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Status invisibility alleviates the economic gradient in happiness in social network experiments

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Economic status is positively associated with subjective well-being (SWB), happiness and mental health, but debate persists about the determinants of SWB in circumstances involving economic inequality. Here we implemented online experiments where subjects interact financially, gain or lose wealth, report their SWB and adjust their social ties with others across time. We assigned 1,289 subjects to be initially rich or poor in 100 networked groups and manipulated wealth visibility in the groups. In the visible wealth condition, we showed subjects the wealth of their immediate neighbours, thereby allowing social comparisons, while in the invisible wealth condition, we kept such information hidden. Results show that invisible wealth condition disproportionally improves the SWB of currently poorer subjects and thus alleviated the economic gradient in SWB. Two phenomena may explain the alleviation observed in the invisible wealth condition: initially rich subjects who become relatively poorer do not experience substantial damage to their SWB, and initially poor subjects who remain poorer may still experience an SWB gain similar to those who become richer.

Wealth and income are positively associated with subjective well-being (SWB) across cultures and countries[1–8]. Although there is a diminishing marginal gain of well-being with greater levels of income in general[2,6,9,10], richer individuals are happier on average. But do people have to be rich to be happy? Is the wealth–well-being linkage specific to certain settings, including modern human society? In what social setting might poorer individuals be as happy as richer individuals? Evidence from previous observational studies gives us a clue to answer these questions: a large portion of the wealth–well-being linkage comes from the existence of relative wealth (that is, having higher/lower wealth than others in one's social network) and not just absolute wealth (for example, purchasing power)[11–14].

The impact of relative wealth comes from social comparison, which is a process of comparing one's social characteristics, behaviours and outcomes with other people[15,16]. For example, a well-known experimental economics study reported that a majority of individuals prefer to choose A (your current yearly income is 50,000 USD; others earn 25,000 USD) over B (your current yearly income is 100,000 USD; others earn 200,000 USD)[17]. The negative impact of social comparison on job satisfaction[18], income satisfaction[19], cooperativeness in social networks[20,21], and economic inequality[20] has been investigated. Regarding the impact of social comparison on emotional well-being, observational studies have shown that individuals compare their income with others' income, and, if others are richer, they feel less happy even given the same purchasing power[22–24]. Such effects are confirmed in country-level analyses[25]. It is known that social comparison alters one's emotions because it induces a feeling of being left behind and of relative deprivation[26–28]. For example, evidence shows that relative income is at least twice as important for individual emotional well-being as absolute income[29,30].

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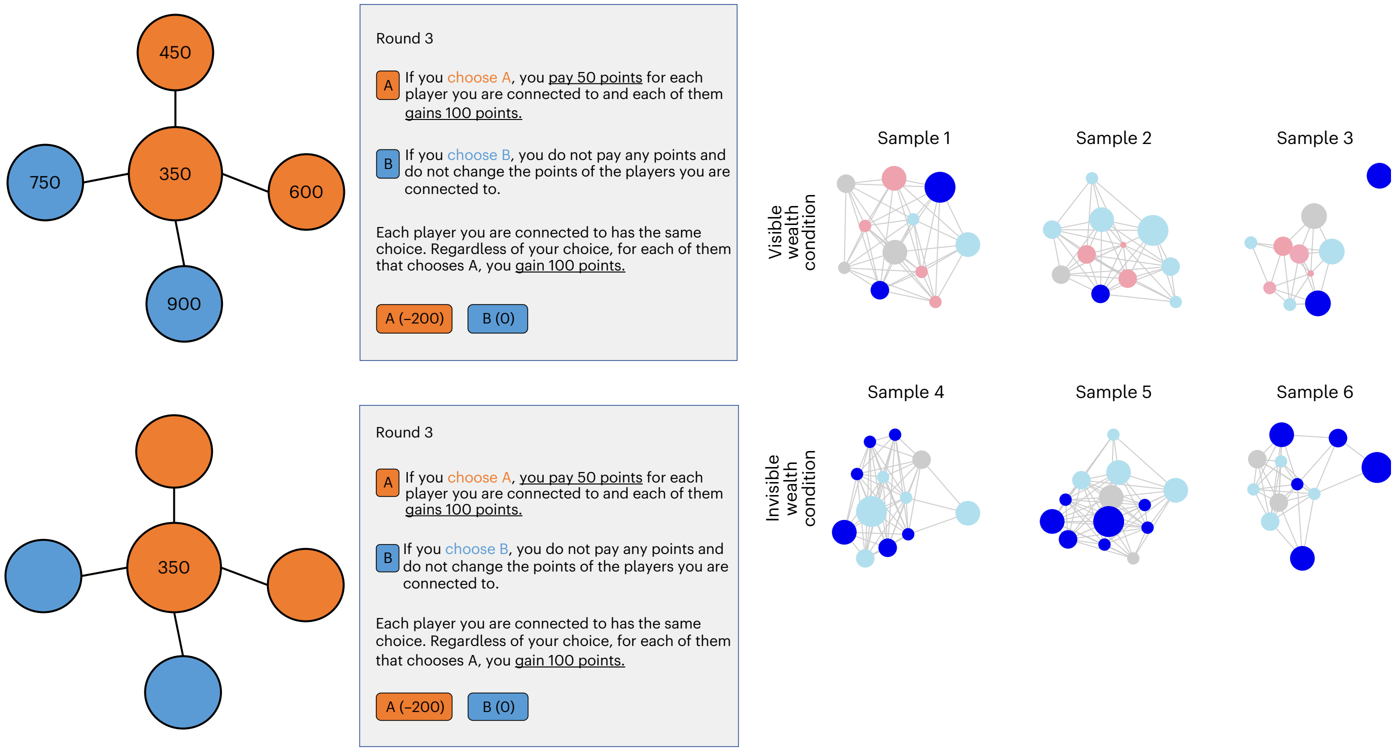

