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Mental Simulation of Visceral States Affects Preferences and Behavior

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Abstract

Preferences and behavior are heavily influenced by one's current visceral experience, yet people often fail to anticipate such effects. Although research suggests that this gap is difficult to overcome—to act as if in another visceral state—research on mental simulation has demonstrated that simulations can substitute for experiences, albeit to a weaker extent. We examine whether mentally simulating visceral states can impact preferences and behavior. We show that simulating a specific visceral state (e.g., being cold or hungry) shifts people's preferences for relevant activities (Studies 1a-2) and choices of food portion sizes (Study 3). Like actual visceral experiences, mental simulation only affects people's current preferences but not their general preferences (Study 4). Finally, people project simulated states onto similar others, as is the case for actual visceral experiences (Study 5). Thus, mental simulation may help people anticipate their own and others' future preferences, thereby improving their decision making.

Keywords

mental simulation, mental imagery, empathy gap, visceral states

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Packing for winter travel can be difficult, and there are countless blogs offering tips for fitting big clothes into small suitcases. But if you are lucky enough to live somewhere warm, you may find it particularly challenging. Even if you have been to the destination before and know that you will need warm clothes, it can be hard to appreciate how many layers you will need to stop the cold and wind when you are currently comfortable in a t-shirt. Tourists who pack in the sun and then buy new hats and gloves in the snow demonstrate this forecasting error.

Preferences and behavior are influenced by a person's current visceral state. For example, the same person will buy and eat more unhealthy food when hungry compared with when satiated (Nisbett & Kanouse, 1969; Read & van Leeuwen, 1998), and express different moral attitudes when sexually aroused compared with when in a neutral state (Ariely & Loewenstein, 2006). Although the influence of visceral states (which we define as attention-consuming bodily experiences, for example, hunger, cold; Loewenstein, 1996; Risen & Critcher, 2011) is undeniable, people nevertheless often fail to accurately predict their preferences and behavior in different states (Wilson & Gilbert, 2003).

Due to this cold-to-hot empathy gap (Loewenstein, 1996), people underestimate the influence of thirst or pain when they are not currently experiencing these states (Read & Loewenstein, 1999; Van Boven & Loewenstein, 2003; Van Boven, Loewenstein, Welch, & Dunning, 2012). The empathy gap can emerge when making judgments about the self or about others. Indeed, even when people have previous experience with a powerful visceral state, like pain, they show surprisingly little ability to vividly recall the state or to predict how it affects someone (including themselves) when they are not currently experiencing it (Loewenstein, 1996; Loewenstein, Prelec, & Shatto, 1998; Morley, 1993). Research has also demonstrated an empathy gap when people in a hot state try to predict what the absence of the state would be like. When warning fatigued people that their behavior might be driven by their tired state, they nevertheless underestimate its influence, unable to overcome the gap (Nordgren, van der Pligt, & van Harreveld, 2006). Biased by one's current visceral state, this inability to sufficiently modify predictions for future preferences can result in suboptimal judgments and decisions.

Although simple manipulations such as warning people of visceral influences or recalling visceral states do not seem to help optimize predictions, deeper and more engaging mental simulation can substitute for actual experiences (Kappes &

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Morewedge, 2016). Mentally simulating an experience by imagining it in detail can evoke the same consequences as actually experiencing it, albeit to a lesser extent. Such simulation-as-substitution has been demonstrated for a wide range of experiences. For example, mental rehearsal can substitute for the physical practice of playing music instruments or performing complex surgeries (Cratty, 1984; Driskell, Copper, & Moran, 1994). Similarly, simulation of repeated food consumption leads to habituation to the particular food that people imagined consuming (Larson, Redden, & Elder, 2013; Morewedge, Huh, & Vosgerau, 2010).

Mental simulation can also give rise to similar physiological effects as actual experience. Imagining a spider or a painful experience can increase sympathetic nervous system activation (Holmes & Mathews, 2010), and evoke corresponding neural activity (Christian, Parkinson, Miles, Macrae, & Wheatley, 2015). Likewise, simulating sinking one's teeth into a lemon can lead one's mouth to fill with saliva (Keesman, Aarts, Vermeent, Häfner, & Papies, 2016). Unlike simply remembering a past experience or predicting one's reactions to a future visceral state, engaging in deeper mental simulation provides an "imitative representation of some event" (Taylor, Pham, Rivkin, & Armor, 1998, p. 430). By recruiting the same neural networks that accompany the actual experience (Ganis, Thompson, & Kosslyn, 2004; Jeannerod, 2001), simulations create plausible alternative realities by imagining concrete and specific events (Taylor & Schneider, 1989).

Given that mental simulation can induce analogous experiential effects, mental simulation may help people predict their reactions to visceral states that they are not currently experiencing. For example, people might have difficulty imagining a sour flavor or being scared, but actively simulating touching a spider or biting into a lemon can indeed produce corresponding physiological changes (Holmes & Mathews, 2010; Keesman et al., 2016). If mental simulation can substitute to some extent for visceral experience, then people who actively simulate a given state (say, hunger) should report feeling it more than those who do not. And, if current feelings predict preferences and behavior, then simulating hunger should lead people to be more interested in eating because they currently feel hungrier. If this is indeed the case, mental simulation might eventually help people to make more accurate predictions about themselves and others in alternative states. We provide a test of the first step by examining how mental simulation affects people's current feelings, preferences, and behavior.

In addition to having people report on their current visceral states, we test whether mental simulation produces effects similar to those when actually experiencing a visceral state, and whether they are moderated by the same factors. For example, we expect someone who is feeling cold to be especially interested in drinking a warm beverage at that moment but not to be permanently more excited about drinking coffee or tea. By extension, if simulating a particular visceral state leads people to momentarily experience it to some extent, then current preferences but not general preferences should be affected. Beyond temporal distance, social distance appears to be a boundary condition of projecting visceral states. In particular, research has demonstrated that people project their current visceral experiences onto similar but not onto dissimilar others (O'Brien & Ellsworth, 2012). Analogously, visceral states experienced as a result of mental simulation should be more readily projected onto similar rather than dissimilar others.

