



# Inhibitory spillover: Increased urination urgency facilitates impulse control in unrelated domains

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IMPULSE CONTROL IN UNRELATED DOMAINS

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### Abstract

Visceral states are known to have a (detrimental) impact on our ability to exert self-control. In the current research, we investigate the impact of a visceral factor associated with inhibition, rather than with approach: bladder control. We argue that inhibitory signals are not domain specific, but can spill over to unrelated domains, resulting in increased impulse control in the behavioral domain. We show that urination urgency correlates with improved performance on color naming but not word meaning trials of a Stroop task (Study 1). In Study 2 and 3, we show that higher levels of bladder control result in an increasing ability to resist more immediate temptations in monetary decision making. We show that inhibitory spillover effects are moderated by sensitivity of the behavioral inhibition system (BIS, Study 3), and can be induced by exogenous cues (Study 4). Implications for inhibition and impulse control theories are discussed.

## Inhibitory Spillover: Increased Urination Urgency Facilitates Impulse Control in Unrelated Domains

People are often confronted with choices that involve trade-offs, such that obtaining the benefits of one option implies that one cannot obtain benefits associated with the rejected option. For example, people regularly choose between the short term pleasure of going out for dinner versus saving the money in order to buy a car next year. This type of choice dilemma has been characterized as a self-control conflict, whereby the impulsive urge (instigated by the immediate temptation) has to be overridden by a more deliberative and effortful process (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Vohs, 2006). Previous research has extensively examined how people deal with self-control conflicts (Hagger, Wood, Stiff, & Chatzisarantis, 2010; Vohs & Heatherton, 2000). Recently, scholars have begun to demonstrate that visceral states (such as hunger and sexual desire) can impact responses to self-control conflicts, even in unrelated domains (Briers, Pandelaere, Dewitte, & Warlop, 2006). However, the bulk of prior research in this area has investigated visceral factors associated with approach, while it remains unclear whether and how visceral factors associated with inhibition (such as controlling one's bladder in the face of accumulating urine) impact people's responses to temptations. Does this type of visceral factor result in a similar deteriorating ability to control impulses? Or, intriguingly, can bladder pressure provide a condition under which people's ability to control impulses and hence their ability to act in their own long-term best interest, will actually improve?

Self-control refers to the capacity to alter one's own responses, in order to bring them in line with standards, and to support the pursuit of long-term goals (Baumeister, Vohs, & Tice, 2007). It enables a person to restrain or override one response, thereby making a different response possible. Research has shown that the ability of people to control these more immediate

impulses is not stable, but varies. One condition known to make self-control more difficult is the prior arousal of visceral factors (Loewenstein, 1996). The effects of these visceral factors have been shown not to be bound by the visceral domain. For example, Briers et al. (2006) showed that hunger increases the desire for money and vice versa. Van den Bergh, Dewitte and Warlop (2008) showed that exposing men to sex cues leads to an increase in desire for smaller but sooner rewards over later but larger rewards. Based on neurological evidence (Camerer, Loewenstein, & Prelec, 2005), they argue that the same dopaminergic reward circuitry of the brain is activated for a wide variety of different reinforcers, referred to as a general reward system. This increased intertemporal impatience appeared stronger for people with a relatively sensitive Behavioral Approach System (BAS, Gray, 1990; Torrubia, Avila, Molto, & Caseras, 2001). Li (2008) and Wadhwa, Shiv and Nowlis (2008) provide similar evidence. Thus, prior research suggests the existence of a general reward system with a neurological basis. The reward system can be triggered by reward-related cues, which results in an increased preference for reward-providing cues in general, independent of the nature of the triggering cue.

Although these findings highlight important visceral influences on the inclination to follow one's impulses, they are silent regarding conditions that result in improved ability to control impulses. In the current research, we aim to investigate whether visceral factors which, once aroused call for inhibitory responses (i.e., a filling bladder), do not only result in inhibitory responses within the target domain, but also in unrelated domains. We argue that this inhibitory spillover occurs independently from the previously identified reward system, rather than reflecting a deactivation of the reward system. Preliminary evidence for this claim stems from recent neuroscientific research. Berkman, Burklund and Lieberman (2009) examined the existence of an inhibitory network in the brain. They propose that inhibition of motor, cognitive,

and affective responses has a common origin in the same neurological areas. A by-product of this inhibitory network is that inhibitory signals intentionally directed towards one response, unintentionally spill over to unrelated domains, resulting in increasing inhibitory signals in these domains as well. In line with this reasoning, the authors show that motor inhibition (on a go/ no-go task) spills over to unintentional inhibition of otherwise present neurological responses to negative-affect trials, and they show that the same neurological areas are activated during these different trials. Based on these findings, they conclude that inhibitory signals for differential responses originate from the same neural region, which is vulnerable to inhibitory spillover. In the current research, we examine the occurrence of inhibitory spillover effects in the behavioral domain.

