Despite high objective numeracy, lower numeric confidence relates to worse financial and medical outcomes

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People often laugh about being "no good at math." Unrecognized, however, is that about one-third of American adults are likely too innumerate to operate effectively in financial and health environments. Two numeric competencies conceivably matter—objective numeracy (ability to "run the numbers" correctly; like literacy but with numbers) and numeric self-efficacy (confidence that provides engagement and persistence in numeric tasks). We reasoned, however, that attaining objective numeracy's benefits should depend on numeric confidence. Specifically, among the more objectively numerate, having more numeric confidence (vs. less) should lead to better outcomes because they persist in numeric tasks and have the skills to support numeric success. Among the less objectively numerate, however, having more (vs. less) numeric confidence should hurt outcomes, as they also persist, but make unrecognized mistakes. Two studies were designed to test the generalizability of this hypothesized interaction. We report secondary analysis of financial outcomes in a diverse US dataset and primary analysis of disease activity among systemic lupus erythematosus patients. In both domains, best outcomes appeared to require numeric calculation skills and the persistence of numeric confidence. "Mismatched" individuals (high ability/low confidence or low ability/high confidence) experienced the worst outcomes. For example, among the most numerate patients, only 7% of the more numerically confident had predicted disease activity indicative of needing further treatment compared with 31% of high-numeracy/low-confidence patients and 44% of low-numeracy/high-confidence patients. Our work underscores that having 1 of these competencies (objective numeracy or numeric self-efficacy) does not guarantee superior outcomes.

objective numeracy | numeric confidence | numeric self-efficacy | decision making | financial and health outcomes

People often laugh at being "no good at math," as if innumeracy is unimportant. Unrecognized, however, is that about one-third of American adults are so innumerate (it's like illiteracy but with numbers) that they likely cannot operate effectively in financial and health environments. According to the Organisation for Economic Co-operation and Development (OECD), 29% of American adults (about 73 million people in 2018; ref. 1) can do only simple numeric processes. They can count, sort, do simple arithmetic, and use simple percentages like 50%, but cannot do more complex numeric operations (2). As a result, they likely cannot select the health plan with the lowest cost based on annual premiums and deductibles for a family or calculate the difference in the percentage of patients who survive 1 treatment vs. another (3). Similar issues emerge in personal finances. For example, when told the amount owed on a credit card, monthly payments, and annual percentage rate charged, only 35% of people correctly answered that they could never pay off the debt (4).

Such numeric incomprehension is generally thought to be due to having low objective numeracy (defined as the ability to understand and use probabilistic and other mathematical concepts), but it could be due, in part, to having low numeric self-efficacy (defined as confidence in one's objective numeracy abilities) (5–7). Across domains from math to medicine, objective ability and confidence exist in a positive feedback loop, whereby objective success in solving relevant problems enhances confidence, and having more self-efficacy propels persistence and further learning and success (5, 8–10). For example, arthritis patients more confident in carrying out necessary behaviors enjoyed better clinical outcomes (6, 11). As in other domains, objective numeracy and numeric confidence are related (average $r = \sim 0.45$; refs. 12 and 13). Numeric-confidence measures are even used sometimes as proxies for objective numeracy because they are easier and less stressful for participants than objective numeracy measures (14). However, their correlation is imperfect, and, as reviewed below, they have independent effects on comprehension and decision making.

In the present paper, we considered whether they also have separate associations with medical and financial outcomes, a

Significance

Greater objective ability is thought to lead to more confidence and success across domains. We investigated instead whether objective numeracy and numeric confidence might "mismatch" sometimes and, critically, interact in predicting financial and medical outcomes. The results of 2 studies (secondary analyses of a diverse internet panel and primary analysis of patients with systemic lupus erythematosus) revealed that being more objectively numerate benefits those who are more numerically confident, but not the less numerically confident. Enjoying good outcomes in finances and health appears to require the persistence of numeric confidence and also the human capital of objective numeracy. The patterns further suggest that improving 1 numerical competency without considering the other could cause harm.

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hypothesis mostly unexamined. In addition, we further reasoned that neither numeric competence would lead inevitably to better financial or medical outcomes. Instead, we posited an interaction hypothesis. Below, we first review correlational effects of objective numeracy and numeric confidence in comprehension, decisions, and outcomes. We then explain our interaction hypothesis and examine it in self-reported financial outcomes (a large diverse US internet panel; Study 1) and in the disease activity of systemic lupus erythematosus (SLE) patients (Study 2).

Objective Numeracy and Numeric Confidence Have Separate Relations with Comprehension and Decision Quality

Objective Numeracy. Consistent with OECD data, the more objectively numerate have better comprehension of numeric information (controlling for demographics, numeric confidence, and nonnumeric intelligence; ref. 7). They also make better decisions than the less numerate when numeric information is involved (13, 15). In particular, the highly numerate think longer in numeric decisions (16, 17). They trust numeric information more (18) and do more (usually simple) numeric operations while attempting to understand what numbers, like dollar amounts, mean for a decision (19–21). The highly numerate "have a numeric hammer," and they use it. Decisions of the less objectively numerate instead are more vulnerable to decision heuristics, mental shortcuts used in judgments and choices (21–23). For example, they succumb to framing effects and the compelling power of narratives, emotions, and concrete, easy-to-evaluate information (24–26). As a result, the less objectively numerate tend to make worse decisions when numbers are involved, even after controlling for nonnumeric intelligence.