The Present Research

We test whether actively simulating a visceral state might evoke similar feelings to the actual experience, thereby shifting people's preferences and behavior. In Studies 1a and 1b, we test whether simulating warmth (vs. cold) decreases people's preferences for warming activities, and whether this effect exceeds the effect of priming warmth and cold. In Study 2, we replicate and extend this effect by testing whether simulating being hungry (vs. full) affects people's preferences for relevant satiating activities. In Study 3, we test whether simulating being hungry (vs. full) leads people to choose larger food portions. To determine whether simulations, such as visceral states, specifically inform one's current preferences, in Study 4, we examine whether simulating being hungry (vs. full or a neutral condition) affects momentary but not general preferences. Finally, in Study 5, we test whether people project their simulated visceral states when making judgments about similar and dissimilar others.

Study 1a

In Study 1a, we tested whether mental simulation of visceral states can shift people's current preferences. We provided people with concrete and specific cues (i.e., pictures) to facilitate mental simulation.

Method

Participants and design. We recruited 119 students (65 female, $M_{\text{age}} = 20.50$, $SD = 4.89$) at a North American university for a one-factorial (simulate cold vs. warmth) between-subjects design. We predetermined a sample size of at least 50 participants per condition, based on power analysis of an estimated effect size of $d = 0.55$ and a desired power of .80 with an alpha level of .05 (IJzerman, Schrama, & Pronk, 2016; Steinmetz & Posten, 2017), and collected some more data as data collection went faster than anticipated. Thus, we had 84% power for detecting a medium effect of $d = 0.55$, but 36% power for detecting a small effect of $d = 0.30$. For all studies, we report all measures and manipulations, and explain how sample sizes were determined. No data were excluded from analyses in any of the studies. For all materials and data, see https://osf.io/thf4v/

Materials and procedure. To simulate cold or warmth, participants imagined themselves in a picture for 30 s that depicted a very cold versus very warm environment (glacier/snowy landscape vs. desert/lava lake). After the 30 s, participants reported how vivid their mental imagery was (1 = *not very vivid*, 9 = *very vivid*) and described what they had imagined (Steinmetz & Posten, 2017).

Next, participants indicated their preferences for different consumer goods and activities in fully randomized order (Zhang & Risen, 2014). Five items were preferences between cold and warm activities (e.g., "Right now, I would prefer . . ." 1 = *taking a hot bath*, 9 = *taking a cool, refreshing shower*; reverse coded). The other five items were preferences between neutral temperature activities to mask the questionnaire's purpose. Our dependent measure was the average of the five temperature-related preferences (α = .64), with higher values indicating a stronger preference for warming activities.

Finally, we asked participants how they currently felt (1 = *very cold*, 9 = *very warm*) in addition to four filler items (tired, awake, thirsty, hungry). For exploratory reasons, participants estimated the temperature of the lab room they were in (open-ended item). There were no differences between the warm and cold condition in the room temperature estimates in the vividness of participants' mental imagery, or in how hungry or tired participants felt, all *p*s > .267.[1]

Results and Discussion

Participants in the cold condition preferred more warming activities (M = 6.23, SD = 1.52) than participants in the warm condition (M = 5.19, SD = 1.73), $t(117) = 3.501$, $p = .001$, $d = 0.64$. Participants in the cold condition also felt less warm (M = 5.11, SD = 1.72) than participants in the warm condition (M = 5.79, SD = 1.36), $t(117) = 2.375$, $p = .019$, $d = 0.44$.

The colder the participants felt, the stronger their preferences for warming activities, $\beta = .256$, $SE = 0.096$, $t(117) = 2.755$, $p = .007$, 95% confidence interval (CI) = [0.074, 0.455]. A regression analysis predicting preferences from condition (simulate warm or cold) and how warm participants felt revealed a significant effect of condition, $\beta = .906$, $SE = 0.301$, $t(116) = 3.013$, $p = .003$, 95% CI = [0.311, 1.502], and a significant effect of how warm participants felt, $\beta = -.203$, $SE = 0.095$, $t(116) = 2.136$, $p = .035$, 95% CI = [0.015, 0.391].[2] Although marginal, participants' feelings of warmth partially mediated the effect of condition (95% CI = [−0.057, 0.199], 1,000 bootstrapping samples), Sobel's $z = 1.80$, $p = .072$.

Study 1a provides evidence that mentally simulating being in a very cold environment makes people more interested in warming activities, at least in part because actively simulating being cold made them feel colder in the moment.

Study 1b

In Study 1b, we replicated Study 1a. In addition, we tested whether the effects of mentally simulating visceral states are stronger than the effects of priming visceral states. Some previous literature has found that priming visceral states shifts people's preferences (Shalev, 2014), whereas other literature has found no such effects (Zhang & Risen, 2014). Thus, we expected mental simulations of warmth versus cold to affect participants' preferences (as in Study 1a), and expected an attenuation or elimination of this effect when priming warmth versus cold.

Method

Participants and design. We recruited 242 participants (90 female, M_{age} = 34.30, SD = 9.86) on Amazon Mechanical Turk for a 2 (simulation vs. priming) × 2 (cold vs. warm) between-subjects design. To be consistent with the sample size of Study 1a, we predetermined a sample size of 60 participants per condition. Our sample provided 85% power for detecting a medium effect (d = 0.55) and 37% power for detecting a small effect (d = 0.30).

Materials and procedure. In the simulation conditions, we used the same procedure and materials as in Study 1a. Participants imagined themselves in a picture of a cold versus warm environment for 30 s, and afterward described what they had imagined. In the priming conditions, participants looked at one of the pictures for 30 s but were asked to judge the picture's quality by forming an impression of its colors and resolution. Afterward, participants wrote about their judgment. Thereby, we ensured that primed participants would focus their attention on the picture to a similar extent to those in the simulation conditions.

Next, participants responded to the same preference items as in Study 1a in fully randomized order. Our dependent measure was the average of the five temperature-related choices (simulation conditions: α = .64; priming conditions: α = .54), with higher values indicating a stronger preference for warming activities.

We asked participants how they currently felt (1 = *very cold*, 9 = *very warm*) in addition to four filler items (tired, awake, thirsty, hungry). As a manipulation check, we asked all participants to what extent they had imagined themselves in the environment when looking at the picture (1 = *not at all*, 9 = *very much*). Finally, participants estimated the temperature of the room they were in (open-ended item).