An important and daily experienced physiological sensation that relies on inhibitory responses is controlling one's bladder in the face of accumulating urine. A filling bladder increasingly triggers inhibitory responses (Griffiths & Tadic, 2008). People increasingly have to inhibit their (motor) impulse to void. The inhibition of this motor response is present while people engage in other behaviors, making these simultaneously occurring behaviors susceptible for inhibitory spillover effects. Griffiths and Tadic (2008; Griffiths, 2007) identify the Anterior Cingulate Cortex (ACC) as an important area involved in bladder control and managing urination urgency, while the same region has also been identified as part of the inhibitory network by Berkman and colleagues. This suggests that inhibitory signals due to increasing levels of bladder control might be vulnerable to unintentional inhibitory spillover effects. An implication is that, when stronger inhibitory signals are required due to increasing bladder pressure, people would at the same time show improved performance on other tasks relying on inhibition. In the current research, we aim to examine this hypothesis by investigating the impact

of bladder control on Stroop task performance (Stroop, 1935; Study 1) and intertemporal patience (Study 2-4).

### Study 1

#### *Method*

*Participants.* 193 University students (104 men, age  $M = 20.64$ ) participated in exchange for course credit.

*Procedure.* After two practice rounds of 10 trials, participants completed a Stroop task which consisted of four blocks of 25 trials each. In two blocks (block 2 and 4), participants were instructed to indicate the meaning of the word on each trial. This is the dominant (impulsive) response and does not require response inhibition. We therefore did not expect any effect of urination urgency on these blocks. In the other two blocks (block 1 and 3), participants were instructed to indicate the color of the word. This task requires inhibition of the dominant response (reading). We expected stronger urination urgency to facilitate inhibition of this dominant response, resulting in faster response times on these blocks. After completing the Stroop task, participants indicated the physiological conditions under which they completed the research, the key variable of interest was reported urination urgency (1 = not urgently at all; 7 = very urgently).

#### *Results and Discussion*

Incorrect responses and response times more than 2.5 *SD* below or above the average were removed. Participants who made more than 10% errors were removed, leaving 176 participants. The number of errors did not correlate significantly with reported urination urgency. A GLM with block number and block type (color or word naming) as within subjects variables and urination urgency as between subjects variable showed only the expected significant two-

way interaction between block type and urination urgency,  $F(1,174) = 4.68, p = .03$ . In line with our expectations, response times on the color naming blocks decreased with increasing urination urgency,  $t(174) = -2.13, p = .034, B = -0.015$ , whereas response times on the word meaning blocks did not vary with reported urination urgency,  $t(174) = -0.86, p = .39$ .

Study 1 provides correlational evidence for unintentional inhibitory spillover effects from increased bladder pressure to another domain known to rely on inhibitory responses, namely speeded performance on the color naming trials of the Stroop task.

### Study 2

The aim of Study 2 is to (1) rule out alternative explanations that are inherent to the correlational nature of Study 1 by manipulating bladder pressure, and (2) to generalize the inhibitory spillover effect to another domain known to require inhibition of more impulsive responses, namely intertemporal decision making (Li, 2008; Van den Bergh et al. 2008). Besides adding generalizability, finding inhibitory spillover on an intertemporal choice task would indicate that also more deliberative acts of impulse control can still benefit from unintentional inhibitory spillover effects.

#### *Method*

*Participants.* 102 Student participants (67 men, age  $M = 21.49$ ) were recruited on campus, and received €10 for their participation.

*Procedure.* Bladder pressure was manipulated by means of a water taste test approximately 45 minutes before the intertemporal choice task. Half of the participants were instructed to drink the entire volume of water of five cups (approximately 700 ml), whereas the other half received the instructions to taste the water by sipping from the cups (drinking approximately 50 ml)<sup>1</sup>. After a filler task lasting approximately 45 minutes, participants were

asked to make eight intertemporal choices similar to the task used by Li (2008). Choices were between a smaller reward which they would receive sooner (always tomorrow; hereafter referred to as the SS option) or a larger reward which they would receive later in time ( $X$  days from now; the LL option). A typical choice would be between receiving \$16 tomorrow or \$30 in 35 days. A manipulation check followed where we asked participants to indicate their current level of urination urgency (1 = not urgently at all; 7 = very urgently). After participants completed the study, the experimenter collected the cups from the water test, and checked whether each participant had followed the drinking instructions, which they all did.