Fig. 1 | The experimental social networks in our set-up (experiment 1). Top left: a sample screenshot of the game interface for subjects in the 'visible wealth' condition. Bottom left: a sample screenshot from the 'invisible wealth' condition. 'Points' are equivalent to in-game units in the main text, and we converted these to real dollars at the end of the game. Right: illustrative social networks at the end of the experiment from six different sessions (chosen from the 50 sessions in experiment 1). Circle size represents relative wealth; the colour represents SWB (light pink, bad; grey, neutral; light blue, good; blue, very good). Lines represent a social tie between two subjects. In sample 3, the subject on top right (coloured blue) has no social ties at the end of the experiment.

Therefore, if there were a method to experimentally switch off social comparison between individuals in a group, we might successfully reduce the negative effect of relative wealth (or income) on emotional well-being, which would have a larger impact on poorer individuals. In this sense, status invisibility, which is defined as the state where a focal individual can know her or his own status (such as income, wealth or other attributes) but cannot know that of connected neighbours[20], could be an important factor in policies promoting emotional well-being. There are some real-world examples of both status invisibility (for example, pay secrecy in firms[31,32], and student uniform policies in schools[33,34]) and status visibility (for example, Forbes World's Billionaires List[35] and the University of California's policy on public disclosure of employee pay[18,36]). The use of social media such as Instagram and Facebook is also an example of visibility of others' status, and it can lead adolescents and others to compare themselves with better-off individuals (since their position and belongings are visible) and thus to experience poorer mental health[37,38]. Indeed, a recent paper provides quasi-experimental estimates of the negative impact of Facebook on mental health of US college students[39].

Prior evidence from social network experiments shows that making others' wealth invisible promotes the construction of cooperative social interactions and trust[40–42] and reduces the overall level of wealth inequality[20,43,44]. Making others' wealth invisible can suppress all forms of social comparison on wealth (for example, feelings of being exploited by richer individuals, last-place aversion and effort–reward imbalance). Therefore, we can predict that invisibility may improve people's emotional well-being without changing their economic position, and thus, it may not be costly. However, these studies[20,40–44] have not investigated whether or not making others' wealth invisible has a positive impact on emotional well-being or the disparities therein.

On the other hand, making others' wealth invisible may also have negative effects: suppressing social comparison would reduce the emotional well-being derived from feelings of superiority[45] among people of a higher economic status. Regardless of their socio-economic status, people may be eager to compare themselves with others to evaluate themselves and adjust their strategies[15], and suppressing such an innate basic desire by making others' wealth invisible might, in theory, worsen their emotional well-being. Therefore, we can also predict that making others' wealth invisible may even undermine the overall emotional well-being at the group or population level. Finally, it is well known that intervention programmes constructed from observational evidence often do not work as theorized in an experimental setting or have unintended negative consequences[14,46–48].

To reconcile these two predictions, our experiments focus on manipulating the visibility of others' economic status as a possible macrosocial determinant of mental health[49–51]. In more concrete terms, we use short-lived, online, dynamic social network experiments to explore the macro-level determinants of the economic gradient of SWB: a gradient within SWB that may reflect micro-level socio-economic activities. We performed a series of online network-based experiments ($N = 570$ in 50 groups of people with 15 rounds of interactions in each group), and we furthermore used secondary data from another series of online network-based experiments ($N = 719$ in 50 groups of people with 15 rounds of interactions) (G. Dewey et al., manuscript in preparation) to reproduce the results. The distribution of sociodemographic and other factors across the treatment assignments is presented in Extended Data Table 1. We included the listed covariates in our regression models to minimize the influence of potentially unbalanced covariates.

In our experiments, the subjects were randomly given one of two amounts of wealth (200 in-game units (70% chance) or 1,150 in-game units (30% chance)), which produced endowment heterogeneity[52–57]