Numeric Confidence. Drawing from self-efficacy theory, greater confidence is a major driver of behavior, behavior change, and persistence in the face of obstacles (8, 27). Across domains, it leads to better performance and outcomes (5, 11, 28, 29). Numeric confidence is no exception. The less numerically confident are thought to engage and persist less with numeric information. Ultimately, they understand numeric information less well and take fewer actions in number-heavy decisions (controlling for objective numeracy, demographics, and nonnumeric intelligence; refs. 7 and 12). They also make fewer normatively appropriate choices (30).

Numeric Competencies' Relations with Financial and Health Outcomes

Poorer comprehension and less sound decisions, then, may act as cumulative risk factors over time that exact financial and health tolls for the less objectively numerate and, separately, the less numerically confident. Personal-finance studies have examined objective numeracy, but not numeric confidence. In them, having more objective numeracy predicts better financial behaviors and outcomes, such as retirement planning and greater wealth, over and above general intelligence (23, 31–35).

Having greater objective numeracy also is related to better health behaviors and outcomes. The less objectively numerate adopted fewer protective health behaviors (e.g., exercise or condom usage), controlling for objective numeracy and nonnumeric intelligence (36, 37). They were 40% more likely to have at least 1 chronic disease and took 20% more prescription drugs (controlling for numeric confidence and demographics; ref. 38), but followed complex health regimens less well (39–41). They also ended up in the hospital and emergency room more often (42, 43). Less numerically confident patients, on the other hand, perceived their physical and mental health to be worse (controlling for objective numeracy and demographics; ref. 38). In the only known experimental study, altering numeric confidence to improve objective numeracy in a required university statistics course caused positive effects on healthy-behavior maintenance and financial literacy (9).

The Current Studies

Thus, greater objective numeracy and, independently, more numeric confidence tend to predict better comprehension, decision quality, and outcomes. We reasoned, however, that they should interact. In particular, among those with higher objective numeracy, having more vs. less numeric confidence should lead to better outcomes. This prediction is based on greater self-efficacy helping them persist in numeric tasks critical to making decisions about their finances and health. They then should succeed because they also have the numeric skills needed to support action. Those with higher ability but less numeric confidence, however, should persist less in numeric tasks and do less well as a result. Thus, despite high ability, those with less numeric confidence should suffer poorer outcomes. On the other hand, among less objectively numerate individuals, having more numeric confidence should lead to worse outcomes. This prediction is based on their confidence leading to numeric-task persistence but innumeracy leading to numeric mistakes that go unrecognized. For example, a patient may miscalculate how to reduce her medication dose over time, resulting in less-well-controlled disease. A consumer may make a financial mistake, resulting in late payments and fees (44). Thus, among the less objectively numerate, we predicted that having more numeric confidence would undermine financial and medical outcomes.

We examined this interaction hypothesis in self-reported financial outcomes (Study 1) and SLE patient disease activity (Study 2). We chose these samples for several reasons. First, the Understanding America Study (UAS) included self-reported financial outcomes from a large, diverse sample of Americans who had previously responded to measures of objective numeracy and numeric confidence. Second, the SLE sample offered a clinical rather than self-reported outcome. Finally, examining our hypothesis across domains was key to testing generalizability.

The studies also break ground in several ways. First, numeric confidence has been overlooked in financial research that focuses on objective abilities. The present research underscores the importance of self-efficacy and its associated motivation and persistence. Confidence in managing disease has seen some focus in medical research (e.g., rheumatoid arthritis; ref. 6). However, numeric confidence has not. Understanding more general abstract numeric competencies (objective numeracy and numeric confidence) should highlight psychological mechanisms underlying financial and health outcomes that require numeric persistence and ability. Finally, we questioned the "more is better" mantra of prior numeracy and self-efficacy research, which points toward interventions leading to greater objective numeracy or greater confidence, respectively. No known research has tested our alternative hypothesized interaction and its generalization across financial and health domains. Our results suggest that intervening on 1 numeric competency, without considering the other, may cause harm. Such data provide helpful evidence for those who wish to be (or help others to be) healthier and wealthier.

Study 1—Self-Reported Financial Outcomes. We accessed a sample of $n = 4{,}572$ respondents from the UAS. Respondents had completed measures of positive financial outcomes, objective numeracy (45), numeric confidence (14), financial knowledge (46), and demographics.

Results

Demographics, mean scores, and intercorrelations are included in *SI Appendix*, Tables S1 and S2 (47). Multiple regression analysis was conducted to predict positive financial outcomes from objective numeracy, numeric confidence, their hypothesized 2-way interaction, financial knowledge, and demographics (full model results are in *SI Appendix*, Table S3). Consistent with our hypothesis and independent of financial knowledge and demographics, objective numeracy and numeric confidence interacted to predict financial

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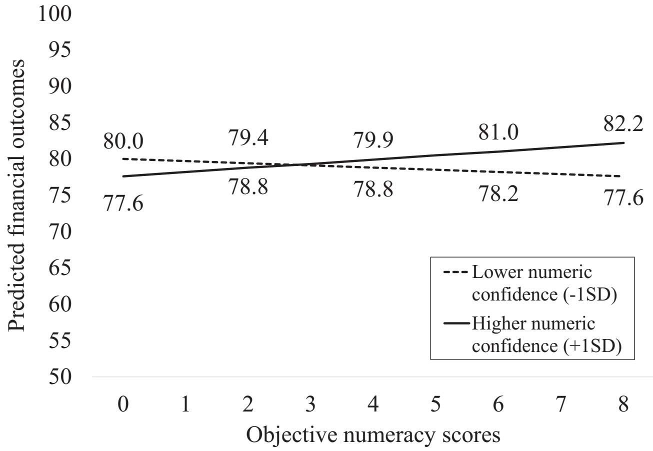

Fig. 1. Predicted financial outcomes for individuals varying in objective numeracy and ±1 SD from the numeric confidence mean. Higher numbers are better, as they reflect more positive financial outcomes. Estimates are based on setting covariates to sample means.