### *Results and Discussion*

People in the ‘drink all’ condition, reported a higher urination urgency ( $M = 4.48$ ;  $SD = 1.92$ ) at the end of the experiment, compared to participants who only sipped the water ( $M = 2.75$ ;  $SD = 1.79$ ),  $t(100) = 4.71$ ,  $p < .001$ .

A t-test showed that, in line with our hypothesis, increased bladder pressure resulted in preferences reflecting increased impulse control,  $t(100) = 2.20$ ,  $p = .03$ ,  $p_{rep} = .98$ . People in the high bladder pressure condition chose more often for the LL reward ( $M = 4.50$ ;  $SD = 1.59$ ) compared to people in the low bladder pressure condition ( $M = 3.83$ ;  $SD = 1.49$ ). These findings indicate that inhibitory signals stemming from increased bladder pressure spill over to the domain of intertemporal choice, reflecting an increasing ability to inhibit the urge to go for the more immediate (but smaller) reward, and opt more often for the reward which is more beneficial in the long term.

### Study 3

The aim of study 3 was to replicate the findings of study 2, and to provide more evidence for the role of an inhibition system, by examining whether inhibitory spillover effects are

moderated by sensitivity of the Behavioral Inhibition System (BIS; Carver & White, 1994; Gray, 1990). As discussed before, the BAS has been identified to play a crucial role in the general reward system (e.g., Van den Bergh et al. 2008). The BIS, on the other hand, is sensitive to signals of punishment, and is involved in inhibition of ongoing behavior in the face of a threat. BIS has been shown to be involved in conflict monitoring and self-regulation (Carver & White, 1994; Shackman, McMEnamin, Maxwell, Greischar, & Davidson, 2009). Furthermore, an examination of the neurocognitive components of BIS and BAS indicated that BIS is associated with ACC activation (Amodio, Master, Yee, & Taylor, 2008; see also Shackman et al. 2009). Following the reasoning that inhibitory signals originate from the same neurological area which is vulnerable for unintentional inhibitory spillover (Berkman et al., 2009), people with a relatively more sensitive BIS are expected to be more prone to inhibitory spillover effects. Hence, we expect to find stronger effects of increased bladder control on intertemporal patience for people with a relatively more sensitive BIS.

### *Method*

*Participants.* 105 Students (76 men, age  $M = 21.08$ ) were recruited on campus, and received €10 for their participation.

*Procedure.* The procedure was identical to the procedure of Study 2, except the addition of the BIS/BAS scales (Carver & White, 1994), which participants completed at the end of the experiment. In line with Van den Bergh et al. (2008), we limited our measure to the BIS scale and the BAS Reward Responsiveness subscale. We added questions to assess participants' current level of thirst and their current mood (1 = very negative; 7 = very positive). After completion, the experimenter collected the cups from the water test, and checked whether the participant followed the drinking instructions.

### *Results and Discussion*

Eight participants did not follow the drinking instructions (they left more than 100 ml in the ‘drink all’ condition, or left less than 500 ml in the ‘taste’ condition), leaving 97 participants. A t-test confirmed our manipulation of bladder pressure on urination urgency,  $t(95) = 9.70, p < .001$  ( $M_{drink\ all} = 4.93; SD = 1.51; M_{taste} = 2.02; SD = 1.39$ ). Mood was not affected by this manipulation.

Replicating Study 2, a t-test revealed a significant effect of the bladder pressure manipulation on intertemporal patience,  $t(95) = 2.11, p < .05, p_{rep} = .98$ . People in the high bladder pressure condition opted more often for the LL reward ( $M = 4.80; SD = 1.91$ ) compared to people in the low bladder pressure condition ( $M = 4.02; SD = 1.63$ ). In order to test for the expected moderation of BIS, we conducted a regression analysis with a contrast code for the manipulation of bladder pressure, the mean-centered scores on the BIS scale, and their interaction. This regression model showed a significant interaction between bladder pressure condition and BIS,  $t(93) = 2.58, p = .01$ . A spotlight analysis (following Fitzsimons, 2008) at one standard deviation below the BIS mean did not show a significant effect of bladder pressure. However, spotlight analysis at one standard deviation above the BIS mean revealed a significant difference between the low and high bladder pressure condition,  $F(1,93) = 10.42, p < .01, B = 1.64$ . People in the high bladder pressure condition chose more often for the later-larger reward than people in the low bladder pressure condition, reflecting increased impulse control (see Figure 1). Importantly, including BAS, thirst, or an interaction term with bladder pressure condition did not reveal any significant effects of these factors, nor changed the significance of the interaction effect between BIS and bladder pressure. These results indicate that inhibitory

spillover effects occur independently of the reward system, rather than reflecting a deactivation of the reward system.