There were no differences between the warm and cold conditions in the room temperature estimates, or in how thirsty, tired, or awake participants felt, all *p*s > .163.[3]

Results and Discussion

For the manipulation check, we found the expected main effect of simulation versus priming, $F(1, 238) = 124.700$, $p < .001$, $\eta^2 = .344$. Participants in the simulation conditions imagined themselves in the pictures more than primed participants did (simulation cold: M = 8.28, SD = 1.25; simulation warm: M = 8.24, SD = 1.43; priming cold: M = 5.48, *SD* = 2.89; priming warm: *M* = 4.75, *SD* = 2.56). There was no main effect of warm versus cold pictures, $F(1, 238) = 1.914$, $p = .168$, $\eta^2 = .008$, and also no interaction effect, $F(1, 238) = 1.544$, $p = .215$, $\eta^2 = .006$.

Turning to preferences, participants in the cold conditions preferred more warming activities than participants in the warm conditions, $F(1, 238) = 17.639$, $p < .001$, $\eta^2 = .069$. There was no main effect of simulation versus priming, $F(1, 238) = 0.045$, $p = .832$, $\eta^2 < .001$. Importantly, we found a marginally significant interaction for simulation versus priming with the warm versus cold pictures, $F(1, 238) = 3.549$, $p = .061$, $\eta^2 = .015$. More specifically, in the simulation conditions, we replicated Study 1a. Participants in the cold condition ($M = 6.09$, $SD = 1.72$) preferred more warming activities than participants in the warm condition ($M = 4.66$, $SD = 1.94$), $p < .001$, $d = 0.78$. Although the same pattern emerged from the priming conditions (cold: $M = 5.70$, $SD = 1.65$; warm: $M = 5.16$, $SD = 1.96$), it was less pronounced, $p = .097$, $d = 0.30$.

For participants' feelings of warmth, we found no main effect of simulation versus priming, $F(1, 238) = 1.975$, $p = .161$, $\eta^2 = .008$, or of the warm versus cold pictures, $F(1, 238) = 0.909$, $p = .341$, $\eta^2 = .004$. We also found no interaction effect, $F(1, 238) = 1.275$, $p = .533$, $\eta^2 = .002$. Yet, the pattern of results is in the expected direction. Participants who simulated being in a cold environment ($M = 5.31$, $SD = 2.10$) felt somewhat (but not significantly) colder than those who simulated being in a warm environment ($M = 5.68$, $SD = 1.56$), $p = .274$, $d = 0.20$. As mentioned above, our sample only provided 37% power for detecting a small effect ($d = 0.30$). This pattern disappeared in the priming conditions (cold: $M = 5.79$, $SD = 1.79$; warm: $M = 5.86$, $SD = 1.79$), $p = .813$, $d = 0.04$. Due to the lack of direct effect on participants' feelings in the simulation condition, current feelings did not mediate the effect of simulation on preferences.

Study 1b provides evidence that mentally simulating visceral states elicits stronger corresponding preferences than priming these states.

Study 2

In Study 2, we tested whether people can simulate visceral states without pictures, and whether preferences match the specific state being simulated. Research shows that experiencing one visceral state does not help overcome the empathy gap for other visceral states. For example, fatigued people found sleep deprivation more harmful than nonfatigued people, but they did not differ in their evaluation of cold-induced discomfort (Nordgren, McDonnell, & Loewenstein, 2011). Thus, we predict that simulating cold affects preferences for warming but not filling activities, and that simulating hunger affects preferences for filling but not warming activities.

Method

Participants and design. We recruited 300 participants (140 female, $M_{age} = 34.21$, $SD = 10.57$) on Amazon Mechanical Turk for a 2 (state: satiation vs. temperature) × 2 (high vs. low intensity of the state; full/warm vs. hungry/cold) between-subjects design. Again, we predetermined a sample size of at least 50 participants per condition, and collected more data as we had additional funds available. Our sample provided 92% power for detecting a medium effect ($d = 0.55$) and 45% power for detecting a small effect ($d = 0.30$).

Materials and procedure. To simulate cold, warmth, hunger, or satiation, participants read the following instructions:

> For the next 60 seconds, please imagine that you are very HOT [versus cold, hungry, or full]. Please think about what it would be like to feel very hot in as much detail as possible. Think about what your experience would be like: What would you be thinking about? How would your body feel? How would you act? Please try to give us a detailed description of your thoughts and feelings. (modeled after Keesman et al., 2016)

During these 60 s, participants wrote about their thoughts and feelings. After 60 s, participants could either continue writing or proceed.

Participants worked on the same preferences questionnaire as in Studies 1a and 1b, in which five items ($\alpha = .63$) indicated a stronger preference for warming activities. To test whether simulating hunger affects participants' preferences for filling activities, we added five items ($\alpha = .56$) about filling activities (e.g., "Right now, I would prefer . . ." 1 = *going on a date to a movie*, 9 = *going on a date to a restaurant*). Higher values indicated a stronger preference for filling activities. Participants responded to all 15 items in fully randomized order (five warmth-related items, five satiation-related items, five fillers).

Finally, we asked participants how hot or cold, full or hungry, thirsty or quenched, and tired or energized they felt. Then, we asked participants how vivid their mental imagery in the simulation task had been and to what extent they had engaged with the simulation task. There were no differences between the warm and cold condition, or the hungry and full condition on any of these items, all *p*s > .100.

Results and Discussion

As predicted, a 2 × 2 × 2 ANOVA with visceral state and intensity as between-subjects factors and preferences for warming versus filling activities as a within-subjects factor revealed a significant three-way interaction, $F(1, 297) = 36.112$, $p < .001$, $\eta^2 = .108$.[4] Next, we examined preferences for warming and filling activities separately.

Replicating Studies 1a and 1b, participants who simulated being hot had weaker preferences for warming activities (*M*

= 4.93, *SD* = 1.78) than participants who simulated being cold (*M* = 7.33, *SD* = 1.44), $F(1, 297) = 84.271$, $p < .001$, $\eta^2 = .221$. There was no difference in preferences for warming activities between participants who simulated being hungry (*M* = 6.13, *SD* = 1.69) versus being full (*M* = 6.24, *SD* = 1.46), $F(1, 297) = 0.173$, $p = .678$, $\eta^2 = .001$. Furthermore, we found a significant interaction of state and intensity, $F(1, 297) = 46.182$, $p < .001$, $\eta^2 = .135$.

