

Constrained Physical Space Constrains Hedonism

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ABSTRACT Prior research shows that people demonstrate greater regulation of motor and social activities when they are in a confined physical space. This article examines whether space constraint affects people's behavior toward hedonistic consumption of vice products (e.g., high-calorie foods) and their self-regulation in general. We propose that space constraint may have a generalized effect that enhances regulation of behaviors that are unrelated to the space. Manipulating space constraint by varying density or by assigning individual participants to different-sized rooms, three experiments demonstrated that smaller (vs. larger) spaces reduce impulsive purchase of vice products, lead to lower consumption of high-calorie foods, and yield fewer false alarms in a go/no-go task. Consistent with our findings, both international and US data showed that more densely populated regions have a lower prevalence of outcomes associated with low self-control (e.g., prevalence of overweight and obesity, death caused by road traffic accidents).

Impulse buying is prevalent among consumers. Previous studies show that almost 90% of people make purchases on impulse occasionally, and between 30% and 50% of all purchases can be classified as impulse purchases by buyers themselves (Hausman 2000). A more recent study from CreditCards.com found that one out of five Americans report having spent more than \$1,000 on an impulse purchase, and 84% of Americans say they indulged in smaller impulse purchases (Picchi 2016). Overeating is also common among consumers and is one of the most significant factors contributing to the high rates of overweight and obesity in the United States (Kessler 2010). Results from the 2011–12 National Health and Nutrition Examination Survey indicate that an estimated 33.9% of US adults age 20 and over are overweight, 35.1% are obese, and 6.4% are extremely obese (Fryar, Carroll, and Ogden 2014).

Both impulse buying and overeating represent self-control failures that can be caused by a number of reasons (for a review, see Baumeister and Heatherton 1996; Faber and Vohs 2013). For example, having many conflicting goals (e.g., saving for a house, retirement, and a vacation) may enhance the perceived difficulty of achieving the goal, thus reducing one's commitment to the goal. Moreover, failure to track one's behavior (e.g., losing track of how many calories have already been consumed) also reduces the chance of reaching the self-control goal. In addition, resource depletion is an important factor influencing the success of self-control. To enhance the effectiveness of exercising self-control, cognitive factors (e.g.,

regulatory focus: Scholer and Higgins 2013), social factors (e.g., interpersonal relationship: Rawn and Vohs 2013), and individual difference factors (e.g., temperament: Rothbart, Ellis, and Posner 2013; self-efficacy: Cervone et al. 2013) have been investigated. Recent literature in marketing also demonstrates that environmental factors such as disorganization can reduce self-control (Chae and Zhu 2014).

In this article, we explore the novel influence of another environmental factor—physical space—on people's effectiveness to exercise self-control. We propose that constrained physical space may enhance the control of impulsive behaviors that are irrelevant to the physical space (e.g., eating high-calorie foods).

CONCEPTUAL OVERVIEW AND DEVELOPMENT OF HYPOTHESIS

Spatially constrained physical environments influence people's behaviors by curbing their movements and enhancing bodily control. When personal space is small, even children reduce their locomotion and gross motor activities, such as running and rough-and-tumble play (Smith and Connelly 1972; Loo and Smetana 1978).

Inadequate personal space may also augment the potential frequency and intimacy of social interactions, leading to more careful regulation of behaviors to avoid inappropriate interactions with others. In fact, by manipulating the size of the group (i.e., small, medium, and large), Hutt and Vaizey (1966) found that despite the greater opportunity for social

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interaction with the larger groups, normal children (in contrast to brain-damaged or autistic children) in dense space settings spend less time interacting with others. Loo (1972) manipulated density by fixing the size of the group but varying the size of the room. She observed significantly fewer aggressive acts among children (e.g., physically attacking another person or toy, being destructive with toys or equipment) in the high-density condition than in the low-density condition (see also Preiser 1972; but for different findings, see Loo and Smetana 1978). In the meantime, the children in the high-density conditions also engage in more solitary play.

Similar effects of space constraint on social interactions were observed among adults. For example, college students in waiting areas of densely populated dormitories sit at greater distances from others (Valins and Baum 1973; Baum and Valins 1979) and avoid both positive and negative social interactions (Smith and Haythorn 1972; Bickman et al. 1973; Evans and Lepore 1993). Furthermore, the motivation to avoid excessive social contact among people in high-density regions also impedes the development of cognition related to social interactions. A good example can be found in the case that people in densely populated areas have less favorable norms about handholding and recall words related to interpersonal affiliation less accurately than do people in less densely populated regions (Munroe et al. 1969; Munroe and Munroe 1972). Finally, in addition to real physical confinement, merely anticipating space constraint is sufficient to reduce social interactions (Baum and Greenberg 1975). All the above findings support Sommer's (1969) speculation that segregation may serve to reduce conflict and to protect oneself from spatial intrusions. In other words, enhancing control over social interactions seems to be a popular and effective strategy to cope with space constraint and to avoid inappropriate interactions with others as well as invasion into one another's personal space.

People intentionally control their physical movements and social interactions when within limited personal space because uncontrolled behaviors may lead to negative consequences, such as bumping into walls and objects, bumping into one another, or having excessive and inappropriate social interactions. In contrast to control over physical movements and social interactions, self-control over one's impulsivity has less direct external or interpersonal consequences. However, we propose that space constraint may strengthen self-regulation in general and lead to better self-control over impulsive behaviors.

Recent neuroscience findings indicate that there is an inhibitory network in the right prefrontal cortex governing

the inhibition of responses across various domains (Berkman, Burklund, and Lieberman 2009; Cohen and Lieberman 2010). Therefore, intentional inhibitory control in one domain (e.g., inhibiting a motor response in a go/no-go task) could lead to improved inhibition in other domains (e.g., suppressing affective responses to stimuli with a negative valence; Berkman et al. 2009). Along the same lines, self-regulating movement of a particular body part (e.g., bladder control in response to urine accumulation) facilitates controlled performance on Stroop tasks as well as aiding in the choice of larger, later rewards over smaller, sooner lures (Tuk, Trampe, and Warlop 2011).