outcomes [$b(SE) = 0.32(0.07)$; $P < 0.001$]. As illustrated in Fig. 1, among individuals higher in numeric confidence (+1 SD), greater objective numeracy was associated, on average, with experiencing a greater proportion of positive financial outcomes [$b(SE) = 0.57(0.16)$; $P = 0.002$]. Being lower in numeric confidence (−1 SD) eliminated the benefit of objective numeracy [$b(SE) = -0.30(0.18)$; $P = 0.095$]. Fig. 1's numeric-confidence differences were significant at the lowest and highest numeracy scores [respectively, $b(SE) = -0.87(0.30)$, $P = 0.004$; and $b(SE) = 1.69(0.38)$, $P < 0.001$]. Being older, married, and retired and having a college degree and more household income also related independently to experiencing better financial outcomes, whereas being female and nonwhite were associated with worse financial outcomes.

The hypothesized interaction effects were not small. As a comparison, for an individual with a perfect objective numeracy score of 8, moving from 1 SD above the mean on numeric confidence to 1 SD below (scores of 5.15 and 2.41, respectively) would be equivalent to an annual household income reduction of $93,905. Secondary analyses of financial well-being and decision maker yielded similar results (*SI Appendix*, Table S3 and Figs. S1 and S2).

Using objective data from banks and other financial institutions would have been ideal, but they are difficult to acquire. Like the present study, most studies instead rely on self-reported financial data (9, 23, 34, 35, 46, 48, 49). In Study 2, however, we tested our interaction hypothesis among SLE patients for whom we had a clinical outcome, physician-recorded disease activity.

Study 2—SLE Disease Activity. We recruited patients from The Ohio State University's Lupus, Vasculitis, and Glomerulonephritis (LVG) registry who were ≥18 y old and diagnosed with SLE, a complex autoimmune disease with high morbidity and mortality (50). SLE affects multiple organ systems. It has no cure, but medical interventions and lifestyle changes can help control it (51, 52). However, some interventions and changes require objective numeracy—for example, to understand the risks and benefits of drugs, titrate medications correctly (e.g., prednisone), and make good health insurance and provider choices. Other interventions and lifestyle changes require persisting with the same numeric task over time like adhering to multiple timed medications, navigating frequent treatment changes, adopting healthy behaviors, and attending appointments.

We again measured objective numeracy (45) and numeric confidence (14). We also assessed health literacy (Passage B, Test of Functional Health Literacy; ref. 53) and patient activation (extent of involvement in managing one's health and health maintenance; ref. 54). Lupus disease activity was assessed with the Systemic Lupus Erythematous Disease Activity Index 2000 (SLEDAI) at every clinic visit (55–58). SLEDAI scores ≥6 indicate a possible need for clinical intervention (59).

Results

Demographics, mean scores, and intercorrelations are in *SI Appendix*, Tables S4 and S5 (60). Multiple linear regression analysis was conducted to predict disease activity (SLEDAI scores) from objective numeracy, numeric confidence, their interaction, health literacy, patient activation, and demographics. In this initial planned test, the interaction of objective numeracy and numeric confidence was marginally significant [$b(SE) = -0.27(0.14)$; $P = 0.051$]. We then removed nonsignificant covariates ($P < 0.05$) 1 at a time to attain a final parsimonious model (see *SI Appendix*, Table S6 for full and final models). Results supported the hypothesized interaction of objective numeracy and numeric confidence [$b(SE) = -0.27(0.13)$; $P = 0.037$]; Fig. 2. Among patients with more numeric confidence (+1 SD), having greater objective numeracy was associated with lower SLEDAI scores [less disease activity, $b(SE) = -0.66(0.29)$; $P = 0.023$]. However, objective-numeracy benefits again did not accrue among those with less numeric confidence (−1 SD) [$b(SE) = 0.14(0.27)$; $P = 0.61$]. Based on this model, a patient higher in numeric confidence (+1 SD) was predicted to have a 44% vs. 7% chance of high disease activity (≥6) if she scored, respectively, the lowest vs. highest on objective numeracy. In contrast, a patient lower in numeric confidence (−1 SD) was predicted to be less likely to have high disease activity if she had the lowest vs. highest score in objective numeracy, 21% vs. 31%, respectively. Older age also was associated with less disease activity. Fig. 2's numeric-confidence differences at the lowest and highest numeracy scores, however, did not attain significance (respectively, $P = 0.12$ and 0.08).

General Discussion

Comprehending and using numeric evidence in decisions appears to require 2 types of numeric competence—both objective numeracy to "run the numbers" well and numeric self-efficacy or confidence to persist when numeric tasks become tedious, difficult, or anxiety-provoking. From prior literature, the absence of either competency appeared to act as a risk factor, such that less of either

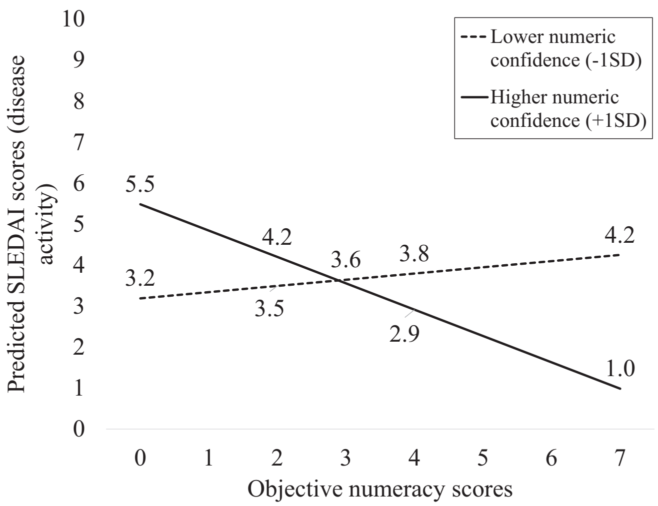

Fig. 2. Predicted disease activity (SLEDAI scores) for individuals varying in objective numeracy and ±1 SD from the numeric confidence mean. Lower numbers are better, as they reflect less disease activity. Estimates are based on setting covariates to sample means.

one was associated with worse outcomes, and more of each one was better. Researchers have demonstrated such correlational effects with objective numeracy in financial and health domains and (less so) with numeric confidence in health. In the present studies, we questioned whether having more objective numeracy and more numeric confidence is always better.