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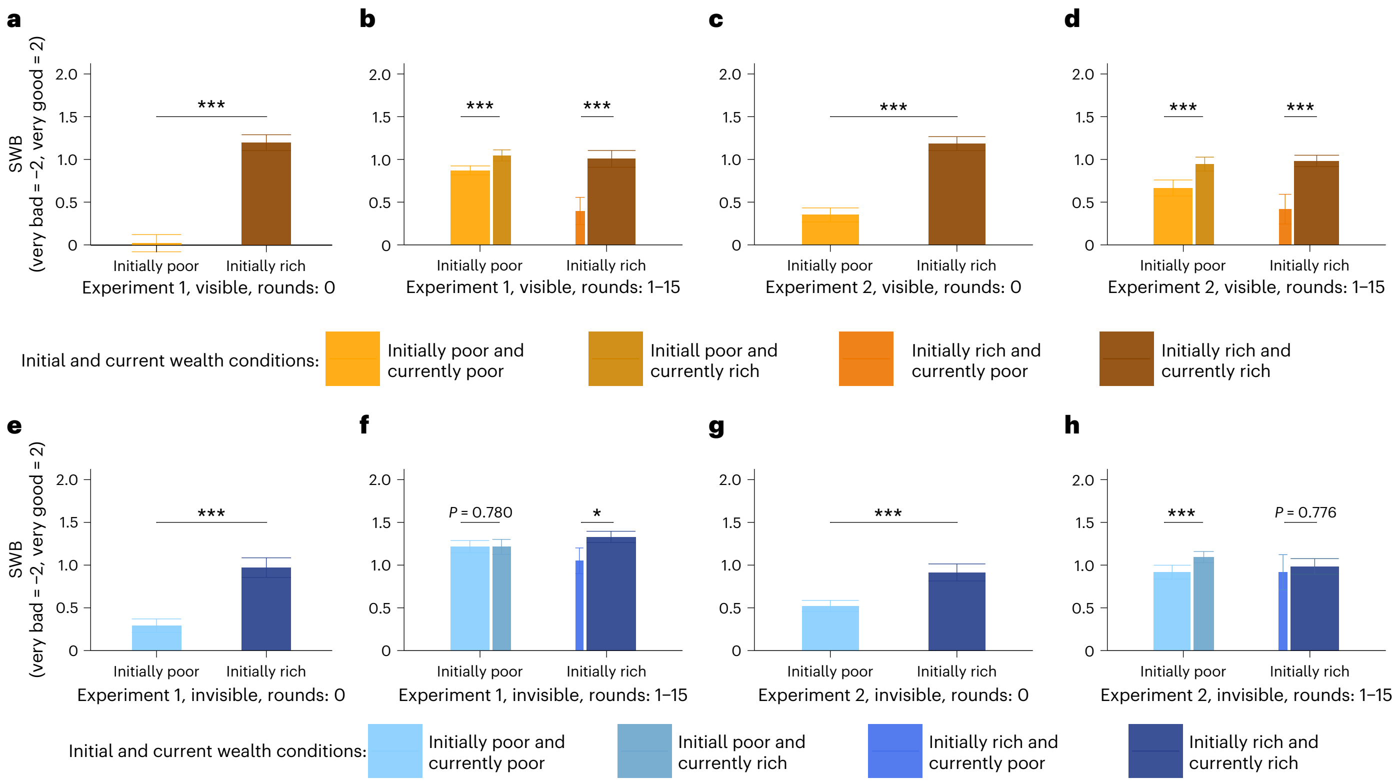

Fig. 2 | Trajectories of average SWB over the 15 game rounds for initially poor and initially rich subjects in different settings. a,**b**, Visible wealth condition in experiment 1 (**a**, round 0 and **b**, rounds 1–15). **c**,**d**, Visible wealth condition in experiment 2 (**c**, round 0 and **d**, rounds 1–15). **e**,**f**, Invisible wealth condition in experiment 1 (**e**, round 0 and **f**, rounds 1–15). **g**,**h**, Invisible wealth condition in experiment 2 (**g**, round 0 and **h**, rounds 1–15). Cohort of subjects who were initially assigned to be poor (left in each panel) or rich (right in each panel) in round 0 could be poor (left in each bar) or rich (right in each bar) with respect to the current-round in-game units between rounds 1 and 15. We displayed the trajectories in different series of the experiments (experiment 1 ($n = 570$) or experiment 2 ($n = 719$)) and in different wealth visibility conditions (orange for visible and blue for invisible). Bar graphs represent averages and lines represent ±1 s.e.m. (obtained from regression models).

but was independent from their actual social standing in the real world. The Gini coefficient[58] before a game started was thus expected to be 0.4 (which is roughly equivalent to the 2020 Gini coefficient of the United States (0.397)[59]). In-game units were converted into USD (2,000 in-game units = 1 USD) as a reward and paid out at the end of the experiment (an average reward of 1.580 USD (standard deviation (s.d.) 1.084 USD) in addition to a guaranteed participation fee of 3.00 USD both in experiments 1 and 2). Subjects interacted with one another financially through a cooperation game (Public Goods Game) with two behavioural options (cooperate or defect) in experiment 1 and with three options (cooperate, defect or harm) in experiment 2. They reported their SWB every round of the game, and they updated their local social network ties based on their and their neighbours' performance and position (making or cutting their social ties with others in the same networked group) (Methods). The flow of the subject's procedures is described in Extended Data Figs. 1 and 2.

The current wealth of the connected neighbours was shown in the visible wealth condition, while it was not shown in the invisible wealth condition. This was our primary experimental manipulation to explore the impact of wealth visibility specifically on the economic gradient in SWB (Fig. 1). We observed the dynamics of in-game wealth and also the SWB of the subjects at each round in each group.

Results and discussion

Initial wealth–happiness association

The visibility of wealth had several effects on game dynamics. We begin by re-documenting the economic gradient in SWB that is often observed in real-world interactions in the visible wealth condition at the beginning of laboratory settings (that is, round 0). In experiment 1, subjects rated their SWB at 0.412 (between neutral and good; standard error (s.e.m.) 0.074) and at 0.634 (s.e.m. 0.063) in experiment 2. In experiment 1, initially poor subjects rated their SWB at 0.020 (slightly above neutral; s.e.m. 0.101), whereas initially rich subjects rated their SWB at 1.196 (between good and very good; s.e.m. 0.093) (Fig. 2a). This means that, in our experimental setting, we could reproduce a setting resembling the real world in which richer individuals often times feel better than the poorer individuals in the same group ($\beta = 1.256$, s.e. 0.153, and $P < 0.0001$ in an adjusted model). This finding was confirmed in experiment 2 in Fig. 2c and in an adjusted model ($\beta = 0.877$, s.e. 0.131, and $P < 0.0001$).