Study 3 again showed that increasing levels of bladder control result in an increasing ability to forego a more immediate rewarding option in favor of the more long term beneficial option, reflecting increased impulse inhibition and indicating that inhibitory signals are not domain specific but can spill over. Furthermore, inhibitory spillover effects are stronger for people with a more sensitive BIS, in line with the idea that various inhibitory signals originate from a general inhibitory network (Berkman et al. 2009).

#### Study 4

In Study 4, we examined whether exogenous cues can also induce increased bladder control, and thereby instigate inhibitory responses in unrelated domains. This would be in line with the general notion of a bidirectional link between perception and behavior (Dijksterhuis & van Knippenberg, 1998). Both Li (2008) and Van den Bergh et al. (2008) used pictures of appetitive stimuli (either desirable food or sexually appealing women) in order to induce craving for rewards. So in both studies, desire was induced by exposing participants to exogenous cues. Finding that the concept of urination can trigger increased bladder sensations and accompanying inhibitory signals would suggest that the occurrence of inhibitory spillover effects is not necessarily limited to physiological processes (i.e., a full bladder), but can be triggered by cues in the environmental as well.

#### *Method*

*Participants.* 131 Students (65 men, age  $M = 20.1$ ) participated in exchange for partial course credit.

*Procedure.* Participants were randomly assigned to one of two priming conditions (Urination versus Control Prime). The experiment was presented as two unrelated studies. The first task was a word-search paradigm. Participants saw a list of nine words, and were instructed to identify these words in a 10x9 letter matrix (see Lammers, Galinsky, Gordijn, & Otten, 2008 for a similar procedure). Participants in the urination prime condition had to search for urination related words (e.g., ‘urination’, ‘toilet’, bladder’). Participants in the control condition searched for words unrelated to urination (e.g., ‘table’, ‘watching’, ‘hammer’). After finishing this task, participants completed the same intertemporal choice task as used in Study 2 and 3, followed by a question regarding urination urgency. After completing these questions, participants were thanked and debriefed.

### *Results and Discussion*

We expected the urination prime to increase feelings of bladder sensations, which subsequently would trigger more inhibitory responses and generalize to the domain of intertemporal patience. Therefore, we tested for mediation following recommendations of Shrout and Bolger (2002) and Preacher and Hayes (2004; see also Zhao, Lynch Jr., & Chen, 2010). We first tested the effect of the independent variable (urination prime) on the mediator (reported urination urgency), which was significant,  $t(129) = 2.27, p < .05$ . Participants reported a higher urination urgency after searching for urination-related words ( $M = 2.43, SD = 1.54$ ), compared to participants who had searched for control words ( $M = 1.84, SD = 1.39$ ). Second, we tested the impact of the mediator on the dependent variable (intertemporal patience) while holding the independent variable constant. A regression analysis revealed that this effect was also significant,  $t(128) = 2.71, p < .01, B = 0.34$ , indicating that participants who reported a higher urination urgency made choices that reflected more temporal patience. Finally, in order to test whether the

mediation was significant, we performed the bootstrapping procedure following Preacher and Hayes, with 5000 resamples. This procedure showed that the mediation effect was significant at 95% confidence interval level (between 0.006 and 0.49), indicating that there was a significant effect of the urination prime on intertemporal patience, via increased sensations of urination urgency.

Study 4 showed that exogenous cues that are associated with urination result in increased feelings of urination urgency and accompanying bladder control. These increased inhibitory responses again spilled over to the domain of intertemporal choice, and resulted in increased intertemporal patience.

### General Discussion

Visceral drives have an enormous impact on our daily life (Loewenstein, 1996). On an empty stomach, we buy a lot more (unhealthy) food than when satiated. When experiencing sexual arousal, we are more prone to engage in unsafe sex (Ariely & Loewenstein, 2006), even though we are aware of the potential consequences. And in hindsight, we have a hard time fully realizing the impact of these visceral states on our behaviors (Nordgren, van der Pligt, & van Harreveld, 2006). These visceral drives are recognized as important determinants of increasing impulsive and reward seeking behavior. The impact of visceral drives generalizes beyond the domain of the visceral drive, resulting in a general increase in impulsive behavior (Van den Bergh et al., 2008). However, where previous research focused on the approach-related visceral states, we investigated the impact of an important and so far overlooked inhibitory-related visceral factor on impulsive behavior, namely urination urgency.

