

showed a similar pattern to H3 after the first GSC division (fig. S3).

The consistent asymmetric cell divisions of GSCs could be lost under certain conditions, such as ectopic activation of the key JAK-STAT signaling pathway in the niche (23–25). It has been shown that overexpression of the JAK-STAT ligand *unpaired* (*OE-upd*) induces overpopulation of GSCs (23, 24). Consistent with the loss of asymmetry in expanded GSCs, the asymmetric distribution pattern of the histone H3 was not observed in *OE-upd* testes 16 to 20 hours after heat shock (Fig. 4). These results demonstrate that the asymmetric histone distribution pattern is dependent on GSC asymmetric divisions. We propose a two-step process as our favored explanation (fig. S4A; an alternative explanation is discussed in fig. S4B): Old and newly synthesized histones are incorporated to different sister chromatids during S phase; then, during mitosis, the sister chromatid preloaded with old histones is preferentially segregated to GSC.

These data reveal that stem cells preserve preexisting histones through asymmetric cell divisions. The JAK-STAT signaling pathway required for the asymmetric GSC divisions contributes to the asymmetric histone distribution pattern. This work provides a critical first step toward identifying the detailed molecular mechanisms underlying old histone retention

during GSC asymmetric division. These findings in the well-characterized GSC model system will facilitate understanding of how epigenetic information could be maintained by stem cells or reset in their sibling cells that undergo cellular differentiation.

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#### Supplementary Materials

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## Some Consequences of Having Too Little

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Poor individuals often engage in behaviors, such as excessive borrowing, that reinforce the conditions of poverty. Some explanations for these behaviors focus on personality traits of the poor. Others emphasize environmental factors such as housing or financial access. We instead consider how certain behaviors stem simply from having less. We suggest that scarcity changes how people allocate attention: It leads them to engage more deeply in some problems while neglecting others. Across several experiments, we show that scarcity leads to attentional shifts that can help to explain behaviors such as overborrowing. We discuss how this mechanism might also explain other puzzles of poverty.

The poor often behave in ways that reinforce poverty. For instance, low-income individuals often play lotteries (1, 2), fail to enroll in assistance programs (3), save too little (4), and borrow too much (5). Currently there are two ways to explain this behavior. The first focuses on the circumstances of poverty, such as

education (6), health (7), living conditions (8), political representation (9), and numerous demographic and geographic variables (10, 11). Put simply, the poor live in environments (for sociological, political, economic, or other reasons) that promote these behaviors. The second view focuses on personality traits of the poor (12–14). But we suggest a more general view: Resource scarcity creates its own mindset, changing how people look at problems and make decisions.

To understand this hypothesis, consider how people manage expenses. When money is abundant, basic expenses (e.g., groceries, rent) are handled easily as they arise. These expenses come and go, rarely requiring attention and hardly lin-

gering on the mind. But when money is scarce, expenses are not easily met. Instead of appearing mundane, they feel urgent. The very lack of available resources makes each expense more insistent and more pressing. A trip to the grocery store looms larger, and this month's rent constantly seizes our attention. Because these problems feel bigger and capture our attention, we engage more deeply in solving them. This is our theory's core mechanism: Having less elicits greater focus.

This view is not bound to the specific circumstances of poverty, nor does it make assumptions about the dispositions of the poor. This mindset stems from the most fundamental feature of poverty: having less. And this hypothesis is about scarcity more generally, not just poverty. Indeed, just as expenses capture the attention of the poor, researchers have found that people who are hungry and thirsty focus more on food- and drink-related cues (15, 16). Likewise, the busy (facing time scarcity) respond to deadlines with greater focus on the task at hand (17). Across many contexts, we see a similar psychology. People focus on problems where scarcity is most salient.

The second part of our theory follows readily from the first. Because scarcity elicits greater engagement in some problems, it leads to neglect of others. While focusing on the groceries from week to week, we might neglect next month's rent. While consumed with meeting tomorrow's

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manuscript deadline, we might fail to prepare next week's lecture. Attentional neglect appears in many domains. Low-income homeowners often do not attend to regular home maintenance while they focus on more pressing expenses (18). Neglected, these small repairs become major projects. Similarly, in areas where water-borne illness is common, families might focus on pressing daily expenses while failing to procure periodic water treatments (19).