We also examined whether the simulation effect on preferences for warming activities was mediated by currently feeling warm. Participants who simulated being warm felt warmer (*M* = 4.95, *SD* = 1.28) than participants who simulated being cold (*M* = 4.13, *SD* = 1.45), $F(1, 296) = 11.524$, $p < .001$, $\eta^2 = .037$. The colder the participants felt, the stronger their preferences for warm activities, $\beta = -0.578$, $SE = 0.105$, $t(148) = -5.491$, $p < .001$, 95% CI = [−0.786, −0.370]. A regression predicting preferences for warming activities that includes condition and current feelings of warmth revealed a significant effect of simulation, $\beta = 2.163$, $SE = 0.256$, $t(148) = 8.441$, $p < .001$, 95% CI = [1.657, 2.670], and a significant effect of feeling warm, $\beta = -0.359$, $SE = 0.090$, $t(148) = -3.972$, $p < .001$, 95% CI = [−0.538, −0.180]. Moreover, feelings of warmth mediated the effect of simulation on preferences for warming activities (95% CI = [−0.507, −0.107], 1,000 bootstrapping samples), Sobel's $z = 3.033$, $p = .002$.

Turning to preferences for filling activities, participants who simulated being hungry had stronger preferences for filling activities (*M* = 5.57, *SD* = 1.82) than participants who simulated being full (*M* = 4.32, *SD* = 1.97), $F(1, 297) = 19.089$, $p < .001$, $\eta^2 = .060$. However, participants who simulated being cold also had stronger preferences for filling activities (*M* = 5.83, *SD* = 1.64) than participants who simulated being warm (*M* = 5.17, *SD* = 1.57), $F(1, 297) = 3.087$, $p = .023$, $\eta^2 = .017$. Thus, we found no significant interaction of state and intensity, $F(1, 297) = 2.157$, $p = .143$, $\eta^2 = .007$.

Next, we tested whether the simulation effect on preferences for filling activities was mediated by currently feeling hungry. Participants who simulated being hungry felt hungrier (*M* = 5.17, *SD* = 2.34) than participants who simulated being full (*M* = 4.00, *SD* = 2.10), $F(1, 296) = 10.129$, $p = .002$, $\eta^2 = .033$. The hungrier participants felt, the stronger their preferences for filling activities, $\beta = .463$, $SE = 0.060$, $t(150) = 7.721$, $p < .001$, 95% CI = [0.345, 0.582]. A regression predicting preferences for filling activities that included condition and feelings of hunger revealed a significant effect of simulation, $\beta = .758$, $SE = 0.278$, $t(150) = 2.726$, $p = .007$, 95% CI = [0.208, 1.307], and a significant effect of feeling hungry, $\beta = .421$, $SE = 0.061$, $t(150) = 6.928$, $p < .001$, 95% CI = [0.301, 0.541]. Feelings of hunger mediated the effect of simulation on preferences for filling activities (95% CI = [0.178, 0.847], 1,000 bootstrapping samples), Sobel's $z = 2.979$, $p = .003$.

In addition to the predicted effects, we found an unexpected effect of simulating being warm versus cold on participants' preferences for filling activities, partially mediated by their slightly increased feelings of hunger. Specifically, participants who simulated being cold felt marginally hungrier (*M* = 5.07, *SD* = 2.35) than participants who simulated being warm (*M* = 4.37, *SD* = 2.21), $F(1, 296) = 3.543$, $p = .061$, $\eta^2 = .012$. And when simulating warmth versus cold, the hungrier participants felt, the stronger their preferences for filling activities, $\beta = .202$, $SE = 0.056$, $t(148) = 3.594$, $p < .001$, 95% CI = [0.091, 0.313]. A regression predicting preferences for filling activities that included condition (warm vs. cold) and feelings of hunger revealed a significant effect of simulation, $\beta = .544$, $SE = 0.258$, $t(148) = 2.104$, $p = .037$, 95% CI = [0.033, 1.055], and a significant effect of feeling hungry, $\beta = .184$, $SE = 0.056$, $t(148) = 3.275$, $p = .001$, 95% CI = [0.073, 0.295]. Feelings of hunger partially mediated the effect of simulation on preferences for filling activities (95% CI = [0.002, 0.364], 1,000 bootstrapping samples), Sobel's $z = 1.650$, $p = .099$. It is possible that this effect is related to the finding in animal research that cold can induce hunger, whereas warmth leads to (relative) satiation (Zhang & Wang, 2006; Zhao, 2011) due to the greater energy expenditure in colder climates, which requires increased calorie intake. However, future research is necessary to ascertain the robustness (or spuriousness) of this particular effect.

Study 2 replicated the effects from Studies 1a and 1b for temperature but without requiring pictures to facilitate the simulation process. The results also generalize our earlier findings to show that mentally simulating different visceral states can affect preferences. Furthermore, the results provide additional evidence that simulation can work through substitution—the effects on preferences are state specific and are mediated by current feelings for the state that people simulated.

Study 3

Study 3 tested whether mental simulation affects actual (rather than hypothetical) choices of food portion sizes.

Method

Participants and design. We recruited 111 community participants (64 female, $M_{age} = 37.44$, *SD* = 15.63) at a North American museum for a 2 (simulate being hungry vs. full) between-subjects design. Again, we predetermined a sample size of at least 50 participants per condition, and were able to recruit some more participants on the designated data collection days. Our sample provided 81% power for detecting a medium effect ($d = 0.55$) and 34% power for detecting a small effect ($d = 0.30$).

Materials and procedure. Participants simulated being hungry versus full with the same procedure as in Study 2. Next, participants made six consumer choices about the same item in different sizes. Critically, we told participants that they would receive one of their selected choices in the selected size after the study. Thus, participants knew that one of their choices would determine their actual reward. Three of the six choices were about different sizes of snack food items (popcorn, chocolate ice cream, potato chips, $\alpha = .66$), whereas the other three items were fillers (notepad, picture frame, toothpaste). For each item, participants chose between a small, medium, or large item, or nothing (e.g., 1 = *small popcorn*, 2 = *medium popcorn*, 3 = *large popcorn*, 0 = *no popcorn*).

Finally, we asked participants how they currently felt (hot/cold, full/hungry, thirsty/quenched, tired/energized), and how long ago they had last eaten something (a snack or a full meal). There were no differences between the hungry and full condition on any of these items, all ps > .205.