Building on the above research, we propose that consciously controlling motor and social behaviors in response to space constraint may establish automatic associations between the constraint and behavioral regulation more generally, which could, in turn, enhance control of other mental and behavioral activities that are less relevant to the physical environment. Specifically, when exposed to spatially constrained environments, people may exercise greater control over action impulses that arise at the temptation of hedonistic consumption (e.g., enjoying a box of chocolates) or from tasks that induce action inertia (e.g., hitting a key as quickly as possible when the "go" word appears in a go/no-go task).

The proposed effect is more aligned with the inhibitory spillover account than with the ego-depletion account in self-control literature. The inhibitory spillover account suggests that inhibition of one response could unintentionally facilitate response inhibition in unrelated domains (Berkman et al. 2009; Tuk et al. 2011). In contrast, the ego-depletion account based on the limited resource model suggests that acts of self-control need to draw cognitive resources from a common and limited pool. Depleting these resources by exercising self-control in one task could reduce self-control in subsequent tasks (Baumeister et al. 1998). A recent work (Tuk, Zhang, and Sweldens 2015) identifies an important contingency under which each account may predict self-control behaviors. Specifically, when self-control challenges are faced simultaneously, exerting effortful self-control in one task may improve self-control in unrelated domains, whereas when self-control challenges are encountered sequentially, exerting effortful self-control in one task may result in ego depletion and impair self-control in subsequent domains. The current research context resembles a simultaneous self-control situation. Constrained physical space simultaneously enhances control over physical movements and strengthens self-control over impulsive behaviors.

We conducted three lab studies and two archival data analyses to test the hypothesis that spatial constraint can enhance self-control over impulsive behaviors that are less relevant to the physical environment. We used multiple methods, including experiments and archival data analysis. Although the literature has examined several broad domains in which self-control can be exercised, in the current research we first focus on self-control over impulses that urge people to seek short-term pleasures at the expense of long-term benefits in consumption, health, and safety repertoires. Specifically, two lab experiments established the causal relationship between space constraints and self-control in domains of impulsive buying and impulsive eating of vice products. Next, we generalized findings to a different setting requiring self-control to inhibit motor actions in a classic neuropsychological task (i.e., go/no-go task). Finally, based on analyses of both international and US data, two archival studies showed that population density is negatively correlated with outcomes associated with low self-control (i.e., prevalence of overweight and obesity, and death caused by road traffic accidents).

EXPERIMENT 1: DENSITY AND IMPULSIVE PURCHASE DECISIONS

In this experiment, we manipulated space constraint by varying the number of participants in each experimental session (i.e., density). Participants took part in a hypothetical shopping task in which they made purchase decisions on a series of food and drink products. Previous literature (Wertenbroch 1998) distinguished between virtue products (i.e., products that maximize delayed utility at the expense of immediate pleasure) and vice products (i.e., products that maximize immediate pleasure at the expense of long-term benefits) and suggested that vice products—such as cakes and pies—were more likely to trigger impulsive purchase decisions (Loewenstein 1996; Thomas, Desai, and Seenivasan 2011). Based on those findings, we additionally manipulated product type (vice vs. virtue) as a within-participant variable. We predicted that space constraint would reduce participants' impulsive purchase of vice products but have less influence on their purchase of virtue products

Method

Participants and Design. One hundred and six students at University of Minnesota (50% female, $M_{\text{age}} = 20.31$, $SD = 1.79$) took part in the study in exchange for partial course credit. They were assigned into one of two conditions with a 2 (density: high vs. low; between-participants) \times 2 (product type: virtue vs. vice; within-participants) mixed design. All

participants took part in the study in the same room (165 square feet), with laptops set up on a rectangular table (see appendix, available online). In the high-density condition, participants worked on individual laptops in groups of up to eight participants, whereas in the low-density condition, participants worked on individual laptops in groups of up to four participants.

Procedure. All participants worked on a hypothetical shopping study on individual laptops. This shopping task was adapted from Thomas et al. (2011, study 2). Specifically, participants were informed that we were interested in their shopping habits because a large retail chain that was planning to open a food store in the local area wanted to know consumers' food preferences. They were asked to imagine that they were in a grocery store aisle and saw several food items that were available. Under this pretense, they were presented with the name, picture, and price of 20 food/drink products, of which half were vice products (e.g., Mrs. Smith's Pumpkin Pie, \$5.85; Sara Lee Cheesecake, \$8.99) and half were virtue products (e.g., Special K Cereal, \$5.15; Health Valley Granola, \$4.59). Products were displayed one at a time on the laptop screen. Participants were asked to indicate whether they would buy the displayed product if they were shopping at the time. Participants could click the icon of "Add to shopping cart" or the icon of "Continue shopping" to move on.

Upon completing the shopping study, participants evaluated the study room on dimensions such as spaciousness (measured by three 7-point scales, anchored by not spacious vs. spacious, small vs. large, cramped vs. roomy, respectively; Cronbach's alpha = .85) and a number of control dimensions pertaining to the room, such as decoration appeal, brightness, temperature, distinctiveness, comfort, noisiness (all scales: 1 = lowest, 7 = highest). Finally, participants reported demographic information such as gender and age.