Results of these studies supported our hypothesis that objective numeracy interacts with numeric confidence to predict self-reported financial outcomes and a clinical outcome (SLE disease activity). Although medical and psychological studies demonstrate that greater self-efficacy leads to better performance and outcomes (5, 6, 29), these confidence benefits accrued only among those with adequate objective skills. In 2 studies, those with high objective numeracy and high numeric confidence had the best outcomes. Individuals who lacked objective numeracy skills but had high numeric confidence fared the worst, presumably because they persisted in doing numeric tasks critical to their finances and health, but made mistakes that went unnoticed. Consistent with this reasoning, they perceived their financial well-being as similar to those with high confidence and high objective numeracy, who actually experienced better financial outcomes (*SI Appendix*, *SI Text* and Fig. S1). As a result, opportunities to improve financial outcomes, including through receipt of help from others, may go unrecognized and/or be seen as lacking value. Thus, having high numeric confidence is insufficient and may be harmful when ability is low. Similarly, having high objective numeracy does not guarantee good outcomes. The benefits of objective numeracy did not accrue among those who were not numerically confident. In particular, those with greater objective numeracy and lower confidence appear to have disengaged, as they are much less likely to be the financial decision maker in their household compared to those with similar skills and more numeric confidence. These results are consistent with other research suggesting that having confidence can be beneficial (61), but overly positive self-beliefs can lead to negative consequences (62–65). In the present studies, it was not ideal to have low ability with high confidence or high ability with low confidence.

These "mismatched" portions of the population are not small. In Study 1 (n = 4,572), we calculated median splits on objective numeracy (scores of 0–3 and 4–8) and numeric confidence (scores of 0–4 and 5–6). In this sample, 18% had greater objective numeracy and lower numeric confidence (we'll call them the numerically underconfident). An additional 12% had lower objective numeracy and high confidence (the numerically overconfident). Using these same scale splits (scores of 0–3 for low objective numeracy and 0–4 for low numeric confidence), 20% and 13%, respectively, of SLE patients fell into these mismatched groups.

Although our regression models explained small to medium amounts of variance, the effect sizes were not trivial (66). For example, for a person scoring highest on objective numeracy and numeric confidence (scores of 8 and 6, respectively), the predicted percentage of positive financial outcomes experienced was 83%, compared to only 74% for a person scoring highest on objective numeracy and lowest in numeric confidence (scores of 8 and 1, respectively), controlling for other variables. Considering the variety and severity of possible financial outcomes included in our study (e.g., bankruptcy, house foreclosures, or unpaid taxes), this difference could have a big impact. Similarly, uncontrolled SLE can cause irreversible organ damage and subsequent heart failure, stroke, or chronic kidney failure.

Further research is needed on the precise psychological mechanisms underlying these effects. Past research indicates that those with less confidence lack persistence. In fact, having objective skills made little difference among those who lack numeric confidence, as if they did not even attempt numeric tasks important to their finances and health. Objective skills did matter among those high in numeric confidence, with the subset of individuals lower in objective skills presumably trying and failing in these same tasks. We did not measure task persistence or performance directly, however. Also unclear are the boundary conditions for when the "mismatch" of the 2 numeric competencies is associated with negative effects.

More experimental research is needed, given our correlational results. Researchers have successfully altered objective numeracy and numeric self-efficacy in past studies, although doing so is difficult (9, 28). Indeed, manipulations of self-efficacy have been successful across domains ranging from snake phobias (67) to investment decisions (68). Nonetheless, in the present studies, we do not know if the combination of objective numeracy and numeric self-efficacy causally improved financial or health outcomes. Although we statistically controlled for various demographics (including education), financial knowledge (Study 1), and health literacy (Study 2), doing so reduced, but did not eliminate, the possibility of third-variable effects.

Nonetheless, findings in 2 very different life domains clarified psychological and health-behavior theory and findings. First, they highlighted the importance of self-efficacy (numeric confidence in the present studies) and objective numeracy to life outcomes (6, 8, 13, 15) and likely to task persistence, comprehension, and decision quality. Instead of concluding that more of each competency is better, however, we demonstrated that their effects depend on each other. Being numerically underconfident and especially overconfident appeared to undermine patients' medical status and consumers' financial outcomes.

The results further suggest that improving numeric confidence among individuals lower in objective numeracy paradoxically may cause them harm. At the same time, improving objective numeracy without ensuring that numeric confidence follows could also produce negative effects, although that effect was smaller. Overall, the results suggest that people can take better charge of their finances and health through numeric ability and numeric confidence, and both numeric competencies are required.

The most potent assistance, then, would differ based on the individual's combination of numeric confidence and objective numeracy, with discordant people needing the greatest assistance. Individuals should attempt to understand their own numeric competencies to ascertain whether they would be better off working on their numeric confidence (because their skills are adequate already) or their objective numeracy (either by building skills and/or asking for additional assistance in numeric tasks important to finances and health). For example, those with higher objective numeracy and lower numeric confidence may need the confidence boost that can come from psychological interventions such as values affirmation or expressive writing (9, 10, 69). Individuals with lower objective numeracy and lower numeric confidence likely would benefit from objective numeracy training in addition to these psychological interventions.