Results and Discussion

We combined the size choices for the three food items. Participants who simulated being hungry chose larger food portion sizes ($M = 2.33$, $SD = 0.86$) than participants who simulated being full ($M = 1.88$, $SD = 0.71$), $t(109) = 3.031$, $p = .003$, $d = 0.57$.[5] The hungrier participants felt, the larger their chosen food portions, $\beta = 0.137$, $SE = 0.031$, $t(110) = 4.346$, $p < .001$, 95% CI = [0.074, 0.199].[6] Unlike Studies 1a and 2, there was no direct effect of simulation condition on how hungry participants felt (hungry: $M = 4.62$, $SD = 2.32$; full: $M = 4.07$, $SD = 2.25$), $t(109) = 1.261$, $p = .210$, $d = 0.24$, though it was in the predicted direction). As mentioned above, our sample only provided 34% power for detecting a small effect ($d = 0.30$). Consequently, how hungry participants felt did not mediate the effect of simulation condition on choices.

Whereas Studies 1a and 2 demonstrated that mentally simulating visceral states can affect how much interest people express for various activities, Study 3 showed that it can affect real choices with immediate consequences.

Study 4

In Study 4, we tested a boundary condition to gain insight into the underlying mechanism. We expected that simulation alters current experiences, which people use when determining their current preferences but not when reporting their general preferences. People have difficulty reporting their preferences in different visceral states (Loewenstein et al., 1998), presumably because their current preferences are heavily influenced by their current experiences. However, people can reliably report their general, stable preferences (Van Haitsma et al., 2014), which are determined by numerous other factors (Galef, 1996; Rozin, 2006). Thus, we expect that people's current but not general preferences are affected by their current (real or simulated) visceral experiences. Such results would suggest that people rely on mental simulations the way they rely on the actual experience of visceral states when inferring their current preferences ("What activity do I currently feel like?"), while basing their general preferences on other factors ("What do I usually like?").

In this study, we included a neutral control condition to test whether simulating being full or being hungry exerted a similar influence on people's preferences.

Method

Participants and design. We recruited 405 participants (165 female, $M_{age} = 34.62$, $SD = 11.56$) on Amazon Mechanical Turk for a 3 (state: hungry vs. full vs. control) × 2 (timing: now vs. in general) between-subjects design. Again, we predetermined a sample size of at least 50 participants per condition, and collected more data as we had additional funds available. Our sample provided 88% power for detecting a medium effect ($d = 0.55$) and 41% power for detecting a small effect ($d = 0.30$).

Materials and procedure. The simulation procedure was identical to Studies 2 and 3. Participants imagined, for at least 60 s, being hungry or being full. In the control condition, participants imagined one of two neutral activities (traveling to a different city vs. playing with a childhood toy).

To measure participants' momentary versus general preferences, they worked on the same filling activities questionnaire as in Study 2. Five items measured their preference for filling activities ($\alpha = .67$ for momentary preferences, $\alpha = .48$ for general preferences), in random order, mixed with five neutral filler items. To vary the timing, participants either responded in the same wording as in Study 2 (i.e., "Right now, I would prefer . . .") or reported their general preferences (i.e., "I would always prefer . . .").

Finally, we asked participants how they currently felt (hot/cold, full/hungry, thirsty/quenched, tired/energized), how vivid their mental imagery had been, and to what extent they had engaged with the simulation task. There were no effects of the simulation condition on vividness or on engagement, or on how thirsty or tired participants felt, all ps > .436.[7]

Results and Discussion

For participants' preferences, we found a significant main effect of simulation, $F(2, 399) = 56.249$, $p < .001$, $\eta^2 = .098$, and a marginally significant main effect of timing, $F(1, 399) = 3.517$, $p = .061$, $\eta^2 = .009$. The main effects were qualified by the predicted interaction of simulation and timing, $F(2, 399) = 19.791$, $p < .001$, $\eta^2 = .090$.

For momentary preferences, we replicated Study 2. When participants simulated being hungry, they had stronger preferences for filling activities ($M = 6.30$, $SD = 1.63$) than when they simulated being full ($M = 3.89$, $SD = 1.73$), $p < .001$, $d = 1.43$. Preferences for filling activities in the control condition ($M = 5.55$, $SD = 1.64$) were weaker than those in the hungry condition, $p = .009$, $d = 0.46$, but stronger than those in the full condition, $p < .001$, $d = 0.98$.[8]

In contrast, as predicted, we found no effect of simulation on participants' general preferences. When participants simulated being hungry, they had almost identical general preferences for filling activities ($M = 5.49$, $SD = 1.55$) as when they simulated being full ($M = 5.48$, $SD = 1.54$), $p = .971$, $d = 0.01$. Preferences in the control condition ($M = 5.69$, $SD = 1.56$) were similar to the hungry condition, $p = .474$, $d = 0.13$, and to the full condition, $p = .450$, $d = 0.14$.

For participants' feelings of hunger, we found a significant main effect of simulation, $F(2, 399) = 54.799$, $p < .001$, $\eta^2 = .064$. We found no effect of timing, $F(1, 399) = 0.980$, $p = .323$, $\eta^2 = .002$, and no significant interaction, $F(2, 399) = 2.327$, $p = .099$, $\eta^2 = .012$. Thus, mental simulation affected participants' current experience of hunger, regardless of whether they reported their current or general preferences. Specifically, in the current preferences condition, when participants simulated being hungry, they felt hungrier ($M = 5.38$, $SD = 2.16$) than when they simulated being full ($M = 3.74$, $SD = 1.88$), $p < .001$, $d = 0.81$. The control condition fell in between ($M = 4.82$, $SD = 2.06$), with participants feeling similarly hungry as in the hungry condition, $p = .124$, $d = 0.27$, but hungrier than in the full condition, $p = .002$, $d = 0.55$. In the general preferences condition, when participants simulated being hungry, they felt hungrier ($M = 5.00$, $SD = 1.90$) than when they simulated being full ($M = 4.13$, $SD = 1.99$), $p = .013$, $d = 0.45$. The control condition again fell in between ($M = 4.21$, $SD = 2.09$), with participants feeling similarly hungry as in the full condition, $p = .832$, $d = 0.04$, but less hungry than in the hungry condition, $p = .023$, $d = 0.40$.