Attentional neglect can explain another particularly striking behavior: why low-income individuals take short-term, high-interest loans, with interest rates that can approach 800% (20–22). These loans make it easier to meet today's needs, but the loans' deferred costs make it difficult to meet future expenses. If scarcity creates a focus on pressing expenses today, then attention will go to a loan's benefits but not its costs. This suggests a clear prediction: Scarcity, of any kind, will create a tendency to borrow, with insufficient attention to whether the benefits outweigh the costs.

Consistent with this prediction, the busy also borrow. Facing tight budgets (i.e., deadlines), they borrow time by taking extensions. Like the poor, the busy often take extensions because they focus on urgent tasks, but neglect important tasks that seem less pressing (23). We suggest that both forms of borrowing stem from how scarcity shifts attention.

We test this theory with the use of an approach that psychologists have employed to study other social problems, such as obedience to authority (24), helping behavior (25), and conformity (26). Simple experiments can distill a problem's primary features in the lab, abstracting from the complexities of the world and highlighting how selected features guide behavior. Here, we distill scarcity and test its influence on how people borrow. Experiments 1 and 2 show that scarcity creates increased focus. Experiments 2 to 5 demonstrate how (and why) scarcity leads people to borrow.

In all experiments, participants were randomly assigned budgets; "poor" participants had smaller budgets than "rich" participants [see (27) for a full description]. These budgets were distributed in "paychecks" across multiple rounds

of a game. Poor participants had proportionally smaller paychecks than rich participants. On each round, participants used the resources to earn rewards. If participants moved on from a round without exhausting their paycheck, unspent units were saved for future use. Participants were also assigned to different borrowing conditions. Some could not borrow—when a paycheck was exhausted, they moved to the next round. Other participants could borrow at a cost  $R$ : Borrowing an additional resource unit for the current round subtracted  $R$  units from their overall budget.

In experiment 1, 60 participants played a version of *Wheel of Fortune* (*WoF*). Scarcity was manipulated by budgeting participants' chances to guess letters in word puzzles. Poor participants had 84 total guesses (6 per round); rich participants had 280 guesses (20 per round). Previous work suggests that greater engagement in *WoF* will cause cognitive fatigue and worse performance on subsequent cognitive tasks (28). As a measure of cognitive fatigue, after *WoF*, participants completed a version of the Dots-Mixed task, which assesses executive functions such as attention and cognitive control (29). Participants responded to visual stimuli presented to the left or right of a fixation cross. On congruent trials, participants had to press a key on the same side as the stimulus; on incongruent trials, they had to press a key on the opposite side. Congruent and incongruent trials (40 each) were randomly presented. Although *WoF* included a scarcity manipulation, the Dots-Mixed task was identical for all participants.

A simple model of effort might suggest that the rich should be more fatigued because they spent more time and made more guesses playing *WoF*. In our model, however, the poor would engage more deeply and could be more fatigued despite spending less time.

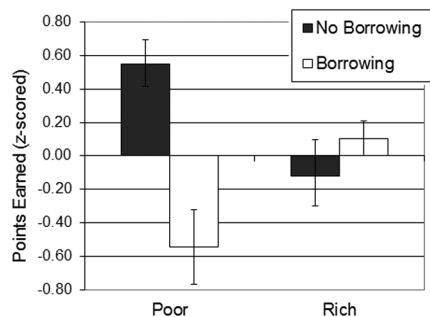
We measured the total number of correct responses in the attention task. Four participants were removed from the analyses for having zero correct responses. Poor participants performed worse (mean  $\pm$  SD,  $45.12 \pm 15.87$ ) than did rich participants ( $52.93 \pm 12.79$ ) [ $F(1, 54) = 4.16$ ,

$P < 0.05$ , effect size  $\eta_p^2 = 0.07$ ; see table S1 for performance based on trial type]. Scarcity seems to have created greater engagement: Even with less time played (and fewer guesses made), the poor were more depleted.

Experiment 2 offers a more precise look at how scarcity changes engagement. Sixty-eight participants played a video game similar to *Angry Birds*. They fired shots from a slingshot, earning points for clearing targets. The poor had budgets of 30 shots (3 per level); the rich had 150 shots (15 per level). Some participants could not borrow shots, whereas others could borrow with  $R = 2$  (essentially, 100% interest). Participants played until exhausting their budget.