Individuals with lower objective numeracy and higher numeric confidence may represent the biggest challenge because they may resist negative feedback. For them, practicing simple arithmetic with feedback should improve objective numeracy (70), so long as they take the task seriously. In addition, offering assistance in specific numeric tasks to anyone lower in objective numeracy would be useful. For example, in medication titration for patients, it may be helpful to provide them with a calendar that explicitly shows the number of pills to take each day of the week and have them set a goal to consult the calendar each day. Identifying and providing tailored communication or other assistance to subgroups of patients and consumers based on numeric confidence and objective ability may allow a more focused use of financial and health care dollars. It is also possible that such numeracy interventions may help patients with other chronic diseases in which lower objective numeracy has been associated with worse outcomes (e.g., chronic kidney disease, congestive heart failure, or diabetes).

Breakthroughs in medical science have meant that we live longer and with fewer problems. The accumulation of financial wealth also allows our society greater economic security and independence, and it creates opportunities for the next generation (71). One's status, however, depends at least in part on the decisions people make. They decide whether to save for retirement, adhere to a medication, follow a budget or their doctor's advice, and do all of the many things that can promote one's finances and health. Many of these decisions relate to how objectively numerate and numerically confident they are. Realizing one's financial and medical potential appears to depend on both numeric competencies.

Methods

Methods were reviewed and approved by the Institutional Review Board at the University of Southern California (USC; UP-14-00148-CR005; Study 1) and The Ohio State University (Biomedical Sciences 2011H0094; Study 2). All participants gave their informed consent to participate. SLE patients also consented at the time of joining the registry, including giving permission to access their medical records. Data are available at https://osf.io/72feh/ (47, 60).

Survey Materials Used in Both Studies. Numeric confidence was measured with the first 4 items of the subjective numeracy scale (e.g., "How good are you at working with fractions?") (14). The results are reported as an average score of 1–6 for participants who completed more than half of the items. Higher scores mean patients believe their numeric abilities are high. Objective numeracy was assessed with the original (Study 1) and a modified version (Study 2) of an 8-item math test developed and validated in prior research (45). Objective numeracy scores were calculated by counting the number of questions answered correctly; missing responses were counted as incorrect (as long as the respondent answered any questions). Higher scores indicated higher numeric ability.

Study 1. Financial Outcomes.

Participant recruitment and data collection. Participants were internet panel members of the UAS, which is maintained by the USC. The USC uses an address-based sampling method to recruit participants (72). Participants who did not have internet access were provided internet access by the USC. Panel members completed surveys and were paid for completed questionnaires (e.g., $20 for a 30-min survey). Response rates for questionnaires tend to be high, and missing data are rare (72). At the time of our analysis, the panel included over 6,000 members who had completed questionnaires measuring financial behavior, financial literacy, financial planning, and cognitive abilities (e.g., refs. 23 and 24). We compiled data across 4 questionnaires (*SI Appendix*, Table S7). Panelists who completed all relevant measures were included in analyses, a final n = 4,572. Relative to 2010 US Census records, our sample was higher-income (median household income = $55,000 vs. $46,326; *SI Appendix*, Table S8), more educated (bachelor's degree or more = 36.6% vs. 27.2%), and older (median age = 49 vs. 37) and included more females (57.1% vs. 50.9%) and non-Hispanic whites (74.1% vs. 63.7%).

Survey materials.

Financial outcomes. To assess financial outcomes, we examined participants' experiences with 13 positive financial outcomes (e.g., has investments, has not received a foreclosure notice, does not have credit card debt, or has not taken out a payday loan) developed by the US Social Security Administration. To compute an overall financial outcome score, positive financial outcomes were coded as 1, summed, divided by the total number of outcomes the participant had the opportunity to experience, and multiplied by 100 (possible range = 0–100). The absolute number of positive financial outcomes was not used because not all questions applied to all participants (e.g., not all participants owned credit cards; see *SI Appendix*, Table S9 for item questions and frequencies and *SI Appendix*, Table S1 for descriptives and reliability). Higher scores indicated better financial outcomes.

Financial knowledge. Financial knowledge was assessed by using a 20-item scale (e.g., "Bonds are normally riskier than stocks." True/False; refs. 46 and 73). Each item was scored as correct or incorrect, summed, and converted to an estimated item response theory score (range = −2.43 to 1.73; *SI Appendix*, *SI Text*). Reliability of scale scores was adequate (ref. 46; *SI Appendix*, Table S1).

Demographics. Age, education, gender, race/ethnicity, and household income were recorded. Age was treated as a continuous variable. Two age responses (i.e., 106 and 98) were treated as outliers and winsorized to 96. Responses to education, gender, and income were categorical. For education, responses were categorized into high school education, some college or associate's degree, and bachelor's degree or more. For gender, male was coded as 0, and female was coded as 1. Race/ethnicity was assessed as non-Hispanic White, Black, Hispanic, Asian, Pacific Islander, Native American, multiple, and not reported. Participants who did not report (0.1% of the sample) were dropped from analyses. Each other response was recoded as a dummy variable (coded as 0) compared to White (coded as 1). Income was treated as a continuous variable by taking the middle household income level within each of 16 categories (*SI Appendix*, Table S8).

Study 2. SLE Patients.