Although simulation affected participants' current feeling of hunger in both conditions, we expected participants to use their feelings of hunger only to determine their current preferences but not their general preferences. To test this prediction, we ran separate mediation models for the momentary and general preferences conditions.[9]

In the momentary preferences condition, the hungrier the participants felt, the stronger their preferences for filling activities, $\beta = .488$, $SE = 0.054$, $t(200) = 8.963$, $p < .001$, 95% CI = [0.381, 0.596]. When controlling for feeling hungry, the effect of simulation became marginally significant, $\beta = -.283$, $SE = 0.146$, $t(200) = -1.939$, $p = .054$, 95% CI = [−0.571, 0.005], whereas feeling hungry remained a significant predictor of participants' preferences, $\beta = .475$, $SE = 0.055$, $t(200) = 8.714$, $p < .001$, 95% CI = [0.368, 0.583]. How hungry participants felt partially mediated the effect of simulation on momentary preferences (95% CI = [−0.361, 0.005], 1,000 bootstrapping samples), Sobel's $z = -1.729$, $p = .084$.

We found no effect of simulation on participants' general preferences, so that computing a mediation analysis would be uninformative. Moreover, hungrier participants did not report stronger general preferences for filling activities, $\beta = .067$, $SE = 0.054$, $t(202) = 1.241$, $p = .216$, 95% CI = [−0.039, 0.172]. Thus, feelings of hunger informed participants' current but not general preferences.

Study 4 showed again that simulating a visceral state can affect people's preferences by making them feel like they are experiencing the state. The control condition in this study highlighted that simulating feeling hungry and full can both affect a person's current state and thereby his or her momentary preferences. Importantly, mental simulation affected feelings of hunger for people in both the momentary and the general preferences condition. However, simulation only affected momentary (but not general) preferences. Thus, feelings of hunger were only relied upon in the momentary preferences condition.

If our manipulation had an effect because participants had the theory that simulation should affect their preferences (e.g., experimental demand), then there should be an effect across conditions. Instead, if simulating a visceral state affected people's feelings, then they should respond as if they were actually feeling hungry or full. The results supported the latter interpretation—just like hunger affects current preferences for eating but not general preferences, we found that simulating hunger affected current but not general preferences.

We directly tested participants' theories for how simulation would affect their preferences to address concerns of experimental demand. We recruited a separate sample of 114 Amazon Mechanical Turk participants (53 female, $M_{age} = 36.79$, $SD = 13.42$). Participants reported how they thought someone who had just mentally simulated being hungry versus being full (between subjects) for 1 min would behave. Specifically, all participants indicated what they thought the person would prefer on the same five momentary preferences for filling activities items ($\alpha = .92$) and five general preferences for filling activities items ($\alpha = .88$), in addition to the same filler items. Participants predicted that the person would show stronger momentary preferences for filling activities after having simulated being hungry ($M = 7.11$, $SD = 1.74$) compared with being full ($M = 3.96$, $SD = 2.21$), $t(112) = 8.478$, $p < .001$, $d = 1.584$. Thus, participants correctly anticipated the effects of simulation on momentary preferences. However, participants also predicted that the person would show stronger general preferences for filling activities after having simulated being hungry ($M = 6.48$, $SD = 1.72$) compared with being full ($M = 4.43$, $SD = 2.01$), $t(111) = 5.848$, $p < .001$, $d = 1.096$. Contrary to our findings, participants' lay theories suggested that simulation would also affect general preferences. Had experimental demand caused our effects in Study 4, mental simulation should have affected participants' general preferences.

Study 5

In Study 5, we tested whether simulating visceral states also affects people's predictions about other people's visceral states. The literature suggests that people project their current visceral experiences onto others (Van Boven & Loewenstein, 2003). We expected that the same holds when simulating visceral states, as simulations can affect current states (as we have shown in our earlier studies). We further tested whether projection of simulated states is moderated by the perceived similarity to the other person. Research has shown that people project their visceral states onto similar, but not dissimilar, others (O'Brien & Ellsworth, 2012). We expected the same pattern for projection of simulated visceral states. If this is indeed the case, the effects of simulated visceral states on judgments would very closely resemble the effects of actual visceral experiences. Such a finding would further support the notion of simulation as substitution, and thereby demonstrate the potential of mental simulation to overcome notoriously persistent empathy gaps.

Method

Participants and design. We recruited 200 participants (93 female, M_{age} = 34.26, SD = 10.26) on Amazon Mechanical Turk for a 2 (state: hungry vs. full) × 2 (other person: similar vs. dissimilar) between-subjects design. Again, we predetermined a sample size of at least 50 participants per condition. Our sample provided 78% power for detecting a medium effect (d = 0.55) and 32% power for detecting a small effect (d = 0.30).

Materials and procedure. First, participants were asked to provide the name of someone they knew personally who was either very similar or very dissimilar to them. We further specified that the person should not currently be in the same location as the participant (to prevent people from simply asking the other person about their current feelings). Participants read that they would be asked a few questions about that person but would first work on another task. With this question order, participants immediately responded to the projection items after the simulation task without requiring further instructions. Participants followed the simulation procedure, which was identical to Studies 2 to 4. For at least 60 s, participants imagined being hungry or being full.

Next, participants were asked to guess how the person they named earlier is currently feeling on four items (in randomized order). On the critical item, participants reported whether they thought the other person was currently feeling full or hungry (1 = *very full*, 9 = *very hungry*). As fillers, participants additionally reported how thirsty versus quenched, hot versus cold, and tired versus energized they thought the other person was feeling.[10] Finally, as a manipulation check, participants reported how similar they felt to the other person (1 = *very similar*, 9 = *very dissimilar*). Participants felt more similar to the other person in the similar condition (M = 7.04, SD = 1.46) compared with the dissimilar condition (M = 3.26, SD = 1.84), $t(198) = 16.007$, $p < .001$, d = 2.276. Note that we did not ask participants how hungry or full they were currently feeling to avoid potential carryover effects from the item asking how hungry or full the other person was feeling.

Results and Discussion

For the other person's (projected) feelings of hunger, we found no main effect of simulation, $F(1, 196) = 0.374$, $p = .541$, $\eta^2 = .002$, or of similarity (vs. dissimilarity), $F(1, 196) = 0.118$, $p = .732$, $\eta^2 = .001$. However, as expected, we found a significant interaction of simulation and similarity, $F(1, 196) = 6.657$, $p = .011$, $\eta^2 = .033$.

