressing this point, our work suggests that changing the relative fluency of even vs. odd numbers can be an effective way to influence people's decisions away from such tendencies if desired. Likewise, the present research has implications for both understanding and improving people's quantity decisions.

In this research, we report three studies that examine the prevalence of even numbers in quantity decisions. In Study 1, we examine whether people are disproportionately more likely to choose even numbers than odd numbers across a variety of contexts. In Study 2, we show that this tendency attenuates when people can fluently retrieve an odd focal number. In Study 3, we show that this tendency also diminishes when people can fluently process an odd quantity. All of these studies are pre-registered, and all study instruments, data, and analyses publicly available at the link provided in the appendix. Together, these studies address whether, why, and when people may choose even quantities over odd quantities.

Study 1

In this study, we examined whether people are more likely to choose even or odd numbers across a variety of quantity decision contexts using an online survey. We hypothesized that people would choose even numbers more frequently than odd numbers in these decisions, beyond choosing round numbers that are multiples of ten.

Methods

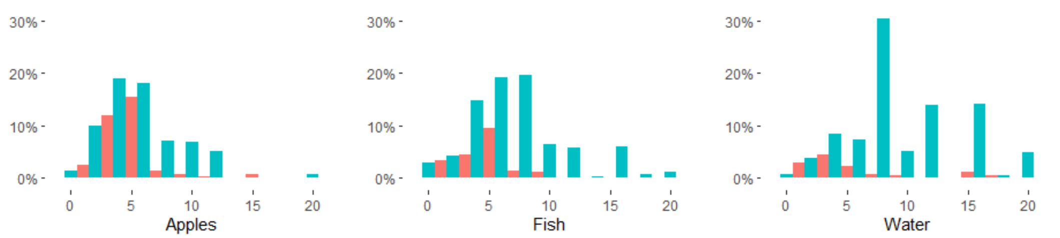
We conducted the study on MTurk. We pre-registered to request 400 participants and to exclude responses from participants who responded to the survey more than once using the same MTurk ID, who did not complete the entire survey, or whose work was not submitted for payment. The final sample consisted of 397 participants (38 years old on average; 46% women and 54% men).

Participants answered 11 questions involving quantity decisions. An example is "When you buy apples at a grocery store, how many do you usually buy for yourself at a time?" (see the link in the Appendix for a complete list). The questions intended to reflect a wide range of common quantity decisions, including different types of quantities (e.g., discrete, continuous), items (e.g., tangible, intangible), and contexts (e.g., choosing for an individual vs. an organization). Participants answered these questions by entering any integer greater than or equal to zero. For each question, we re-coded participants' responses into a binary variable indicating even vs. odd numbers and conducted a binomial test to compare the proportion of even vs. odd numbers against 50%. We repeated the analyses excluding responses that were multiples of five or ten (labeled as “without 0/5” in Table 1) as well as excluding responses that were multiples of ten only (labeled as “without 0” in Table 1) as the most conservative test against our hypothesis.

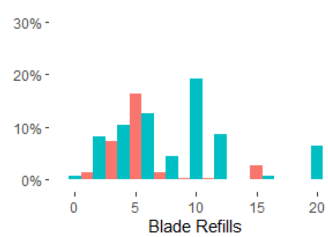
Results

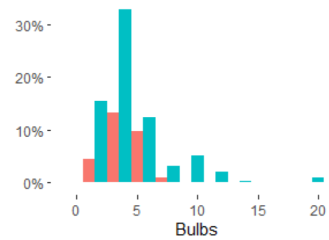
Participants were more likely to choose even quantities than odd quantities across all 11 questions (Table 1). The proportion of even quantities was significantly higher than 50% in all 11 decisions (*M*s = 65-89%), *p*s < .001. Importantly, this prevalence was not merely driven by the prevalence of round numbers that were multiples of ten. Even when we excluded round numbers that were multiples of ten—as the most conservative test against our hypothesis—the proportion of even numbers was significantly higher than 50% in 7 decisions (*M*s = 59-87%), *p*s < .010, and directionally higher in the remaining 4 decisions (*M*s = 54-57%), *p*s > .050. In addition, we conducted exploratory analyses to examine the effects of numeracy, gender, and evenness of household size and found no consistent, systematic effects of any of these variables. In other words, we found a robust prevalence of even numbers across these quantity decisions.