Participant recruitment and data collection. SLE patients ≥ 18 y were recruited from June 2015 to December 2017 from The Ohio State University's LVG registry. They provided consent at the time of joining the registry, including permission to access their medical records. They then reconsented to complete our questionnaires including objective numeracy (45), numeric confidence (14), health literacy (Passage B, Test of Functional Health Literacy; ref. 53), and patient activation (extent of involvement in managing one's health and health maintenance; ref. 54), either online or on paper. Lupus disease activity was assessed at clinic visits with the SLEDAI (55–58). SLEDAI scores ≥6 indicate a possible need for clinical intervention (59). This well-validated composite disease activity score uses weighted physician-observed clinical variables and laboratory data of 9 organ systems (*SI Appendix*, Table S10 for its factors and scoring; ref. 74). Factor scores range from 1 to 8, with a total possible score of 105 across all 24 factors. Data were analyzed from patients (n = 91) who completed all questionnaires and had an up-to-date SLEDAI score.

Survey materials. Health literacy was assessed with the well-validated Short Test of Functional Health Literacy in Adults, a 36-item, reading-comprehension measure, providing a continuous numerical score (53). Finally, patient activation was measured with a 10-item self-reported survey, a licensed version of the Patient Activation Measure (54). Higher scores represent higher levels of patient activation.

Demographics. Age, education, gender, race/ethnicity, and household income were recorded. Age was treated as a continuous variable. Responses to education, gender, and income were categorical. For education, responses were categorized into high-school education and less (0) and more than high-school education (1). For gender, male was coded as 0, and female was coded as 1. Race/ethnicity was coded as a dummy variable (Hispanic, Black, Asian, Native American, Other, or Multiple coded as 1) compared to non-Hispanic White (coded as 0). Income was coded as 0 = less than $50,000 and 1 = more than $50,000 (*SI Appendix*, Table S8).

Disease activity. Lupus disease activity was assessed with the SLEDAI at every clinic visit (*SI Appendix*, Table S10; refs. 55–58).

Data sharing. All materials, data, and exact analysis syntax not already included in *SI Appendix*, have been deposited in the Open Science Framework, https://osf.io/72feh/. Materials and data from Study 1 also are available at https://uasdata.usc.edu/index.php (*SI Appendix*, Table S7; refs. 47 and 60).

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1. US Census Bureau, U.S. Census Bureau QuickFacts: United States. (2019). https://www.census.gov/quickfacts/fact/table/US/PST045218#PST045218. Accessed 1 February 2019.
2. R. Desjardins *et al.*, *OECD Skills Outlook 2013: First Results from the Survey of Adult Skills* (Organisation for Economic Co-operation and Development, Paris, France, 2013).
3. E. Peters, L. Meilleur, M. K. Tompkins, "Numeracy and the Affordable Care Act: Opportunities and challenges" in *Health Literacy and Numeracy: Workshop Summary*, Institute of Medicine, Ed. (The National Academies Press, Washington, DC, 2013), pp. 91–136.
4. A. Lusardi, P. Tufano, Debt literacy, financial experiences, and overindebtedness. *J. Pension Econ. Finance* **14**, 332–368 (2015).
5. G. Hackett, N. E. Betz, A self-efficacy approach to the career development of women. *J. Vocat. Behav.* **18**, 326–339 (1981).
6. K. Lorig, R. L. Chastain, E. Ung, S. Shoor, H. R. Holman, Development and evaluation of a scale to measure perceived self-efficacy in people with arthritis. *Arthritis Rheum.* **32**, 37–44 (1989).