In the invisible wealth condition, initially poor subjects were also less happy than initially rich subjects in round 0 in experiment 1 (Fig. 2e). However, the SWB gap in the invisible wealth condition ($\beta = 0.658$, s.e. 0.125, and $P < 0.0001$) was smaller than that in the visible wealth condition (the aforementioned β of 1.256) in experiment 1 (interaction $P = 0.002$). This finding implies that both the absolute and relative wealth jointly shape SWB. Initially poor subjects in the visible wealth condition, but not in the invisible wealth condition, could recognize that they were low on the economic ladder of the same networked group. This finding was confirmed visually in experiment 2 (Fig. 2g) and in an adjusted model (interaction $P = 0.005$).

Mobility in in-game units (wealth)

Next, we explored the question of whether initial wealth predicted economic position over the 15 rounds of the game, or whether substantial economic mobility occurred. Since our experiments were

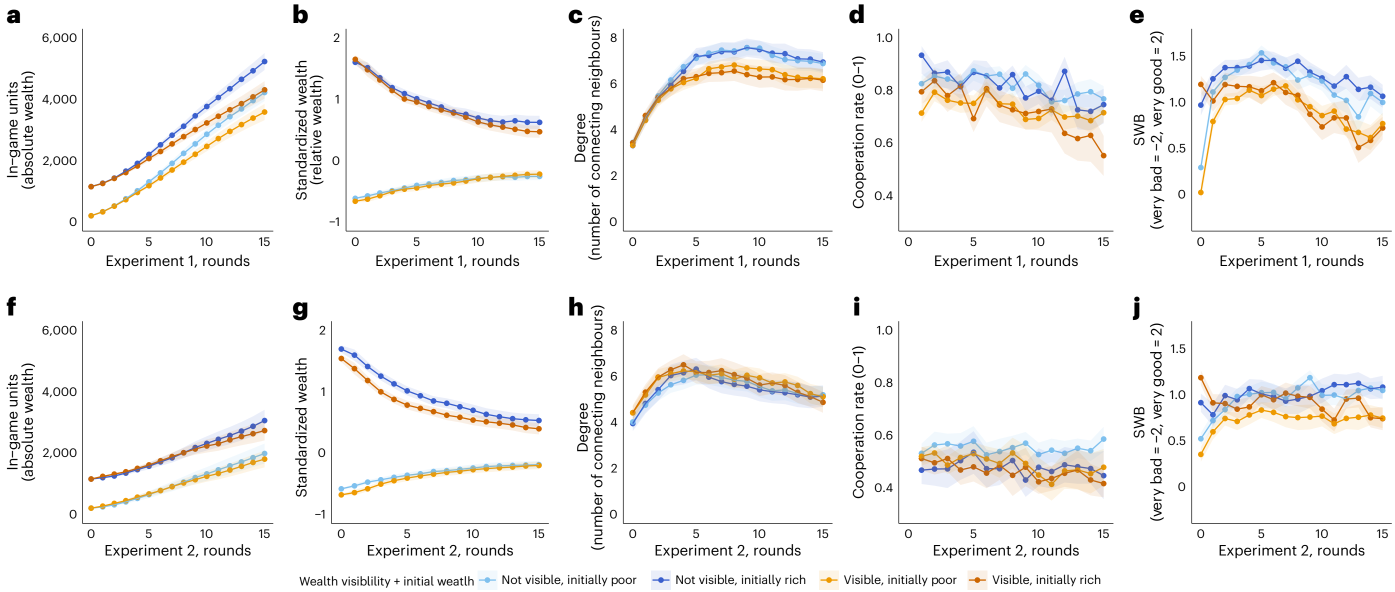

Fig. 3 | Trajectories of various outcome variables for initially poor and rich individuals in visible and invisible wealth conditions. **a**–**e**, Experiment 1 ($n = 570$). **f**–**j**, Experiment 2 ($n = 719$). **a**,**f**, in-game units. **b**,**g**, standardized wealth. **c**,**h**, degree. **d**,**i**, cooperation rate. **e**,**j**, SWB. The lines with dots represent the estimated mean and the shades represent ±1 s.e.m.

deliberately dynamic (wealth, social ties, and SWB could change as subjects chose how and with whom to interact cooperatively), the magnitude of economic growth varied across sessions (that is, the sum of in-game units in different rounds in different sessions), and so we statistically standardized it over the rounds across the presentation of the main results here.

As shown in Extended Data Fig. 3, 85.4% of the initially rich subjects in experiment 1 and 84.5% of those in experiment 2 stayed at above the mean (that is, the line of $y = 0$ in standardized wealth), while 77.4% of the initially poor subjects in experiment 1 and 71.6% of those in experiment 2 stayed at below the mean. This tendency was inherently the same in the actual in-game units (absolute wealth) (Extended Data Fig. 3a,b,e,f). Most of the orange (the initially rich) and blue (the initially poor) lines in Extended Data Fig. 3 move in parallel with some attenuation, implying that the initial wealth difference did not disappear over the rounds (interaction P (initial wealth × round) ≤ 0.001 and 0.586 for the first and second series of the experiments, respectively). In other words, there was no dramatic economic mobility in our experiment. This is expected according to the game rules[20], as the endowment of the initially poor subjects (200 in-game units) is too low to cooperate with 3–4 initially connected individuals on average (50 points per connected neighbour) in earlier rounds, which obliged them to be left behind in constructing reciprocal relationships to be financially better off in a longer term.