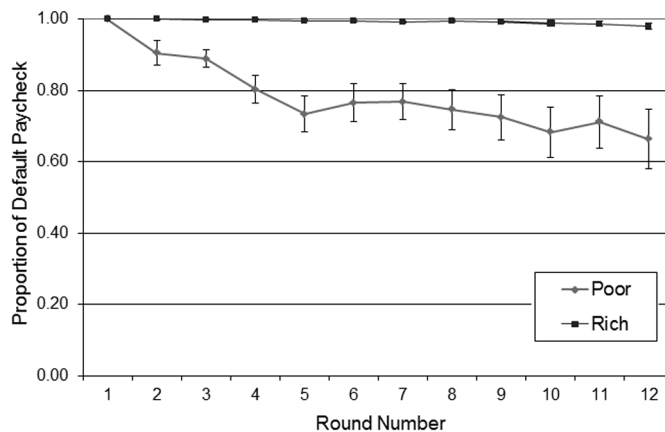
To analyze how scarcity affected focus, we measured how long participants spent aiming each shot (i.e., how careful they were with their resources). Poor participants spent more time aiming the first shot of each level (log-transformed milliseconds,  $8.08 \pm 0.42$ ) than did rich participants ( $7.73 \pm 0.39$ ) [ $F(1, 64) = 12.96$ ,  $P < 0.001$ ,  $\eta_p^2 = 0.17$ ]. These results held for subsequent shots as well. Because the rich could always earn more points (and each additional point increased the chances of winning a prize), they had an incentive to remain engaged and use their resources well. Yet they were less engaged than the poor. Still, one might argue that these differences are driven by rich participants losing interest later in the game. However, these differences emerged on the very first shot of the game (poor:  $8.19 \pm 0.52$ ; rich:  $7.86 \pm 0.52$ ) [ $F(1, 64) = 6.58$ ,  $P < 0.05$ ].

This engagement had some benefits for the poor. Among participants who could not borrow, the poor earned more points per shot ( $2.31 \pm 0.60$ ) than did the rich ( $1.67 \pm 0.37$ ) [ $F(1, 31) = 11.92$ ,  $P < 0.005$ ]. Rich participants had 5 times as many shots as the poor, but earned far fewer than 5 times as many points. If the rich had played as if they were poor, they would have performed better. It seems that to understand the psychology of scarcity, we must also appreciate the psychology of abundance. If scarcity can engage us too much, abundance might engage us too little.



**Fig. 1.** Performance in experiment 1: Standardized points earned by the rich and poor. Error bars represent SE of the mean.

**Fig. 2.** The accumulation of debt in experiment 4. The paycheck for each round is shown as a proportion of the default paycheck allocated. Errors bars represent SE of the mean. Data are shown for the median number of rounds completed by all participants.



These results illustrate scarcity's focusing effect. Field data also show scarcity-induced focus. For instance, instead of offering bulk discounts, some retailers raise the per-unit cost of an item as purchase quantity increases. Most people overlook these occasional "quantity surcharges," but low-income consumers are more likely to notice these surcharges (30). Low-income consumers are also more sensitive to "hidden" taxes—those not included in the posted price (31).

Our experiments also suggest that scarcity leads people to neglect future rounds and borrow away from them. In experiment 2, each shot used beyond a round's paycheck counted as a shot borrowed. Borrowed shots were summed across a participant's game. As a fraction of their budget, poor participants borrowed more shots ( $0.24 \pm 0.15$ ) than the rich ( $0.02 \pm 0.05$ ) [ $F(1, 33) = 27.53, P < 0.001$ ].

Performance data suggest that this borrowing was counterproductive. We measured performance in  $z$ -scores, standardizing points earned separately for the poor and the rich (Fig. 1; see table S2 for unstandardized data). Rich participants performed similarly whether they could not borrow ( $-0.12 \pm 0.77$ ) or could ( $0.10 \pm 1.18$ ), whereas poor participants fared better when they could not borrow ( $0.55 \pm 0.65$ ) than when they could ( $-0.55 \pm 1.00$ ) [scarcity  $\times$  borrowing interaction,  $F(1, 64) = 8.47, P < 0.005, \eta_p^2 = 0.12$ ]. This suggests that the poor overborrowed.