7. T. Låg, L. Bauger, M. Lindberg, O. Friborg, The role of numeracy and intelligence in health-risk estimation and medical data interpretation. *J. Behav. Decis. Making* **27**, 95–108 (2014).
8. A. Bandura, *Self-Efficacy: The Exercise of Control* (W.H. Freeman, New York, NY, 1997).
9. E. Peters *et al.*, Improving numeracy through values affirmation enhances decision and STEM outcomes. *PLoS One* **12**, e0180674 (2017).
10. G. M. Walton, T. D. Wilson, Wise interventions: Psychological remedies for social and personal problems. *Psychol. Rev.* **125**, 617–655 (2018).
11. T. Bodenheimer, K. Lorig, H. Holman, K. Grumbach, Patient self-management of chronic disease in primary care. *JAMA* **288**, 2469–2475 (2002).
12. E. Peters, P. Bjalkebring, Multiple numeric competencies: When a number is not just a number. *J. Pers. Soc. Psychol.* **108**, 802–822 (2015).
13. V. F. Reyna, W. L. Nelson, P. K. Han, N. F. Dieckmann, How numeracy influences risk comprehension and medical decision making. *Psychol. Bull.* **135**, 943–973 (2009).
14. A. Fagerlin *et al.*, Measuring numeracy without a math test: Development of the subjective numeracy scale. *Med. Decis. Making* **27**, 672–680 (2007).
15. E. Peters, Beyond comprehension: The role of numeracy in judgments and decisions. *Curr. Dir. Psychol. Sci.* **21**, 31–35 (2012).
16. S. Ghazal, E. T. Cokely, R. Garcia-Retamero, Predicting biases in very highly educated samples: Numeracy and metacognition. *Judgm. Decis. Mak.* **9**, 15–34 (2014).
17. J. D. Jasper, C. Bhattacharya, R. Corser, Numeracy predicts more effortful and elaborative search strategies in a complex risky choice context: A process-tracing approach. *J. Behav. Decis. Making* **30**, 224–235 (2017).
18. A. D. Gurmankin, J. Baron, K. Armstrong, The effect of numerical statements of risk on trust and comfort with hypothetical physician risk communication. *Med. Decis. Making* **24**, 265–271 (2004).
19. E. T. Cokely, C. M. Kelley, Cognitive abilities and superior decision making under risk: A protocol analysis and process model evaluation. *Judgm. Decis. Mak.* **4**, 20–33 (2009).
20. E. Peters, M. G. Fennema, K. E. Tiede, The loss-bet paradox: Actuaries, accountants, and other numerate people rate numerically inferior gambles as superior. *J. Behav. Decis. Making* **32**, 15–29 (2018).
21. E. Peters *et al.*, Numeracy and decision making. *Psychol. Sci.* **17**, 407–413 (2006).
22. L. D. Scherer, J. F. Yates, S. G. Baker, K. D. Valentine, The influence of effortful thought and cognitive proficiencies on the conjunction fallacy: Implications for dual-process theories of reasoning and judgment. *Pers. Soc. Psychol. Bull.* **43**, 874–887 (2017).
23. A. Sinayev, E. Peters, Cognitive reflection vs. calculation in decision making. *Front. Psychol.* **6**, 532–547 (2015).
24. W. Bruine de Bruin, A. Wallin, A. M. Parker, J. Strough, J. Hanmer, Effects of anti- versus pro-vaccine narratives on responses by recipients varying in numeracy: A cross-sectional survey-based experiment. *Med. Decis. Making* **37**, 860–870 (2017).
25. N. F. Dieckmann, P. Slovic, E. M. Peters, The use of narrative evidence and explicit likelihood by decisionmakers varying in numeracy. *Risk Anal.* **29**, 1473–1488 (2009).
26. T. Pachur, M. Galesic, Strategy selection in risky choice: The impact of numeracy, affect, and cross-cultural differences. *J. Behav. Decis. Making* **26**, 260–271 (2013).
27. N. E. Betz, "Assessment of self-efficacy" in *APA Handbook of Testing and Assessment in Psychology*, K. F. Geisinger, B. A. Bracken, J. F. Carlson, J. C. Hansen, N. R. Kuncel, Eds. (American Psychological Association, Washington, DC, 2013), pp. 379–391.
28. A. Bandura, D. H. Schunk, Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *J. Pers. Soc. Psychol.* **41**, 586–598 (1981).
29. L. Damisch, B. Stoberock, T. Mussweiler, Keep your fingers crossed!: How superstition improves performance. *Psychol. Sci.* **21**, 1014–1020 (2010).
30. J. Traczyk, A. Sobkow, K. Fulawka, J. Kus, D. Petrova, Numerate decision makers don't use more effortful strategies unless it pays: A process tracing investigation of skilled and adaptive strategy selection in risky decision making. *Judgm. Decis. Mak.* **13**, 372–381 (2018).
31. J. Banks, C. O'Dea, Z. Oldfield, Cognitive function, numeracy and retirement saving trajectories. *Econ. J. (Lond.)* **120**, F381–F410 (2011).
32. J. Banks, Z. Oldfield, Understanding pensions: Cognitive function, numerical ability and retirement saving. *Fisc. Stud.* **28**, 143–170 (2007).
33. D. Christelis, T. Jappelli, M. Padula, Cognitive abilities and portfolio choice. *Eur. Econ. Rev.* **54**, 18–38 (2010).
34. C. A. Estrada-Mejia, M. de Vries, M. Zeelenberg, Numeracy and wealth. *J. Econ. Psychol.* **54**, 53–63 (2016).
35. J. P. Smith, J. J. McArdle, R. Willis, Financial decision making and cognition in a family context. *Econ. J. (Lond.)* **120**, F363–F380 (2010).
36. N. F. Dieckmann *et al.*, The role of objective numeracy and fluid intelligence in sex-related protective behaviors. *Curr. HIV Res.* **13**, 337–346 (2015).
37. C. Maher *et al.*, The associations between physical activity, sedentary behaviour and academic performance. *J. Sci. Med. Sport* **19**, 1004–1009 (2016).
38. R. Garcia-Retamero, A. Andrade, J. Sharit, J. G. Ruiz, Is patients' numeracy related to physical and mental health? *Med. Decis. Making* **35**, 501–511 (2015).
39. C. A. Estrada, M. Martin-Hryniewicz, B. T. Peek, C. Collins, J. C. Byrd, Literacy and numeracy skills and anticoagulation control. *Am. J. Med. Sci.* **328**, 88–93 (2004).
40. A. S. Mixon *et al.*, Characteristics associated with postdischarge medication errors. *Mayo Clin. Proc.* **89**, 1042–1051 (2014).
41. D. Waldrop-Valverde *et al.*, Numeracy skills explain racial differences in HIV medication management. *AIDS Behav.* **14**, 799–806 (2010).