Mobility in SWB

Over rounds 1–15, subjects rated their SWB at 1.090 (slightly above good; s.e.m. 0.051) in experiment 1 and 0.894 (slightly below good; s.e.m. 0.050) in experiment 2. In contrast to the persistent economic gap created by the initial 'luck-based' economic position, the SWB gap created by the initial wealth difference was largely and abruptly attenuated in an early stage of the 15-round game of experiment 1 (Fig. 3e versus Fig. 3b). This attenuation is confirmed both in the visible wealth condition (the aforementioned β of 1.256 in round 0 and $\beta = 0.043$, s.e. 0.081, $P = 0.596$ in rounds 1–15) (Fig. 3e, dark orange versus light orange) and in the invisible wealth condition ($\beta = 0.658$ in round 0, $\beta = 0.104$, s.e. 0.063, $P = 0.101$ in rounds 1–15) (Fig. 3e, dark blue versus light blue). The results were confirmed in experiment 2 (Fig. 3j). The happiness mobility reported here is our first main finding: when subjects are given decent opportunities to gain resources, the initial deficit in SWB among the initially poor subjects can be attenuated.

Current wealth–happiness association

Interestingly, however, and in the visible wealth condition, a novel gap in SWB emerged over the 15 game rounds, due to the 'updated' economic position, which is a sum of the initial 'luck-based' in-game units and the over-the-round 'performance-based' in-game units (that is, current wealth) (Fig. 2b,d). As also shown in Fig. 4a, in orange, in an unadjusted model using the data from experiment 1, subjects with the lowest standardized wealth in each round (−1.5 s.d. or less) in the five categories rated their SWB at 0.377 (between neutral and good, s.e.m. 0.235) over the course of the experiment, whereas those with the highest standardized wealth (+1.5 s.d. or more) rated their SWB at 1.270 (between good and very good, s.e.m. 0.102) in experiment 1. This trend is confirmed in experiment 2 (Fig. 4b, in orange).

On the other hand, in the invisible wealth condition, also in an unadjusted model for experiment 1, subjects in the lower standardized wealth category were also less happy than those in the higher standardized wealth category (Fig. 4a, in blue). However, the slope in the invisible wealth condition (slope 0.076, s.e. 0.021, $P < 0.0001$)—that is, the magnitude of the economic gradient of SWB—is almost one fourth as steep as that in the visible wealth condition (slope 0.236, s.e. 0.023, $P < 0.0001$) (interaction $P < 0.0001$) under the assumption of linearity (see 'Limitations' section in Methods and Supplementary Information Additional Analysis 2). This trend is confirmed in experiment 2 (Fig. 4b) (interaction $P < 0.0001$). That is, richer individuals in each round did not benefit much from making others' wealth invisible in terms of SWB, while poorer individuals in each round benefitted substantially. The effect reported here (that of wealth invisibility on the strength of the current-wealth–SWB association, that is, the slope of standardized wealth on SWB) is our second main finding: making others' wealth invisible makes subjects happier, especially in the currently poor ranges.

The attenuation of the current-wealth–SWB association caused by the invisible wealth condition is cleanly confirmed across all the subgroups in both the experiments: initially poor subjects (interaction $P = 0.0012$) and initially rich subjects (interaction $P < 0.0001$) in experiment 1, and initially poor subjects (interaction $P = 0.0073$)

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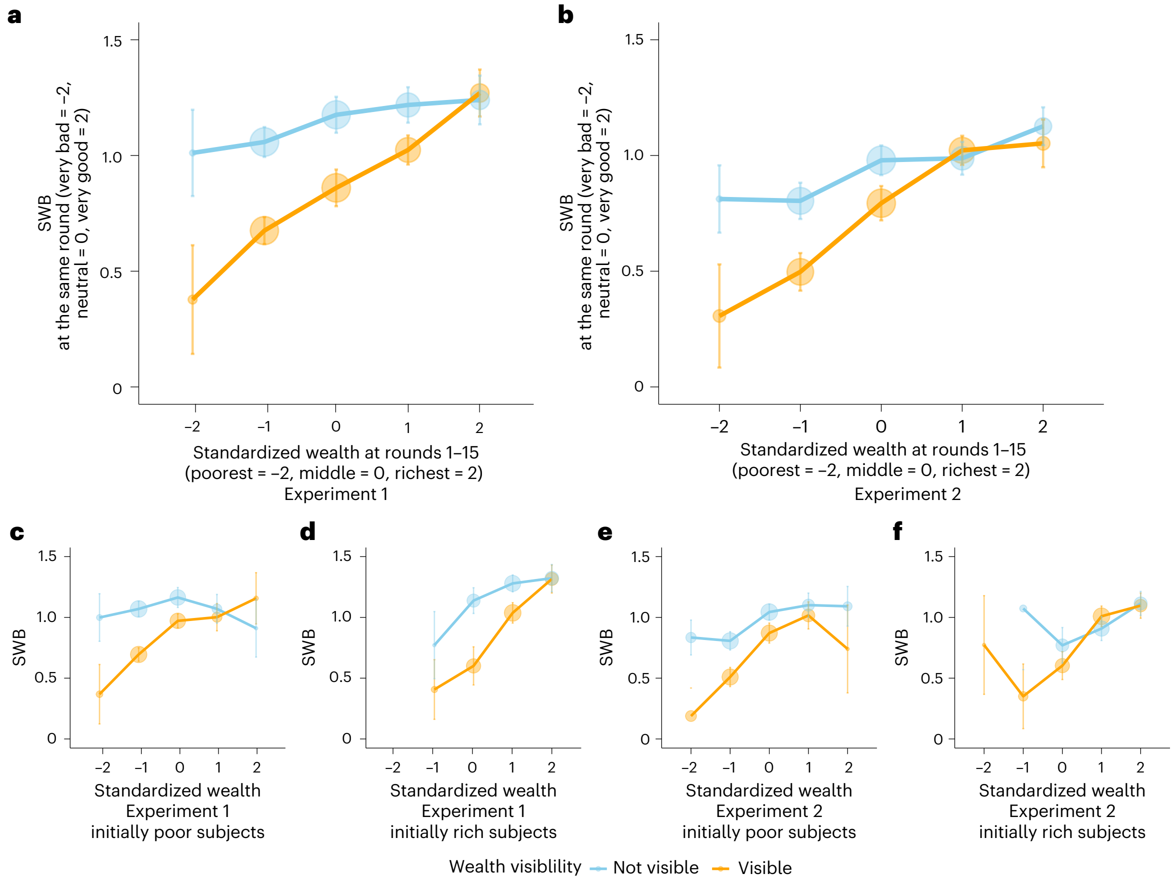