Participants projected their simulated visceral state onto similar others. Participants who simulated being hungry thought that the similar other was hungrier (M = 5.37, SD = 1.84) than participants who simulated being full (M = 4.53, SD = 1.97), $p = .028$, d = 0.44. In contrast, participants did not project their simulated visceral states onto dissimilar others. Participants who simulated being hungry perceived the dissimilar other (M = 4.78, SD = 1.90) to be equally hungry (or, if anything, less hungry) as participants who simulated being full (M = 5.30, SD = 1.72), $p = .157$, d = 0.29.

In Study 5, participants who simulated hunger responded as though they were actually hungry. Namely, participants perceived another person to be hungrier—but only when that person was similar to them. Because we did not measure participants' own feelings of hunger (to avoid carryover effects), we can only assume that our results emerge because participants projected their own experienced hunger onto the other person. Nevertheless, these results provide additional evidence that simulating a visceral experience can lead to behavior that closely resembles having the visceral experience.

General Discussion

In six studies, we show that people are able to mentally simulate visceral states. These simulated experiences appear to substitute for actual visceral experiences, affecting preferences (Studies 1a-2) and behavior (Study 3). People use the feelings that result from simulated experiences to infer their current preferences but not their general preferences (Study 4). Furthermore, people project their simulated experiences onto similar but not onto dissimilar others (Study 5).

Mental simulation of visceral states affects preferences and behavior (at least in part) because people's feelings (e.g., of hunger and cold) are also affected. We found that people's self-reported feelings (partially) mediate the effects of simulation on preferences and behavior in our studies, except for Studies 1b and 3. One reason why we did not consistently find a mediating effect of feelings on preferences and behavior might be that we lacked the statistical power to detect a small effect. Indeed, the effect size for current feelings was small or small/medium in all studies (Study 1a: d = 0.44, Study 1b: d = 0.20, Study 2: η^2 = .033 and .037; Study 3: d = 0.24; Study 4: η^2 = .064). Thus, we conducted a single-paper meta-analysis (McShane & Böckenholt, 2017) across all of our studies in which we measured participants' current feelings (Studies 1a-4). This meta-analysis showed an overall significant effect of simulation on current feelings at 0.87 ($SE = 0.13$; $z = 6.48$, $p < .001$). We conclude that simulation affects current feelings, which (at least partly) explains why simulation also affects preferences and behavior. We also conducted a meta-analysis of simulation on preferences and behavior, which showed an overall significant effect at 1.50 ($SE = 0.33$; $z = 4.53$, $p < .001$).

Note that mere compliance with experimental demand would lead to different predictions. Although we acknowledge that some of our findings might partly originate from experimental demand, we took great care to address this concern. By using consequential choices in Study 3, we render compliance with perceived demand unattractive, as people would in many cases have to forego their desired food portion size to comply with perceived demand. Thus, we believe that the costs of compliance with perceived demand in Study 3 exceed the potential benefits, making it unlikely to drive behavior. Neither can experimental demand explain why simulation failed to affect general preferences in Study 4. If people wanted to give presumably desirable answers, they would report stronger general preferences for filling activities after having simulated hunger. Such a finding would be in line with people's lay theories on how simulation affects general preferences, as we demonstrated in our follow-up to Study 4. Thus, we contend that demand is unlikely to be responsible for our effects in Study 4, given that the pattern of results following simulation was different from that in people's lay theories. Finally, in Study 5, compliance with experimental demand would presumably lead people to project their simulated experience onto all others. Taking similarity into account to comply with experimental demand requires a more sophisticated understanding of social psychology than most people have. Yet, as simulation affected people's current behavior and preferences but not their general preferences and affected their projection onto similar but not dissimilar others, we conclude that experimental demand cannot explain our findings as a whole.

Our results demonstrate that simulation not only substitutes for sensorimotor experiences (Kappes & Morewedge, 2016) but can also substitute for the experience of visceral states. Previous literature has long argued that one's current state is extremely difficult to overcome when trying to imagine alternate visceral states (Loewenstein et al., 1998). Indeed, without concrete cues, people may fail to generate a realistic representation of a visceral state (e.g., "imagine being fatigued"; Nordgren, van der Pligt, & van Harreveld, 2007, p. 77). The question thus arises exactly what conditions are necessary for mental simulation to substitute for visceral experiences. Past research suggests that mental simulation requires a detailed representation of the simulated event (Szpunar, Spreng, & Schacter, 2014) that recruits overlapping neural mechanisms that support perception and action (Ganis et al., 2004; Jeannerod, 2001). In our studies, we provided people with concrete cues (pictures in Studies 1a-1b, specific questions in Studies 2-5) to prompt mental simulation. Thus, we show that abstract, semantic representations (e.g., feeling cold) can be translated into detailed episodic simulations (e.g., How does my body feel when I'm cold?), with the corresponding consequences for preferences and behavior.

People do not seem to generate detailed episodic simulations automatically. In Study 1b, the effects on preferences were stronger when participants were instructed to imagine themselves in the pictures, compared with when they simply looked at the pictures. Previous literature (Keesman et al., 2016) has also shown that mentally simulating eating a specific attractive food increases salivation compared with merely looking at the food. Although the mental simulations in these cases lasted only a few minutes at most, they affected preferences and behavior. Thus, mental simulation seems to require an explicit (but not necessarily lengthy) engagement with the specific stimulus that exceeds any spontaneous engagement evoked by looking at the stimulus. Future research could test whether interindividual differences exist in the extent to which people spontaneously generate mental simulations. Our results as well as previous research (Keesman et al., 2016) suggest that prompting people to mentally simulate leads to more elaborate engagement than it occurs in the absence of such prompts.

The question might arise why we consistently find assimilative effects of mental simulation (e.g., people who simulate warmth feel warmer) and not contrast effects (e.g., people who simulate warmth notice a contrast to their current experience and feel colder). We expected to find assimilative effects because the literature has shown that mental simulation effects mirror the effects of the actual experience (see Kappes & Morewedge, 2016, for a review). Asking people to deliberately reflect on the fact that they were not currently in the simulated state could perhaps encourage contrast effects.