42. A. A. Ginde, S. Clark, J. N. Goldstein, C. A. Camargo, Jr, Demographic disparities in numeracy among emergency department patients: Evidence from two multicenter studies. *Patient Educ. Couns.* **72**, 350–356 (2008).
43. C. D. McNaughton *et al.*, Low numeracy is associated with increased odds of 30-day emergency department or hospital recidivism for patients with acute heart failure. *Circ Heart Fail* **6**, 40–46 (2013).
44. S. Agarwal, X. Gabaix, J. C. Driscoll, D. Laibson, The age of reason: Financial decisions over the life cycle and implications for regulation. *Brookings Pap. Econ. Act.* **2009**, 51–117 (2009).
45. J. A. Weller *et al.*, Development and testing of an abbreviated numeracy scale: A Rasch analysis approach. *J. Behav. Decis. Making* **26**, 198–212 (2013).
46. C. R. Houts, M. A. Z. Knoll, The financial knowledge scale: New analyses, findings, and development of a short form. *J. Consum. Aff.* **46**, 381–410 (2019).
47. E. Peters, M. K. Tompkins, M. A. Z. Knoll, Data from "Study 1 data. Peters et al. (2019)." Open Science Framework. https://osf.io/cd785/. Deposited 3 August 2019.
48. L. Farrell, T. R. L. Fry, L. Risse, The significance of financial self-efficacy in explaining women's personal finance behaviour. *J. Econ. Psychol.* **54**, 85–99 (2016).
49. D. Fernandes, J. G. Lynch, R. G. Netemeyer, Financial literacy, financial education, and downstream financial behaviors. *Manage. Sci.* **60**, 1861–1883 (2014).
50. J. A. Singh, N. Shah, C. Green, Individualized patient decision-aid for immunosuppressive drugs in women with lupus nephritis: Study protocol of a randomized, controlled trial. *BMC Musculoskelet. Disord.* **18**, 53 (2017).
51. M. B. Urowitz, D. D. Gladman, B. D. Tom, D. Ibañez, V. T. Farewell, Changing patterns in mortality and disease outcomes for patients with systemic lupus erythematosus. *J. Rheumatol.* **35**, 2152–2158 (2008).
52. M. Zen *et al.*, Prolonged remission in Caucasian patients with SLE: Prevalence and outcomes. *Ann. Rheum. Dis.* **74**, 2117–2122 (2015).
53. D. W. Baker, M. V. Williams, R. M. Parker, J. A. Gazmararian, J. Nurss, Development of a brief test to measure functional health literacy. *Patient Educ. Couns.* **38**, 33–42 (1999).
54. J. H. Hibbard, E. R. Mahoney, J. Stockard, M. Tusler, Development and testing of a short form of the patient activation measure. *Health Serv. Res.* **40**, 1918–1930 (2005).
55. C. Bombardier, D. D. Gladman, M. B. Urowitz, D. Caron, C. H. Chang; The Committee on Prognosis Studies in SLE, Derivation of the SLEDAI. A disease activity index for lupus patients. *Arthritis Rheum.* **35**, 630–640 (1992).
56. I. N. Bruce *et al.*, Factors associated with damage accrual in patients with systemic lupus erythematosus: Results from the Systemic Lupus International Collaborating Clinics (SLICC) inception cohort. *Ann. Rheum. Dis.* **74**, 1706–1713 (2015).
57. D. D. Gladman, D. Ibañez, M. B. Urowitz, Systemic lupus erythematosus disease activity index 2000. *J. Rheumatol.* **29**, 288–291 (2002).
58. G. Hawker *et al.*, A reliability study of SLEDAI: A disease activity index for systemic lupus erythematosus. *J. Rheumatol.* **20**, 657–660 (1993).
59. K. Tselios, D. D. Gladman, M. B. Urowitz, How can we define low disease activity in systemic lupus erythematosus? *Semin. Arthritis Rheum.* **48**, 1035–1040 (2019).
60. E. Peters, M. K. Tompkins, S. P. Ardoin, A. S. Meara, Data from "Study 2 data. Peters et al. (2019)." Open Science Framework. https://osf.io/m28ar/. Deposited 2 February 2019.
61. S. E. Taylor, J. D. Brown, Illusion and well-being: A social psychological perspective on mental health. *Psychol. Bull.* **103**, 193–210 (1988).
62. D. R. Forsyth, N. K. Lawrence, J. L. Burnette, R. F. Baumeister, Attempting to improve the academic performance of struggling college students by bolstering their self–esteem: An intervention that backfired. *J. Soc. Clin. Psychol.* **26**, 447–459 (2007).
63. R. F. Baumeister, J. D. Campbell, J. I. Krueger, K. D. Vohs, Does high self-esteem cause better performance, interpersonal success, happiness, or healthier lifestyles? *Psychol. Sci. Public Interest* **4**, 1–44 (2003).
64. C. Camerer, D. Lovallo, Overconfidence and excess entry: An experimental approach. *Am. Econ. Rev.* **89**, 306–318 (1999).
65. J. Kruger, D. Dunning, Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. *J. Pers. Soc. Psychol.* **77**, 1121–1134 (1999).
66. J. Cohen, Statistical power analysis. *Curr. Dir. Psychol. Sci.* **1**, 98–101 (1992).
67. A. Bandura, Self-efficacy: Toward a unifying theory of behavioral change. *Psychol. Rev.* **84**, 191–215 (1977).
68. L. Hadar, S. Sood, C. R. Fox, Subjective knowledge in consumer financial decisions. *J. Mark. Res.* **50**, 303–316 (2013).
69. C. S. Rozek, G. Ramirez, R. D. Fine, S. L. Beilock, Reducing socioeconomic disparities in the STEM pipeline through student emotion regulation. *Proc. Natl. Acad. Sci. U.S.A.* **116**, 1553–1558 (2019).
70. J. Park, E. M. Brannon, Training the approximate number system improves math proficiency. *Psychol. Sci.* **24**, 2013–2019 (2013).
71. T. Shapiro, T. Meschede, S. Osoro, *The Roots of the Widening Racial Wealth Gap: Explaining the Black-White Economic Divide* (Institute on Assets and Social Policy, Waltham, MA, 2013).
72. L. Alattar, M. Messel, D. Rogofsky, An introduction to the Understanding America Study Internet panel. *Soc. Secur. Bull.* **78**, 13–28 (2018).
73. M. A. Z. Knoll, C. R. Houts, The Financial Knowledge Scale: An application of item response theory to the assessment of financial literacy. *J. Consum. Aff.* **46**, 381–410 (2012).
74. Z. Touma, M. B. Urowitz, D. Ibañez, D. D. Gladman, SLEDAI-2K 10 days versus SLEDAI-2K 30 days in a longitudinal evaluation. *Lupus* **20**, 67–70 (2011).

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