Results and Discussion

Manipulation Check. Participants perceived the room to be less spacious in the high-density condition ($M_{\text{hi den}} = 2.67$, $SD = 0.98$) than in the low-density condition ($M_{\text{lo den}} = 4.01$, $SD = 0.99$); $F(1, 104) = 49.39$, $p < .001$. However, they perceived no difference between the two conditions on all the other dimensions (all $p > .10$).¹

1. Decoration: $M_{\text{hi den}} = 1.76$, $SD = 1.12$; $M_{\text{lo den}} = 1.75$, $SD = 1.27$. Brightness: $M_{\text{hi den}} = 5.78$, $SD = 1.22$; $M_{\text{lo den}} = 5.46$, $SD = 1.29$. Temperature: $M_{\text{hi den}} = 4.10$, $SD = .86$; $M_{\text{lo den}} = 4.21$, $SD = .68$. Distinctiveness: $M_{\text{hi den}} = 2.10$, $SD = 1.30$; $M_{\text{lo den}} = 2.38$, $SD = 1.42$. Comfortableness:

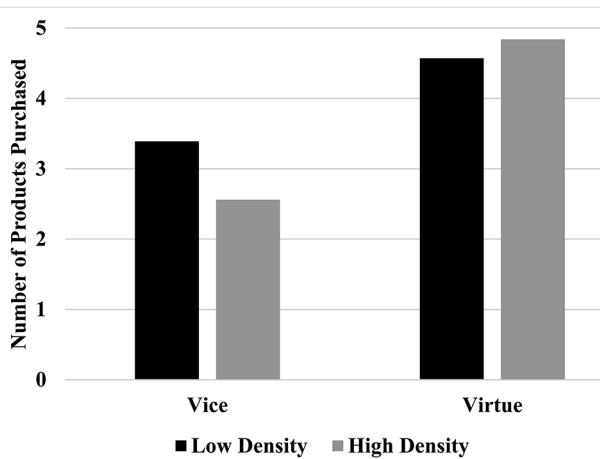


Figure 1. Number of vice and virtue products purchased as a function of density manipulation experiment 1.

Number of Products Purchased. The number of vice products and the number of virtue products in the shopping basket were computed (Thomas et al. 2011) and analyzed as a function of density (between-participants), the type of product (within-participants), and their interactions. The results revealed a main effect of product type, $F(1, 104) = 31.77, p < .001$, and a marginally significant density by product type interaction, $F(1, 104) = 3.22, p = .076$ (see fig. 1). Additional planned contrast showed a marginally significant effect that participants in the high-density condition purchased fewer vice products ($M_{hi\ den} = 2.56, SD = 1.82$) than those in the low-density condition did ($M_{lo\ den} = 3.39, SD = 2.51$), $F(1, 104) = 3.74, p = .056$. However, density manipulation did not influence the number of virtue products that participants purchased in either high-density or low-density conditions ($M_{hi\ den} = 4.84, SD = 2.48$; $M_{lo\ den} = 4.57, SD = 2.43$), $F(1, 104) = .32, p = .575$.

Experiment 1 manipulated space constraint by varying the density (i.e., number of participants in each experimental session) and showed that participants in the high-density condition purchased fewer vice food products than those in the low-density condition did. In the next experiment, we tested the influence of space constraint on people's real consumption of a vice product.

EXPERIMENT 2: ROOM SIZE AND IMPULSIVE EATING

Experiment 2 investigated the influence of space constraint on eating high-calorie foods. Different from experiment 1

$M_{hi\ den} = 4.56, SD = 1.34$; $M_{lo\ den} = 4.89, SD = 1.20$. Noisiness: $M_{hi\ den} = 2.34, SD = 1.33$; $M_{lo\ den} = 2.16, SD = 1.41$.

in which space constraint was manipulated by density, this experiment manipulated space constraint by varying the room size while controlling for the number of participants (i.e., one participant at a time). We aimed to achieve two goals. First, we would like to establish that when the focal self-control behavior is irrelevant to the physical environment, density and room-size manipulations have a similar impact. Second, by having individual participants take part in the study, we could minimize the impact of other confounding factors associated with density manipulations (e.g., the presence of others, social desirability concerns, distraction) on consumption of vice products.

Method

Pretesting. A separate group of 36 participants from the same population as those in the main study were randomly assigned to evaluate either a large room (154 square feet) or a small room (30 square feet), neither of which had windows. They rated on dimensions such as spaciousness (measured by three 7-point scales, anchored by not spacious vs. spacious, small vs. large, cramped vs. roomy, respectively; Cronbach's alpha = .91) and a number of control dimensions pertaining to the room, such as decoration appeal, brightness, temperature, distinctiveness, comfort, and noisiness (all scales: 1 = lowest, 7 = highest). Participants perceived the large room ($M_{large} = 5.00, SD = 1.55$) to be more spacious than the small room ($M_{small} = 2.63, SD = 1.22$; $F(1, 34) = 26.15, p < .001$). However, they perceived no difference between the two rooms on all the other dimensions (all $p > .10$).²

Procedure. One hundred and fourteen students at University of Illinois (66% female, $M_{age} = 20.92, SD = 3.71$) took part in the main study individually, in either the small room or the large room, receiving partial course credit for compensation. They participated in a blind taste test of chocolate balls (i.e., malted milk balls) that have a pleasant flavor but are high in calories and sugar (each serving of 18 pieces contained 190 calories, with 24 grams of sugar and 7 grams of saturated fat). Chocolate consumption has been used as a measure of impulsive behavior in literature on self-control (Baumeister et al. 1998; Hong and Lee 2008). Each partici-

2. Decoration: $M_{small} = 1.83, SD = 1.34$; $M_{large} = 1.78, SD = 1.31$. Brightness: $M_{small} = 6.78, SD = .43$; $M_{large} = 6.56, SD = .78$. Temperature: $M_{small} = 4.06, SD = .24$; $M_{large} = 4.00, SD = .34$. Distinctiveness: $M_{small} = 2.00, SD = 1.24$; $M_{large} = 1.56, SD = .98$. Comfortableness: $M_{small} = 4.56, SD = 1.58$; $M_{large} = 5.28, SD = 1.27$. Noisiness: $M_{small} = 1.17, SD = .38$; $M_{large} = 1.11, SD = .32$.

pant was presented with a bowl of 20 chocolate balls and instructions to eat as many pieces as they wanted during the taste test. Participants then rated how much they liked the taste, sweetness, and appearance of these chocolate balls, from -5 (dislike very much) to 5 (like very much) (Cronbach's $\alpha = .85$). At the end, participants reported their mood, from -5 (sad) to 5 (happy), and how hungry they were, from 0 (not at all hungry) to 10 (very hungry), among other filler and demographic questions. They returned the bowl to an experimenter who later counted the number of chocolate balls eaten by the participants.