Fig. 4 | Wealth visibility decreases SWB and exacerbates the economic gradient in SWB. **a**, Standardized-wealth-stratified result from experiment 1 ($n = 570$). **b**, Standardized-wealth-stratified results from experiment 2 ($n = 719$). **c**,**d**, Stratified by initial wealth, experiment 1 (**c**, initially poor subjects and **d**, initially rich subjects). **e**,**f**, Stratified by initial wealth, experiment 2 (**e**, initially poor subjects and **f**, initially rich subjects). Study participants' wealth in each round (rounds 1–15) was classified into one of the five categories based on standardized wealth (poorest: −1.5 s.d. or less and placed at −2; poorer: −1.49 s.d. to −0.5 s.d. and placed at −1; middle: −0.49 s.d. to 0.49 s.d. and placed at 0; richer: 0.5 s.d. to 1.5 s.d. and placed at 1; and richest: 1.5 s.d. or more and placed at 2) for visualization. The area of the circle in each category represents the relative sample size in each category. Each error bar represents point estimate of mean ± 1 s.e.m.

and initially rich subjects (interaction $P < 0.0001$) in experiment 2 (Fig. 4c–f). This finding identifies the two distinct cohorts of subjects who can gain happiness regardless of their poorer economic status in the invisible wealth condition.

First, in the invisible wealth condition, a majority of the initially poor individuals remained in the poor range, but they were eventually as happy as those who moved up to the rich range in experiment 1 (Fig. 2f, left) and the difference between the two is small in experiment 2 (Fig. 2h, left). Here we speculate that such happiness among those who stayed poor from start to finish in the invisible wealth condition is due to their happiness production function, which includes their actual in-game units and their gains, but not the wealth of others. Indeed, they could not know that they were poorer than others, and so they could be satisfied with their steady absolute wealth gain from round to round, even if it was not enough to catch up with richer others.

Second, in the invisible wealth condition, a minority of the initially rich subjects fell into the poor range, but their happiness almost mirrored those who remained in the rich range (Fig. 2f,h, right). Such an equivalence was not observed in the visible wealth condition: those who fall into the poor range are less happy (Fig. 2b,d, right). Here we speculate that such happiness among those who are downwardly mobile in the invisible wealth condition derives from a feature of the condition: they do not have to recognize, face or struggle with the truth that they cannot protect their given wealth status and have fallen down the economic ladder.

Does standardized wealth represent relative wealth?

The standardized wealth variable in the unadjusted models above (shown in Fig. 4) may not only reflect how people engage in social comparison and interpret their relative wealth, because in the invisible wealth condition, the data show that standardized wealth was weakly associated with SWB. A relative wealth variable should not predict SWB in the invisible wealth condition because social comparison was not possible. Therefore, we have included several covariates in adjusted regression models, including absolute wealth (in-game units) and absolute wealth gain (in-game unit gain since a previous round), so that the standardized wealth variable would not represent these covariates. The results from experiment 1 show that the slope of standardized wealth on SWB is completely flattened in the invisible wealth condition ($\beta = -0.039$, s.e. 0.028, $P = 0.163$), while it is not flattened in the visible wealth condition ($\beta = 0.172$, s.e. 0.028, $P < 0.0001$) (P of the interaction term between wealth visibility and standardized wealth <0.0001). In contrast, none of the interaction terms between wealth visibility and absolute wealth (in-game units) or between wealth visibility and absolute wealth gain were substantial (interaction $P = 0.938$ and 0.883, respectively), supporting our model specification: the association of the absolute wealth or its gain with SWB should appear at a similar level between the visible and invisible wealth conditions. We also used the Yitzhaki index[60] and relative rank instead of the standardized wealth variable (Extended Data Table 2 and Supplementary Information

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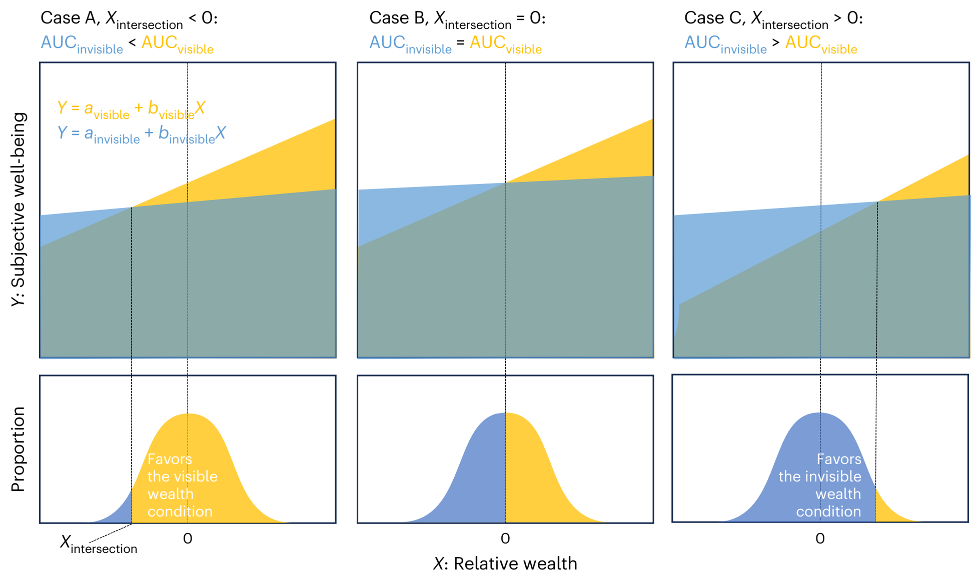
BOX 1