With four studies, we show that inhibitory signals stemming from increasing levels of bladder pressure can spill over to other domains, resulting in increased ability to control impulses

in unrelated domains. In Study 1, we showed that increased levels of bladder pressure correlate with speeded performance on color naming trials of the Stroop task, but not with performance on the word meaning trials, indicating that bladder control facilitates impulse inhibition. In Study 2 and 3, we manipulated bladder pressure and showed that it facilitates intertemporal patience in the monetary domain, reflected by increased tendency to resist more immediately rewarding options in favor of long-term beneficial options. Furthermore, we provided additional support for the idea of a general origin of inhibitory responses by showing a moderating effect of the sensitivity of the behavioral inhibition system. In Study 4, we showed that even exogenous cues can trigger a sense of urination urgency, which subsequently led to increased intertemporal patience.

To the best of our knowledge, the current studies are the first to examine the impact of inhibitory-related visceral factors on self-control conflicts, and to provide evidence for inhibitory spillover effects in the behavioral domain. Where Berkman and colleagues (2009) provided evidence for spillover effects of inhibitory signals at the level of brain activation, we show that inhibitory signals from one domain (due to increased levels of bladder control), can increase impulse control in unrelated domains. We show this effect both with a Stroop task (which requires inhibition of an automatic, but incorrect response in order to respond correctly as fast as possible), and with a task relying on more deliberative acts of control (intertemporal choice). Together with the previously mentioned neurological evidence, these findings seem to suggest that people possess a general inhibition system. The inhibition of various behaviors (motor and cognitive) seems to have its origin in the same neural area. Once inhibitory signals are sent, they are not completely bound to the focal task requiring inhibition, but spill over to other domains.

Our findings seem to contradict a large body of research in the domain of self-control and ego depletion (Baumeister, 2002; Baumeister et al. 1998). A common finding in this area is that the execution of self-control in one domain causes subsequent self-control impairment in a second domain. We identify two important conditions that differ between our studies and the typical ego depletion studies. A first difference regards the nature of the first task requiring control. Tasks known to result in a state of ego depletion rely on the exertion of deliberative and conscious efforts to control the self (see Hagger et al., 2010 for a meta-analysis). Bladder control, on the other hand, is a largely automatized, highly learned and nonconscious form of control (this type of control has also been referred to as self-regulation; Baumeister et al., 2007). The degree to which exerting control on the first task is effortful might be an important determinant for whether impulse control on a subsequent task will improve (inhibitory spillover effect) or deteriorate (depletion effect).

A second difference regards the timing of the different control tasks. A decline in performance has always been demonstrated on tasks following a previous task requiring self-control (i.e., sequentially occurring control tasks). As Berkman and colleagues (2009) showed, inhibitory spillover effects occur when the inhibitory signals originating from one task are present while executing the unrelated task. This condition also holds for the current studies: our participants were inhibiting their voiding impulse while they participated in the Stroop or intertemporal choice task. This suggests that inhibitory spillover effects are likely to occur when the different control tasks occur simultaneously.

Recently, Dewitte, Bruyneel and Geyskens (2009) demonstrated that the ability to exert self-control can increase after previous acts of self-control, when the two tasks involve similar response conflicts. Furthermore, Hung and Labroo (in press) argue that firmed muscles which

usually result when people try to recruit willpower (e.g., clenching one's fist) can also work in opposite direction and firm willpower, resulting in increased self-control. Together with the current set of findings, this calls for future research to shed more light on the conditions under which performance on control tasks is likely to improve, and conditions under which deterioration of task performance is expected.

Furthermore, future research may investigate whether spillover effects may also originate from other relatively automatic inhibitory responses. Gaining more insight in the underlying process of inhibitory spillover effects and its' boundary conditions provides valuable insights in response inhibition (both physiological and cognitive in nature), the existence of a general inhibition system, impulsive and self-control processes, and in conditions that potentially improve people's ability to inhibit impulses.

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## Footnote

<sup>1</sup> A bladder usually contains 300 ml of urine, and a bladder of an adult is reasonably full when it contains 500 ml. Liquid takes between 20 minutes and 3 hours to reach the bladder, depending on body size and liquid type (Marieb, Hoehn, Hutchinson, & Hutchings, 2007).