	Number of apples to buy for self at a grocery store			Ounces of fish to buy per person			Fluid ounces of water to drink at a time		
	N	Even	*p*	*N*	Even	*p*	*N*	Even	*p*
All	397	68%	<.001	397	81%	<.001	397	89%	<.001
without 0/5	298	79%	<.001	316	88%	<.001	336	91%	<.001
without 0	362	65%	<.001	353	78%	<.001	349	87%	<.001

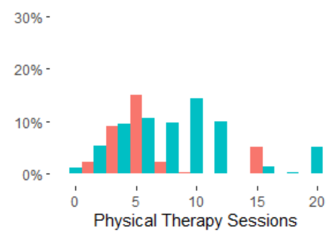


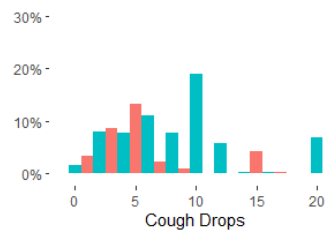
	Number of sushi pieces to take at an all-you-can-eat restaurant			Number of razor blade refills to buy			Number of light bulbs to buy		
	N	Even	*p*	*N*	Even	*p*	*N*	Even	*p*
All	397	65%	<.001	397	71%	<.001	397	72%	<.001
without 0/5	290	69%	<.001	215	81%	<.001	334	78%	<.001
without 0	337	59%	.001	289	61%	<.001	373	70%	<.001

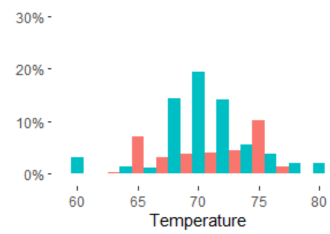




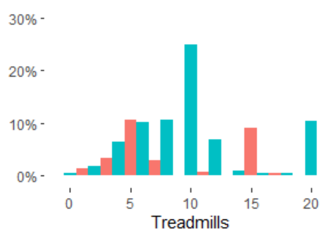
	Number of physical therapy sessions needed to recover			Number of throat lozenges to take to work when sick			Ideal temperature for home in Fahrenheit		
	N	Even	*p*	*N*	Even	*p*	*N*	Even	*p*
All	397	68%	<.001	397	68%	<.001	397	65%	<.001
without 0/5	235	78%	<.001	213	73%	<.001	229	71%	<.001
without 0	312	59%	.003	283	55%	.096	299	54%	.165







	Number of treadmills needed for a public gym			Number of computers needed for a local public library		
	N	Even	*p*	*N*	Even	*p*
All	397	72%	<.001	397	79%	<.001
without 0/5	172	82%	<.001	121	90%	<.001
without 0	252	56%	.068	192	57%	.071



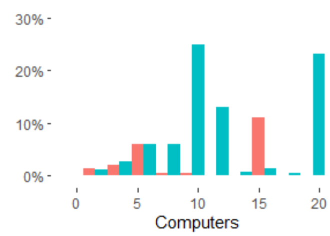


Table 1. A summary of the stimuli and results for the 11 quantity decisions in Study 1. Extreme outliers outside of the scales, if any, were excluded from the graphs but were included in the analyses.

Despite the robust prevalence of even numbers in these decisions, we expected that this tendency would rely on the relative fluency of even numbers compared to odd numbers. Consequently, we hypothesized that this tendency would attenuate when odd numbers become more fluent—either in terms of retrieval fluency or processing fluency. In the next study, we tested this hypothesis with regard to retrieval fluency.

Study 2

In this study, we examined how the prevalence of even numbers changes when the retrieval fluency of an odd number increases. Specifically, we conducted an experiment drawing on one of the quantity decisions from Study 1 (i.e., choosing the number of sushi pieces), but we varied how fluently people could retrieve an odd number in this decision. Even though we previously observed a robust prevalence of even quantities in this context, we expected that this tendency would attenuate when people can fluently retrieve another focal number that happens to be odd.