Results and Discussion

The size of the room did not influence reported mood ($M_{\text{large}} = 2.98$, $SD = 1.64$ vs. $M_{\text{small}} = 2.64$, $SD = 1.89$; $F(1, 112) = 1.05$, $p = .307$) or how hungry participants felt ($M_{\text{large}} = 4.10$, $SD = 3.02$ vs. $M_{\text{small}} = 4.52$, $SD = 2.89$; $F(1, 112) = .56$, $p = .456$). The number of chocolate balls consumed was submitted to an ANCOVA, with the size of the room (coded as $1 = \text{small}$, $2 = \text{large}$) as a fixed factor and self-reported hunger as a continuous covariate. Not surprisingly, hungrier participants ate more chocolate balls than less hungry participants, $F(1, 111) = 5.29$, $p = .023$. More central to our hypothesis, participants ate a greater number of chocolate balls when the taste test was conducted in the large room ($M_{\text{large}} = 5.31$, $SD = 5.22$) than when it was conducted in the small room ($M_{\text{small}} = 3.88$, $SD = 2.74$; $F(1, 111) = 4.09$, $p = .046$). Moreover, participants' ratings on how much they liked the taste, sweetness, and appearance of these chocolate balls were averaged to form a measure of chocolate ball evaluation. We submitted the chocolate ball evaluation submitted to an ANCOVA, with the size of the room as a fixed factor and self-reported hunger as a continuous covariate. The results revealed that neither the size of the room ($M_{\text{large}} = 2.11$, $SD = 2.15$ vs. $M_{\text{small}} = 2.07$, $SD = 2.09$; $F(1, 111) = .03$, $p = .857$) nor self-reported hunger ($F(1, 111) = 1.47$, $p = .227$) influenced the evaluation of chocolate balls.

The above results were consistent with previous findings that factors influencing consumers' self-control abilities (e.g., depletion) could change their choice of products without affecting product evaluations (Neal, Wood, and Drolet 2013). To further determine the relationship between the consumption of chocolate balls and evaluations of them, we submitted the number of chocolate balls consumed to an ANCOVA, with the size of the room as a fixed factor and chocolate ball evaluation and self-reported hunger as two continuous covariates. The results showed that the con-

sumption of chocolate balls was positively and independently influenced by room size, $F(1, 110) = 4.16$, $p = .044$; chocolate ball evaluation, $F(1, 110) = 8.51$, $p = .004$; and self-reported hunger, $F(1, 110) = 4.11$, $p = .045$.

Experiment 2 showed that space constraint induced by small room size increased participants' control over impulsive eating and consequently reduced the amount of chocolate balls consumed. Therefore, density and room size could have parallel effects on self-control over impulsive behaviors that are unrelated to the physical space itself. In the next experiment, we sought to generalize the findings to a different setting requiring self-control to inhibit impulsive motor actions in a classic neuropsychological task (i.e., go/no-go task).

EXPERIMENT 3: ROOM SIZE AND MOTOR INHIBITION

A go/no-go task is a neuropsychological task in which stimuli (e.g., words) are presented in a continuous stream, and participants make a binary go/no-go behavioral decision in response to each stimulus. Two different types of stimuli are typically used. One type (i.e., the "go" stimulus) requires participants to make a motor response, whereas the other (i.e., the "no-go" stimulus) requires participants to withhold a motor response. Accuracy and reaction time are measured. Go events typically occur with higher frequency than no-go events; thus, making a motor response at the presentation of a word is the dominant response in a go/no-go task. In experiment 3, we manipulated room size, and the "go" word appeared three times as often as the "no-go" word. We assessed participants' ability to inhibit the dominant motor response to a tempting "no-go" stimulus in the go/no-go task, which has been shown to be associated with self-control behavior in domains such as alcohol abuse (Dom et al. 2006), nicotine use (Mitchell 2004), and violence (Dolan and Fullam 2004). The main dependent measure of this experiment is false alarm rate, which refers to the proportion of "no-go" trials on which participants should have withheld a response but failed to do so. A higher false alarm rate indicates an inability to inhibit the dominant motor response and thus reflects lack of self-control. We also calculate two other standard performance measures of a go/no-go task—hit rate and mean reaction time to respond to "go" stimuli (RT)—that are irrelevant to impulsivity control. Hit rate refers to the proportion of "go" trials on which a participant should and did respond to "go" stimuli. Hit rate measures attention. RT measures efficiency of motor responses. We predicted that participants in the smaller room would

have fewer false alarms. However, we did not predict room sizes to influence either hit rate or RT.