Gross happiness in the visible and invisible wealth conditions

All else being equal, subjective well-being (Y) is produced by an intercept representing the baseline level of well-being (a), a slope representing the influence of relative wealth (b), and relative wealth (X). The well-being production function in the visible wealth condition (orange) differs from that in the invisible wealth condition (blue). Gross happiness can be calculated as the sum of all community individuals in a state (area under the curve (AUC) weighted by proportion). If the weighted AUC of the invisible wealth condition ($AUC_{invisible}$) is larger than the weighted $AUC_{visible}$, group voting or consensus should favor the invisible wealth condition. In this case, the X-value for the intersection of the two curves is in the range of $X > 0$ (Case C). This means that a majority of individuals in the community may be better off emotionally, and thus theoretically agree or vote to make the others' wealth invisible as the default community setting.



Additional Analysis 1), and the model fit between the three variables is compatible, which implies that standardized wealth is an acceptable measure to examine the role of relative wealth in the adjusted models.

The results from experiment 2 show a similar result: the slope of standardized wealth on SWB in the invisible wealth condition was almost flattened ($\beta = 0.045$, s.e. 0.026, $P = 0.083$), while that in the visible wealth condition was not flattened ($\beta = 0.198$, s.e. 0.031, $P < 0.0001$) (interaction $P < 0.0001$) (Extended Data Table 2). Again, here, the interactions with absolute wealth and its gain were not substantial (interaction $P = 0.844$ and 0.596, respectively). In sum, we conclude that the standardized wealth variable, conditioned on the covariates in the adjusted model, may more purely represent the influence of relative wealth in SWB than in the unadjusted model.

The adjusted models confirm that the subjects not only in the poorer ranges (below the mean) but also in many parts of the richer ranges (above the mean) can be emotionally better off in the invisible wealth condition than in the visible wealth condition. This is the third main finding: under the assumption of linearity, the intersection of the two post-adjustment lines, which was calculated from the coefficients in Extended Data Table 2, models 1 and 6, is located on the right side on the x value of the standardized wealth variable ($x = +0.796$ s.d. for experiment 1 and $x = +1.221$ s.d. for experiment 2). This means that, even if a subject's wealth is above the mean, he or she is emotionally better off in the invisible wealth condition than in the visible wealth condition.

The third main finding is counterintuitive since the invisible wealth condition in our experimental setting can simultaneously achieve a higher average in-game wealth (Fig. 3a,f) and a better SWB among a majority of the subjects (Fig. 3e,j). The invisible wealth condition may be favoured when we assume no cost for making others' wealth invisible or visible (for more discussion, see Box 1). In reality, however, socioeconomic status in modern societies is often visible; people maintain a desire to compare their status with others[15]; and some people engage in conspicuous consumption to demonstrate their high economic status[61]. Therefore, future research is warranted to explore why people in modern human societies prefer the visibility of wealth, even if most of them sacrifice their financial and emotional well-being.

Summary and further discussion

In sum, we find that making the current wealth of connected neighbours in people's social groups invisible can improve SWB for most of the subjects except those in the very rich category and attenuate the impact of an economic gradient upon SWB, compared with identical circumstances where neighbours' wealth is visible. That is, we could successfully reduce the rich–poor gap in happiness in our experimental setting by making neighbours' wealth invisible. The effect size of making the current wealth of connected neighbours invisible for subjects in the poorest category (0.5–6 in the −2-to-2 SWB range) is comparable with that of moving them to the richest category (0.8 in the −2-to-2 SWB range). To be clear, we are not advocating for simply hiding economic inequality instead of redressing the inequality. Rather, we are noting the additional impact of wealth visibility and relative wealth on SWB, and on the gradient in well-being, here demonstrated experimentally.

Since the effect of wealth invisibility on the wealth–well-being relationship is observed continuously both before the actual game rounds begin (Fig. 2) and during the game rounds (Fig. 4 and Supplementary Information Fig. 1), it would seem unlikely that the origin or source of wealth plays a dominant role in making wealth invisibility effective. In our experimental setting, subjects were randomly assigned to be initially rich or poor, and thus their initial wealth was based on luck. On the other hand, they made their own decisions based on their strategy, which shaped their in-game wealth, and thus the current wealth over the rounds was more performance based. Such a difference in the origin of in-game unit gains would make a difference in the level of income deservingness[62] over the course of game rounds, but both luck-based and performance-based wealth seem to translate into SWB in our experimental settings. In fact, people can feel better both when they win a lottery and when they earn money after some persistent effort.