Methods

We conducted the study on MTurk. We pre-registered to recruit 400 participants and applied the same exclusion criteria as Study 1. The final sample consisted of 396 participants (40 years old on average; 48% women and 52% men).

We randomly assigned participants to either the Control or the Odd condition. In both conditions, we showed participants a picture of a sushi roll and asked how many pieces they would take at a newly opened restaurant using a scale ranging from 1 to 10, but we varied the description of the restaurant to manipulate the retrieval fluency of an odd number. In the Control condition, the restaurant was offering all-you-can-eat sushi, whereas in the Odd condition, it was offering free samples of sushi. The rationale was that there is typically an implicit social norm to take only one unit per person when it comes to free samples. Therefore, although two questions were essentially identical, we expected that more participants in the Odd condition would fluently retrieve and choose only one, which would in turn diminish the prevalence of even numbers.

Results

As expected, we found that the prevalence of even quantities depended on whether the context evoked a “choose one” norm and increased the retrieval fluency of the odd quantity. First, we conducted an exploratory analysis to compare the proportion of participants choosing one unit in each condition. In the Control condition, only 18% of the participants chose one, whereas in the Odd, 44% did—suggesting that one was indeed easier to retrieve in the latter, $X^2(1) = 29.65$, $p < .001$. Next, we conducted a confirmatory analysis to compare the proportion of even quantities in each condition. In the Control condition, 59% participants chose even quantities of sushi, whereas in the Odd condition, only 38% did, $X^2(1) = 16.93$, $p < .001$. According to exploratory binomial tests comparing these proportions against 50%, participants were more likely to choose even quantities in the Control condition, $p = .010$ and odd quantities in the Odd condition, $p < .001$.

This study demonstrated that the prevalence for even numbers may not manifest in the presence of other focal numbers that people disproportionately select, especially if such numbers are odd. While we tested this using only one as a possible focal number, we expect that similar results would arise with other classes of numbers. For example, previous research suggests that people disproportionally choose “round numbers” that are multiples of five or ten or “prominent numbers” that are powers of tens or their doubles or halves in certain contexts (Baird, Lewis, & Romer, 1970; Converse & Dennis, 2018; Lynn, Flynn, & Helion, 2013; Pope & Simonsohn, 2011). We expect that the prevalence of even numbers would naturally be less likely to manifest in such cases as well (e.g., if most people use multiples of five and ten to estimate uncertain quantities).

In the next study, we tested how this prevalence changes as a function of processing fluency of even vs. odd numbers. We hypothesized that this effect will again diminish when the processing fluency of odd quantities increases.

Study 3

In this study, we examined how the prevalence of even numbers changes as the processing fluency of odd numbers increases. To manipulate the processing fluency of odd numbers, we drew on research on Gestalt psychology. Previous research in line with this work suggests that one way to make a quantity more fluent is to organize it as a set that can be perceived as a whole or described by simple rules (Barasz, John, Keenan, & Norton, 2017; Evers, Inbar, &, Zeelenberg, 2014; Shaddy & Fishbach, 2017). Therefore, we hypothesized that organizing odd quantities in such a way could increase the processing fluency of the odd quantities and in turn diminish the prevalence of even quantities.

Methods

We conducted the study on MTurk. We pre-registered to recruit 400 participants and applied the same exclusion criteria as Studies 1 and 2. The final sample consisted of 398 participants (39 years old on average; 37% women and 63% men).

We randomly assigned participants to either the Control or the Odd condition. In both conditions, participants imagined buying chocolate truffles and indicated whether they would buy eight or nine chocolates. However, the two conditions differed in visual display of the two quantities of chocolates. In the Control condition, the response options for both eight and nine chocolates featured an identical image of a single chocolate. In the Odd condition, the response options for the eight and nine chocolates featured images of eight and nine chocolates, each organized in a three-by-three array, respectively. The rationale was that, while nine is not a particularly fluent quantity as opposed to eight or ten (King & Janiszewski, 2011), organizing it in a three-by-three array makes it a set that can be perceived as a whole or described by simple rules, making it easier to process. Therefore, we expected that this organization would make the odd quantity more fluent and hence diminish the prevalence of the even quantity.