Method

Fifty-eight students at University of Illinois (71% female; $M_{\text{age}} = 19.91$, $SD = 2.05$) were randomly assigned to complete the go/no-go task in either the large or the small room. A pretest was conducted to confirm that the two target words we would use in this go/no-go task were positive in valence and approach motivation.³ Forty-six participants evaluated two words—CAKE and SEX—on three scales from 1 to 7 anchored by very negative–very positive; very undesirable–very desirable; want to avoid–want to approach. For each word, the responses to the first two items were averaged to form an attitude measure (Pearson's $r = .65$ and $.87$ for CAKE and SEX, respectively), and the third item measured approach/avoidance motivation for these concepts. Participants' attitudes toward both CAKE and SEX were significantly above the scale midpoint ($M = 5.83$, $SD = 1.16$, $t(45) = 10.67$, $p < .001$ for CAKE; $M = 5.89$, $SD = 1.32$, $t(45) = 9.75$, $p < .001$ for SEX). In addition, participants' approach/avoidance motivation for both CAKE and SEX were significantly above the scale midpoint ($M = 5.09$, $SD = 1.62$, $t(45) = 4.56$, $p < .001$ for CAKE; $M = 5.76$, $SD = 1.42$, $t(45) = 8.43$, $p < .001$ for SEX). Therefore, participants had both positive attitudes and approach motivation toward both concepts, and they were used as target words in the go/no-go task.

Participants worked on a computer-controlled visual-motor skill test by (a) pressing the spacebar on the keyboard when a “go” word appeared on the computer screen, and (b) not responding when a “no-go” word appeared on the computer screen. After 20 practice trials, participants were exposed to 100 test trials, in which the “go” word CAKE appeared for 75 trials and the “no-go” word SEX appeared for 25 trials. The order of presentation of the trials was randomized. Specifically, within each trial, the screen first turned black for 400 milliseconds. Then a string of X was presented for 300 milliseconds to alert participants that one word (either CAKE or SEX) would be presented soon. After the screen turned black again for 100 milliseconds, one word (either CAKE or

SEX) was presented for a maximum of 400 milliseconds. The goal was to press the spacebar as quickly as possible when they saw the word CAKE but not to press the spacebar when they saw the word SEX. Responses were recorded as true if (a) CAKE was presented and participants pressed the spacebar within 400 milliseconds and (b) SEX was presented and participants did not press the spacebar. Responses were recorded as false if (a) CAKE was presented and participants did not press the spacebar and (b) SEX was presented and participants pressed the spacebar within 400 milliseconds. Response times were recorded if participants responded by pressing the spacebar while a word was on screen (i.e., responded within 400 milliseconds), no matter whether the word presented was CAKE or SEX.

Results and Discussion

Because the “go” word was presented three times as frequently as the “no-go” word, the default disposition was to press the spacebar when a word appeared. Impulsivity control was reflected in inhibiting the motor response of pressing the spacebar when the “no-go” word was presented. Three performance measures—false alarm rate, hit rate, and RT—were computed by using “count” and “calculate” functions in Excel. They were analyzed as a function of room size in three separate one-way ANOVAs. The results revealed that participants did show better impulsivity control by having a lower false alarm rate when they were in the small room ($M_{\text{small}} = .19$, $SD = .11$) than when they were in the large room ($M_{\text{large}} = .29$, $SD = .16$; $F(1, 56) = 6.82$, $p = .012$). However, room size influenced neither the hit rate ($M_{\text{small}} = .85$, $SD = .10$ vs. $M_{\text{large}} = .83$, $SD = .11$; $F(1, 56) = .49$, $p = .487$) nor RT ($M_{\text{small}} = 317.54$ ms, $SD = 18.78$ vs. $M_{\text{large}} = 319.72$ ms, $SD = 16.03$; $F(1, 56) = .23$, $p = .636$).

The results of experiment 3 showed that a small space increases control over impulsive motor actions during a go/no-go task. However, this finding does not imply that space constraint would enhance task performance in general. Indeed, previous research investigating the influence of density on task performance has produced mixed results. For example, Freedman, Klevansky, and Ehrlich (1971) manipulated room size and the number of participants in the room simultaneously and found that room size did not influence performance on either simple (e.g., crossing out all of a particular number on a sheet containing random numbers) or complex (e.g., creative thinking) tasks. The results of experiment 3, however, imply that space enhances performance requiring impulsivity control even though performance such as hits may not be affected.

3. Those two words were selected from an earlier pretest in which we assessed the valence of four words—cake, chocolate, sex, and condom—on 7-point scales (1 = very negative, 7 = very positive). We chose two words that were positive in valence ($M_{\text{cake}} = 5.82$, $M_{\text{chocolate}} = 6.13$, $M_{\text{sex}} = 5.92$, $M_{\text{condom}} = 4.56$) and similar in length.