The amount of borrowing by the poor was significantly correlated with measures of engagement. On rounds where poor participants borrowed, the average amount of time spent aiming each shot in their paycheck correlated positively with how many shots they subsequently borrowed [ $r(38) = 0.34, P < 0.05$ ]. The more focused the poor were on the current round, the more they neglected (and borrowed away from) future rounds.

To ensure that this was not an artifact of a particular context, we considered a different form of scarcity: having too little time. In experiment 3, 143 participants were given budgets of time with which to play *Family Feud*, a trivia game where each question allows multiple answers. Each round consisted of a new question and participants earned points for each correct answer. Poor participants had budgets of 300 s (15 per round); rich participants had 1000 s (50 per round). Participants played until exhausting their budget. There were three borrowing conditions: no borrowing, borrowing with  $R = 1$  (i.e., "without interest"), and borrowing with  $R = 2$  ("with interest").

Regardless of interest rate, poor participants borrowed a greater proportion of their budget ( $0.22 \pm 0.15$ ) than did rich participants ( $0.08 \pm 0.15$ ) [ $F(1, 102) = 22.39, P < 0.001$ ]. Once again, the poor overborrowed [interaction  $F(1, 137) = 6.54, P = 0.002, \eta_p^2 = 0.09$ ; see table S3 for unstandardized data]. Rich participants performed similarly whether they had no option to borrow ( $0.06 \pm 1.10$ ), borrowed without interest ( $-0.31 \pm$

$0.88$ ), or borrowed with interest ( $0.25 \pm 0.98$ ) [ $F(1, 137) = 2.14, P = 0.15$ ]. The poor performed best when they could not borrow ( $0.60 \pm 1.14$ ), less well when they borrowed without interest ( $0.08 \pm 0.67$ ), and worst when they borrowed with interest ( $-0.48 \pm 0.94$ ) [ $F(1, 137) = 7.49, P < 0.001$ ].

The effects of scarcity appear to be quite general. But one concern with these studies might be that the consequences of borrowing, which were not felt until the end, were not sufficiently salient. In experiment 4, we therefore modified the game so that borrowing would create "debt" in subsequent rounds. That is, the size of each paycheck varied depending on how people borrowed or saved. Initial paychecks were the same as in experiment 3, but on subsequent rounds, paychecks equaled the total time remaining divided by the number of remaining rounds. Participants played until they exhausted their budget or completed 20 rounds, whichever came first. Excessive borrowing on one round would therefore lead to a smaller paycheck on the next round. Some participants could not borrow, whereas others could borrow with  $R = 2$ .

Poor participants borrowed a greater proportion of their budget ( $0.27 \pm 0.14$ ) than did rich participants ( $0.03 \pm 0.04$ ) [ $F(1, 56) = 70.50, P < 0.001$ ] and consequently saw their paychecks shrink during the game (Fig. 2). For this analysis, each round's paycheck was converted to a proportion of the default paycheck (i.e., dividing by 15 for the poor and by 50 for the rich). We regressed these proportions on the round numbers and analyzed the slopes for each participant. The poor accumulated debt at a higher rate (mean of slope  $\pm$  SD,  $-0.13 \pm 0.18$ ) than did the rich ( $-0.01 \pm 0.01$ ) [Mann-Whitney test,  $z = 5.46, P < 0.001$ ]. Furthermore, the poor did not adjust their borrowing as they accumulated debt. Instead, as their budgets shrunk, they gradually increased their borrowing relative to their remaining budget (27). As a result, rich participants performed similarly when they could not borrow ( $-0.09 \pm 0.81$ ) and when they could ( $0.11 \pm 1.20$ ). The poor performed better when they could not borrow ( $0.54 \pm 0.77$ ) than when they could ( $-0.49 \pm 0.94$ ) [interaction  $F(1, 114) = 12.81, P < 0.001, \eta_p^2 = 0.10$ ; see table S4 for unstandardized data].

As in these experiments, neglect also creates many forms of borrowing (beyond conventional loans) among the poor in the world. For example, the poor often focus on certain expenses while neglecting utility payments, thereby incurring reconnection fees that are like interest payments—"borrowing" by paying the bill late (32).