Results

As expected, participants' choice of the even quantity over the odd quantity depended on the fluency of the two quantities. In the Control condition, 68% of the participants indicated that they would buy 8 chocolates, whereas in the Odd condition, only 49% did, $X^2(1) = 14.15$, $p < .001$. According to exploratory binomial tests comparing these proportions against 50%, participants chose the even quantity more frequently in the Control condition, $p < .001$, whereas they chose the even and the odd quantities approximately equally frequently in the Odd condition, $p = .777$. In other words, the result supported our hypothesis the prevalence of even quantities attenuates when the processing fluency of an odd quantity becomes relatively high.

While we tested this hypothesis using nine units only, we expect that similar results would also arise with other odd quantities. For example, consider seven. Seven units of an item may not appear particularly fluent compared to six or eight units. In fact, when people indicated how many apples they usually buy for themselves at a grocery store in Study 1, very few people answered seven compared to six or eight. However, we expect that many people will choose to buy seven apples once we increase the processing fluency of this quantity by framing it as one apple a day for a week. In other words, fluency can serve as a useful tool to influence people's quantity decisions away from choosing even numbers when they are not optimal.

General Discussion

Across three studies, we showed that people are more likely to choose even numbers than odd numbers across a variety of quantity decisions, beyond choosing round numbers that are multiples of ten. This prevalence seems to result from the fluency of even numbers. Consequently, it attenuates when the retrieval fluency or the processing fluency of odd quantities increases—addressing why as well as when this effect may manifest.

As previously discussed, this research provides multiple theoretical and practical implications. To summarize, it first shows that people's tendency to choose focal numbers occurs at a much more granular and concrete level than previously known in the literature. In addition, it extends the literature on even vs. odd numbers, which has previously focused on a limited set of even vs. odd digits in the context of pricing (Schindler & Wiman, 1989). Moreover, it broadens the scope of consumer research on numbers from externally generated numeric stimuli (e.g., brand names, King & Janiszewski, 2011; prices, Schindler & Kirby 1997) to internally generated quantities (Converse & Dennis, 2018). Furthermore, it also suggests that people may be making non-optimal decisions when selecting quantities and that there may be ways to improve such decisions—which can have important consequences for the society at large, especially in the context of high stakes decisions (e.g., blood transfusions in medicine). Together, this research suggests important insights for understanding and improving people's quantity decisions.

While we have examined the prevalence of even numbers across a series of studies, some questions remain. First, we do not address what types of numbers are more likely to lead to this pattern. For example, the data from Study 1 seem to indicate that this pattern is more pronounced among numbers that are greater than five than those that are smaller than five, but we do not provide a systematic comparison across different classes or ranges of numbers. Second, we do not examine what types of quantity decisions are more likely to lead to this effect. Although we find a robust prevalence of even numbers across a variety of contexts, some types of decisions that we have not investigated may be more prone to this effect than others (e.g., hedonic vs.

utilitarian decisions). Third, we also do not show what types of individuals are more likely to demonstrate this pattern. While we find no consistent effects of gender, education, or numeracy on this pattern, it is possible that other individual characteristics may moderate it. Future research is needed to provide a more comprehensive understanding of this phenomenon.

To conclude, we find a robust prevalence of even numbers in a variety of quantity decisions. This prevalence extends beyond some of the previously known focal numbers in the literature but attenuates when odd quantities become more fluent. The results contribute to our understanding of the arbitrariness of people's decisions: Whereas seven apples may seem inadequate, six or eight apples seem just right.

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APPENDIX

All study materials, data, code, and pre-registrations are available at the following links.

Chapter 1: https://osf.io/g2cbe/

Chapter 2: https://researchbox.org/126&PEER_REVIEW_passcode=QTWPUJ