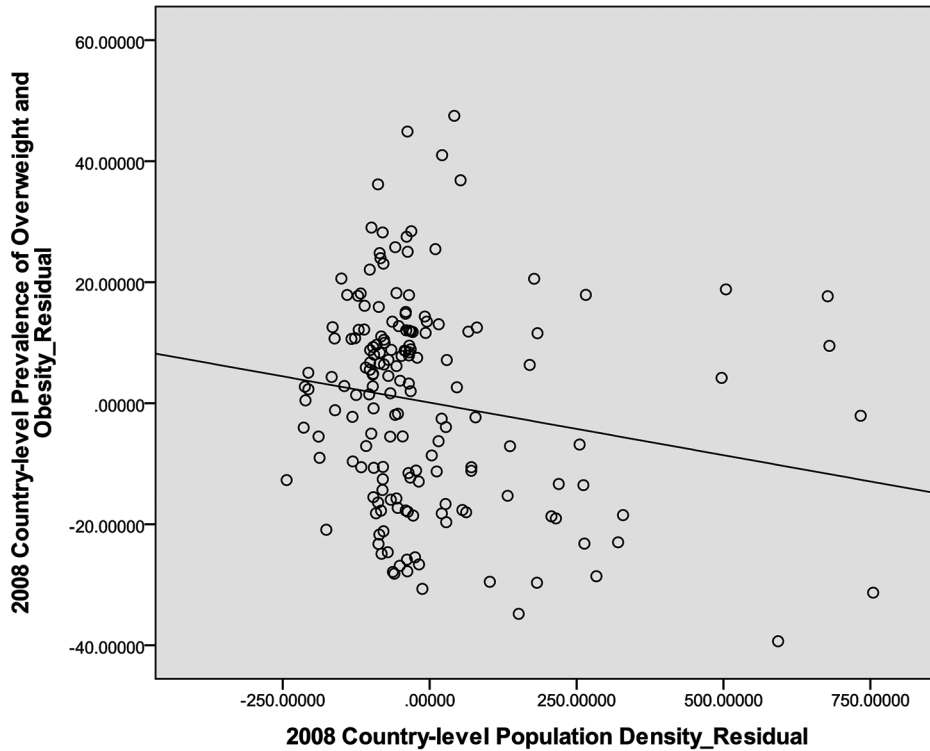


Figure 2. Country-level data scatter plots: 2008 country-level prevalence of overweight and obese populations as a function of population density (winsorized), controlling for per capita GDP (winsorized). The x-axis represents the residuals from regressing the 2008 country-level population density (winsorized) on 2008 country-level per capita GDP (winsorized); the y-axis represents the residuals from regressing 2008 country-level prevalence of overweight and obesity on 2008 country-level per capita GDP (winsorized).

Next, we sought to generalize the above findings to the real world by testing the relationship between population density and behavioral consequences involving self-control.

**EVIDENCE FROM THE FIELD:
COUNTRY-LEVEL ANALYSIS**

This archival study examined the relationship between country-level population density and health and safety outcomes associated with behavioral control. Country-level population density (i.e., population per kilometers of land area) reflected the average amount of physical space available to individuals. The density data were obtained from the International Database of the US Census Bureau (2008, 2010). Impulsive behavior indicators—prevalence of overweight and obesity in 2008⁴ and road traffic death rate in 2010—were obtained from the World Health Organization’s database. Prevalence of overweight and obesity refers to the

percentage of the population with a body mass index (BMI) of 25 or higher (BMI is calculated by dividing an individual’s weight by the square of their height, in kg/m²). As driver error is the number-one cause of road traffic accidents, the estimated road traffic death rate (per 100,000 population) was also used to measure behavioral control. Because income level has been shown to be associated with obesity (Sobal and Stunkard 1989) and road traffic death (Peden et al. 2004), country-level per capita GDP for 2008 and 2010 were retrieved from the World Bank’s (n.d.) database and used as a covariate in multiple regression analyses corresponding to each outcome, with density being the key predictor. One hundred and seventy-one countries having data on the prevalence of overweight and obesity, country-level population density, and country-level per capita GDP in 2008 were included in the first analysis. One hundred and sixty-two countries having data on the estimated road traffic death rate, country-level population density, and country-level per capita GDP in 2010 were included in the second analysis. To ensure that the results of the analyses were

4. Published data from the most recently available year at the time of study were used.

not driven by outliers, extreme values of both density and per capita GDP were winsorized following a standard procedure in the Statistical Package for the Social Sciences (SPSS) software (i.e., outlier values that are more than 3 standard deviations away from the mean are replaced by the cutoff value at the 3 standard deviations; Dixon and Massey 1969; Erceg-Hurn and Miroseovich 2008).

In the multiple regression predicting prevalence of overweight and obesity, density was, as hypothesized, negatively related to prevalence of overweight and obesity ($N = 171$, $\beta = -.16$; $t(168) = -2.24$, $p = .026$; see scatter plots in fig. 2), and per capita GDP was positively related to the same outcome ($\beta = .47$; $t(168) = 6.80$, $p < .001$). In the multiple regression predicting road traffic death rate, density was a negative predictor ($N = 162$, $\beta = -.17$; $t(159) = -2.64$, $p = .009$; see scatter plots in fig. 3), and per capita GDP was also a negative predictor ($\beta = -.54$; $t(159) = -8.28$, $p < .001$).

In sum, these results were consistent with the predictions that overweight and obesity as well as traffic accidents

are more frequent in less dense or less constrained environments than in denser or more constrained environments. However, in making country-level comparisons, physical space may be confounded with cultural differences to influence self-control (Zhang and Shrum 2009). In the next archival data analysis, we sought to replicate the above correlational effects between population density and impulsive behavior indicators by using data from one single country.

EVIDENCE FROM THE FIELD: US STATE-LEVEL ANALYSIS

This study tested the relationship between state-level density and the same health and safety outcomes using data from 50 states and the District of Columbia in the United States. State-level population density data from 2009 (i.e., population per square mile of land area), obtained from the US Census Bureau (2011), were used as a proxy for physical space. Following the procedure in the earlier archival data analysis, outlier values of both density and per capita GDP were winsorized. Prevalence of overweight and obesity data from