Experiment 5 offers more direct support for the notion that scarcity creates attentional neglect. One hundred thirty-seven participants played *Family Feud*. Some participants could see previews of the subsequent round's question at the bottom of the screen; others could not. We expected that poor participants would be too fo-

cused on the demands of the current round to consider what comes next, whereas rich participants would be able to consider future rounds and whether moving on was beneficial. All participants could borrow with  $R = 3$ . As predicted, poor participants performed similarly with previews ( $-0.02 \pm 0.87$ ) and without ( $0.02 \pm 1.11$ ), while rich participants performed better with previews ( $0.32 \pm 0.98$ ) than without ( $-0.35 \pm 0.92$ ) [scarcity  $\times$  borrowing interaction,  $F(1, 133) = 4.29, P < 0.05, \eta_p^2 = 0.03$ ; for unstandardized scores, see table S5]. One concern might be that the poor did not have enough time to consider the previews. But the experiments above found that the poor were using too much; they were overborrowing. Their performance in the no-preview condition left substantial room for improvement. Even if poor participants had used some of the borrowed time to consider the previews and move on sooner, they could have improved. That is, the previews benefited the rich by helping them save more; they could have benefited the poor by helping them borrow less. But it appears they were too focused on the current round to benefit.

Taken together, these studies provide compelling support for the notion that scarcity elicits greater engagement and that a focus on some problems leads to neglect of others (manifesting in behaviors such as overborrowing). An alternative account might be that the poor and rich approached these tasks with the same mindset—playing each round until they were satisfied with their progress before moving on. By this account, the poor borrowed only because they were facing more severe constraints. But evidence from experiments 1 and 2 suggests that the poor and rich did not approach the tasks in the same way. The poor were more engaged.

Another explanation might be that scarcity creates cognitive load, thereby diminishing performance. Cognitive load might prevent people from figuring out the optimal borrowing rates, or it might lead people to use their resources less efficiently or make riskier financial decisions. Although we agree that scarcity creates load, our theory is more specific about the origins of that load and its effects. We suggest that cognitive load arises because people are more engaged with problems where scarcity is salient. This consumes attentional resources and leaves less for elsewhere.

Once we appreciate where attention is drawn under scarcity, we see how this mechanism can explain behaviors other than overborrowing. Scarcity-induced focus is not myopia, nor does it necessarily imply steeper discount rates. The poor often save for the future. However, their savings are not set aside in a generic account, but rather are geared toward specific expenses. That is, the poor often save for the same reason they borrow. This has clear policy implications. Interventions that draw people's attention to specific future needs should be particularly effective at increasing savings (33). This mechanism also

explains why the poor in many countries have a patchwork of financial instruments, with high turnover across accounts. A scarcity mindset leads people to choose the most locally convenient response to pressing demands, leading to constant financial juggling (34).

Questions surrounding poverty are large. Poverty has long occupied philosophers, social scientists, and policy-makers. No experiment can fully explain how poverty, and scarcity more generally, guides behavior. But the hypotheses, methods, and results above offer an approach to unpacking this problem. This paradigm can shed light on the cognitive consequences of poverty. Future research might also suggest ways to alleviate the taxing cognitive consequences of having too little. Finally, this approach can help us to understand circumstances even broader than poverty, because scarcity underlies problems as dire as hunger and as mundane as busyness. These problems have traditionally been studied within their own limited domains. A more general study of scarcity can inform our understanding of many specific contexts at once. This may be the key to a deeper appreciation of the vast psychology that stems from having too little.

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#### Supplementary Materials

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## Some Consequences of Having Too Little

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### Poor Choices

Two categories of reasons for why poor people make economically unsound choices, such as obtaining a payday loan at an extraordinarily high rate of interest, reflect, first, the environment: Poor people are more likely to be living in poor neighborhoods with higher rates of crime and lower rates of social services. Second, they reflect the individual: People are poor in part because of their own psychological dispositions toward impatience and impulsiveness. For both cases, obtaining causal evidence in controlled experiments has been challenging. **Shah *et al.*** (p. 682; see the Perspective by **Zwane**) propose a third category of reasons whereby being poor exerts a bias on cognitive processes and provide evidence for it in laboratory experiments performed in scenarios of scarcity.

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