As mental simulation effects have been found for a large variety of actions (Kappes & Morewedge, 2016), we expect mental simulation to also be possible for a variety of visceral states. We found that simulation of being cold, warm, hungry, or full affects preferences and behavior. People might also be able to simulate other visceral states such as thirst or fatigue. However, the results might not generalize to visceral states that people have not previously experienced, such as feelings of starvation or other extreme states. Presumably, the more familiar a given state, the more detailed simulations people would be able to generate.

We have demonstrated that mental simulation can affect preferences and behavior. Future research should test whether the effects of mental simulation have further downstream consequences. First of all, mental simulation might help reduce empathy gaps from hot to cold states or from cold to hot states. Through mental simulations, people might be able to anticipate what they want in alternative visceral states. Thereby, mental simulations might reduce preference inconsistencies (e.g., buying fattening food when shopping hungry but preferring fruit and vegetables when less hungry) that can result from empathy gaps, when people cannot fully anticipate how their preferences will change when their visceral states change. Furthermore, mental simulations might enable bridging empathy gaps for others. Study 5 shows that people project their simulated states onto similar others. Future research could test whether people also project their preferences onto others, which might enable them to use simulation to anticipate others' preferences and needs more accurately.

Taken together, mental simulation can substitute for actual experiences to an extent, and can thereby affect people's current preferences and behavior. Unlike making individuals aware that their preferences are biased by their current states (Nordgren et al., 2006), mental simulations provide an avenue by which people can mentally test what a different visceral state would feel like, and thus generate more accurate predictions about how it would affect their preferences. By engaging in their imaginations, people might thus reduce the empathy gap, and make better predictions about the wants and needs of other people and of their own future selves.

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Supplemental Material

Supplementary material is available online with this article.

Notes

1. Participants in the warm condition felt marginally thirstier (M = 6.26, SD = 1.81) than participants in the cold condition (M = 5.57, SD = 1.96), $t(117) = 1.976$, $p = .051$. Feeling thirsty had a marginally negative effect on preferences for warm activities, $\beta = -.154$, $SE = 0.081$, $t(117) = -1.902$, $p = .060$, 95% confidence interval (CI) = [−0.314, 0.006].
2. In all studies, we report unstandardized regression coefficients. Variables were not mean centered.
3. Participants in the warm conditions felt marginally hungrier (M = 4.71, SD = 2.59) than participants in the cold conditions (M = 4.13, SD = 2.37), $t(240) = 1.844$, $p = .066$. Feeling hungry had no effect on their preferences, $p = .281$.
4. Looking at the 2 × 2 interaction effects and main effects, the interaction of the between-subjects factors (visceral state and intensity) was significant, $F(1, 297) = 10.889$, $p = .001$, $\eta^2 = .035$, as was the interaction of preferences (warming vs. filling activities) and visceral state, $F(1, 297) = 5.532$, $p = .019$, $\eta^2 = .018$. The interaction of preferences and intensity was not significant, $F(1, 297) = 0.549$, $p = .460$, $\eta^2 = .002$. We found a significant main effect of intensity, $F(1, 297) = 52.590$, $p < .001$, $\eta^2 = .150$, as participants preferred filling and warming activities more when having simulated being hungry/cold (vs. warm/full). The main effect of state was marginally significant, $F(1, 297) = 3.005$, $p = .084$, $\eta^2 = .010$, as participants preferred filling and warming activities more in the temperature conditions. Finally, we found a significant main effect of preferences, $F(1, 297) = 52.284$, $p < .001$, $\eta^2 = .150$, as participants preferred warming more than filling activities.
5. The simulation condition did not affect participants' choices of the sizes of the filler items (toothpaste, notepad, picture frame), all ts < 1.092, all ps > .277.
6. The longer ago participants had last eaten, the larger their chosen food portion sizes, $F(1, 103) = 4.673$, $p = .033$. How long ago they had last eaten a full meal did not affect their food portion size choices, $F(1, 103) = 0.120$, $p = .729$. The effect of simulation condition on food portion size choices remained significant when including both these covariates, $F(1, 103) = 7.405$, $p = .008$.
7. Participants in the full condition felt warmer (M = 5.03, SD = 1.33) than participants in the hungry condition (M = 4.71, SD = 1.20), $p = .036$. Control participants (M = 4.96, SD = 1.24) felt equally warm as participants in the full condition, $p = .658$, and those in the hungry condition, $p = .111$. Feeling warm had a negative effect on participants' current preferences for filling activities, $\beta = -.093$, $SE = 0.044$, $t(199) = -2.113$, $p = .036$, 95% CI = [−0.180, −0.006], but not on their general preferences, $\beta = .034$, $SE = 0.059$, $p = .565$.
8. We also computed the analysis testing for the effect of simulation condition on momentary preferences, including the vividness and the engagement items as covariates. Neither the reported vividness of simulations affected momentary preferences, $F(1, 196) = 0.807$, $p = .370$, nor the reported engagement with the simulation task, $F(1, 196) = 2.449$, $p = .119$. Importantly, the effect of simulation on momentary preferences remained significant when including both these covariates, $F(1, 196) = 37.776$, $p < .001$.
9. We also tested for moderated mediation using the Process macro for SPSS (Hayes, 2013), by pooling the momentary and general preference data and using timing as a moderator, focusing on participants who simulated being either hungry or full to facilitate interpretation of the results. We found a significant direct effect of simulation for participants reporting their momentary preferences ($t = 7.30$, $p < .001$) but not for participants reporting their general preferences ($t = .864$, $p = .388$). In addition, we found a significant indirect effect of hunger on momentary preferences (95% CI = [−0.745, −0.254]). Although there was no direct effect of simulation on general preferences, we found an indirect effect of hunger on general preferences, though it was smaller than for momentary preferences (95% CI = [−0.500, −0.075]). For ease of exposition, we present the momentary and general preferences data separately in the main body of the text.
10. There were no main or interaction effects on participants' perceptions of the other person feeling thirsty versus quenched, ps > .717, or feeling tired versus energized, ps > .326. On the perception of the other person feeling hot versus cold, there was no effect of simulation nor its interaction with similarity, ps > .424, but there was an unexpected main effect of similarity, $F(1, 196) = 6.064$, $p = .015$, $\eta^2 = .030$. Participants thought that a similar other felt warmer than a dissimilar other.

Although this main effect might reflect the psychological relationship between similarity and physical warmth (Steinmetz & Mussweiler, 2011), it is not part of our hypothesis.

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