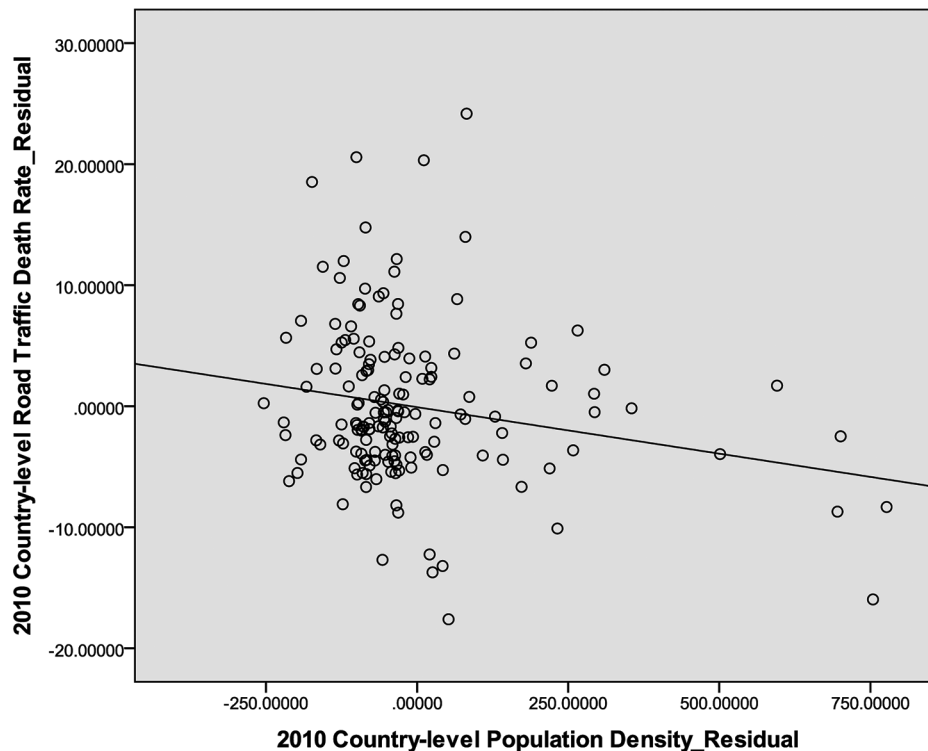


Figure 3. Country-level data scatter plots: 2010 country-level road traffic death rate as a function of population density (winsorized), controlling for per capita GDP (winsorized). The x -axis represents the residuals from regressing the 2010 country-level population density (winsorized) on 2010 country-level per capita GDP (winsorized); the y -axis represents the residuals from regressing 2010 country-level prevalence of road traffic death rate on 2010 country-level per capita GDP (winsorized).

2009 (i.e., percentage of population with BMI equal to 25 or higher; Centers for Disease Control and Prevention 2009) were analyzed as a function of density, controlling for state-level per capita GDP in 2009 (Bureau of Economic Analysis 2009). Prevalence of overweight and obesity was marginally negatively related to density ($N = 51, \beta = -.26; t = -1.95, p = .057$; see scatter plots in fig. 4) and negatively related to state-level per capita GDP ($\beta = -.42; t = -3.19, p = .003$). The road traffic fatality rate in 2009 (i.e., fatalities rate per 100 million vehicle miles traveled; National Highway Traffic Safety Administration 2009) was negatively related to density ($N = 51, \beta = -.38; t(48) = -2.79, p = .008$; see scatter plots in fig. 5) and also negatively related to state-level per capita GDP ($\beta = -.27; t = -2.03, p = .048$).

The above two archival data analyses showed that both country-level density and state-level density negatively predicted outcomes associated with impulsive behaviors. Although those results are correlational in nature and may

be open to more than one explanation, their consistency with the predictions of our theory is provocative.

GENERAL DISCUSSION

Evidence from the laboratory and the field indicates that physical space constraint increases inhibition of impulsive behaviors in domains not directly affected by the space. Manipulating space constraint by varying either the density in the same room or the size of the room not only decreased purchase (experiment 1) and consumption (experiment 2) of hedonistic products but also inhibited impulsive motor behavior in a go/no-go task (experiment 3). Analyses of both international country-level data and US state-level data provided evidence from the field that more densely populated regions have a lower prevalence of overweight and obesity as well as lower road traffic death rates. These findings make important theoretical contributions to two areas of research.

First, research on space and population density boomed in the 1970s and 1980s, demonstrating that constraints of

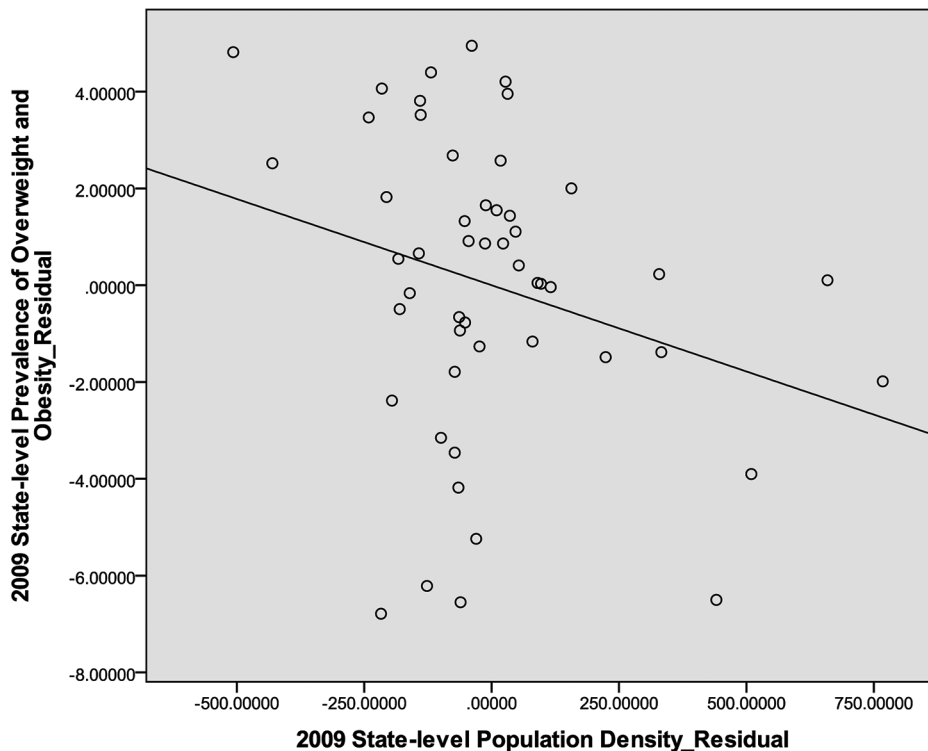


Figure 4. US state-level data scatter plots: 2009 state-level prevalence of overweight and obese populations as a function of population density (winsorized), controlling for per capita gdp (winsorized). The x-axis represents the residuals from regressing the 2009 US state-level population density (winsorized) on 2009 state-level per capita GDP (winsorized); the y-axis represents the residuals from regressing 2009 state-level prevalence of overweight and obesity on 2009 state-level per capita GDP (winsorized).

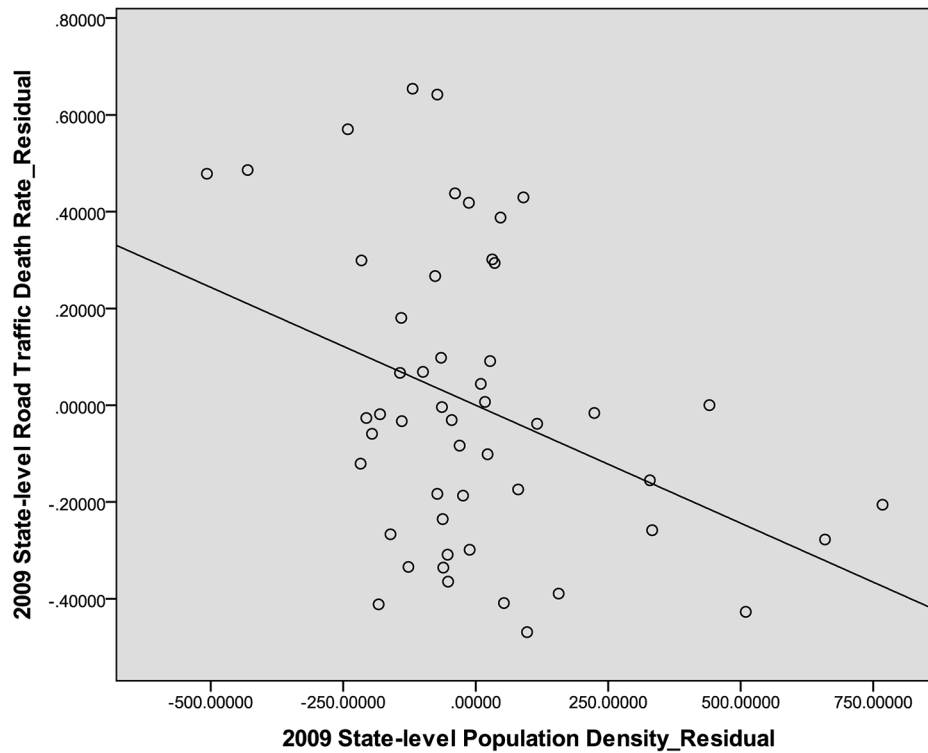


Figure 5. US state-level data scatter plots: 2009 state-level road traffic death rate as a function of population density (winsorized), controlling for per capita GDP (winsorized). The x -axis represents the residuals from regressing the 2009 US state-level population density (winsorized) on 2009 state-level per capita GDP (winsorized); the y -axis represents the residuals from regressing 2009 state-level road traffic death rate on 2009 state-level per capita GDP (winsorized).

physical space or perceived limitations of physical space enhance people's control over behaviors on which space has a direct influence. For example, they control physical movements to avoid bumping into others and reduce social interaction to avoid overstimulation. Our research is the first to demonstrate that constrained physical space can influence self-control over impulsive behaviors in various contexts that are irrelevant to the physical space. The findings broaden the horizons of research on physical space and population density.

Second, the current findings suggest that inhibition of physical movements in constrained space can spill over and facilitate inhibition of impulsive behaviors in unrelated domains. Thus, we identify a new context in which inhibitory spillover may occur (Berkman et al. 2009; Tuk et al. 2011, 2015).

Although the neuroscience findings of a common inhibitory network support the inhibitory spillover account, the psychological process underlying the inhibitory spillover ef-

fect of constrained space has yet to be identified. We discuss several possibilities below, which might be tested in future research.

Priming Self-Control Procedures. Cognitive procedures are stored in memory as part of declarative knowledge, and people can use them to pursue goals (Wyer and Xu 2010). Constrained space may activate self-control procedures because people need to intentionally control their motor and social behaviors to avoid negative consequences. As a result, increased accessibility of self-control procedures may enhance the likelihood of exercising self-control over impulsive behaviors in unrelated domains.

Ease of Implementing Self-Control Procedures. Previous research on processing fluency suggests that increasing the accessibility of semantic concepts (e.g., crib) may increase the ease with which related concepts (e.g., milk) can be processed (Lee and Labroo 2004). In a similar vein, controll-

ing body movement and social interactions can enhance the ease with which self-control procedures can be implemented to overcome impulsivity.

Cognitive Metaphor of Self-Constraint. Previous research shows that people sometimes form metaphoric associations among different concepts (Zhong and Liljenquist 2006; Williams and Bargh 2008). It is possible that spatial constraint is metaphorically associated with the concept of psychological self-constraint, which motivates individuals to curb their impulsive behaviors in various domains.

Future research may also explore the generalizability of this self-control spillover effect induced by constrained space. The current studies provide evidence that constrained physical space constrains hedonistic consumption and impulsive motor behaviors, which have either long-term or immediate negative consequences. Future research may test whether constrained space influences engagement in behaviors with uncertain consequences (e.g., playing a gamble with risky outcomes). In addition, testing whether constrained space could enhance behaviors with positive consequences (e.g., taking preventive medication) will also be fruitful.

Finally, the current findings also have important practical and public policy implications. If a large space promotes impulsive behaviors, more frequent interventions may be designed to remind people to control their behaviors while in large spaces and perhaps even reduce the ever-increasing size of the new single-family houses in the United States (US Census Bureau 2013).

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