The positive consequence of wealth invisibility, also known as the negative consequence of wealth visibility, offers a sharp contrast with positive roles of visibility on enhancing behavioural cascades over people's social networks[63]. For example, making others' reputation (the record of subjects' cooperative behaviour in the past) visible can nurture cooperative social networks, and groups of people can be better off[64–67]; and voting behaviour of others can enhance connected neighbours' (for example, Facebook friends') voting behaviour[68]. The contrast may come from a difference of characteristics between visibility of behaviours, which are mostly easy to learn socially and copy, and visibility of status-related attributes, which are costly and thus difficult to follow even if people witness them and recognize them as attractive[61]. In our experimental setting, others' richer status during the game rounds may indicate that their strategy (a basic principle to decide a choice each round) may be better but the strategy itself is not shown and difficult to infer. Therefore, making something visible may not always be good even if visibility may be implemented for promoting transparency, public accountability or other reasons.

Before considering making others' wealth invisible as much as possible as a potential public policy, we need to discuss the dilemma that we discovered, which is about whether or not making others' wealth invisible is a healthy, sustainable option for producing additional happiness. Indeed, there is a positive aspect: making other people's wealth invisible can address economic inequality in happiness by making poor people happier without eliminating inequality in wealth. It can contribute to the pursuit of 'the greatest happiness for the greatest number'[69]. Meanwhile, only a small number of subjects in the very rich category (small enough not to win a majority vote) lose a limited amount of happiness by making others' wealth invisible. Therefore, at first glance, making others' wealth invisible seem like an attractive option.

But there is also a negative aspect. When we take a closer look at the origins of the excess happiness created by making others' wealth invisible, we can identify two sources (Fig. 2). First, initially poor subjects who stay in the poor range throughout the course of the experiment can only gain SWB when social comparison is not possible. They are not informed that their pace of wealth accumulation is insufficient to catch up with others, or even that they are still in a lower range of the economic ladder. Second, initially rich individuals who fall into the poor range can maintain their high SWB only in the invisible wealth condition. They are not informed that their endowment was high but that they could not maintain this status due to their poor performance. For both groups, hiding such a reality during the game is related to their excess happiness. Conversely, the contribution of wealth invisibility to SWB is small for the other two groups: those who start out poor and move up, and those who start out rich and stay rich. Therefore, although making wealth invisible may address inequality in SWB, it requires careful debate. Hiding an inconvenient truth may not be ethically acceptable.

Methods

Ethical regulations

Our experiments (experiments 1 and 2) were conducted with the approval of the UCLA Office of Research Administration (UCLA IRB#16-001920). Informed consent was obtained online from all participants.

Experiment set-up (experiment 1)

We used an online experiment platform (available at breadboard.yale.edu) and implemented a series of social network experiments. The basic set-up was almost identical to a prior experiment[20], but we modified this set-up in an important way: we added the additional step of measuring SWB at each round (Extended Data Fig. 1). In the experiment, we recruited 581 subjects from Amazon Mechanical Turk (Mturk)[70–72] between July and October 2017 and divided them among 50 sessions (social networks); 570 subjects remained for the first round of the experiment (11 drop-outs). The data of those who dropped out after the first round (n = 44) were included for the further analysis (they received a full payment, as their in-game dropouts could have been caused by an internet problem) (Extended Data Fig. 2). Since we recorded Mturk IDs of those who participated in our experiment, there were no duplicates.

Each session typically lasted 1 h. After the tutorial, which included two practice rounds (Supplementary Information Additional Analysis 5), each subject was randomly assigned to and within groups with an average size of 11.4 individuals embedded in a network with an Erdos–Renyi random graph configuration in which 30% of ties were initially present[20,73–75]. Subjects were initially connected to an average of 4.5 neighbours (s.e.m. 0.14). To artificially generate a rich–poor gap, we randomly assigned subjects to either an initial endowment of 1,150 in-game units (the in-game wealth of the initially rich subjects) or that of 200 in-game units (that of the initially poor subjects)[20]. Initially rich subjects were not necessarily rich in their real life. The ratio of the rich to the poor was 3:7, so that the expected value of the Gini coefficient[58] before a game started (at round 0) was 0.4 (ref. 59).

Subjects played a cooperation game lasting 15 rounds with their neighbours, whereupon the game ended suddenly (to avoid the end-game effect)[74]. Empirically, the level of cooperation over experimental social networks reaches a plateau at around the tenth round or so[20,74,76]. In each round, all the subjects decided to choose whether to cooperate (that is, reducing their own wealth by 50 units per connecting neighbour to increase the wealth of all the connected neighbours by 100 units per connecting neighbour) or to defect (that is, paying zero units and providing connected neighbours with zero units). Subjects were required to make the same choice with all their connected neighbours, which was similar to a conventional public goods game[74,75,77]. For example, a subject might want to cooperate with connected neighbours when they were mostly cooperative in a prior round (this information was made available to the subject), while he or she might not want to do so when they were not. The arbitrary units here were converted to real money at the end of the session (1 USD = 2,000 units). These financial interactions with connected neighbours through a cooperation game allowed us to observe the dynamics of individuals' cooperation behaviour, wealth and SWB. In addition, 3.00 USD was paid as a participation fee.

Subjects were informed of their connected neighbours' choices and their updated wealth (units) after they made their cooperation choice[65,66,78,79]. Then, they had an opportunity to modify their social relationships by making a new social tie or by breaking an existing social tie (a realistic feature of social interactions that we have evaluated in other experiments[74]). In more concrete terms, 30% of all the pairs (existing or non-existing ties) of subjects in a session were chosen at random at each round and allowed to modify (either construct or dissolve) their social relationships. This set-up allowed study participants to modify their social networks as they wished over the 15 rounds. For example, a subject might want to make a social tie with a previously cooperative subject elsewhere and break a social tie with a previously non-cooperative subject to whom they are currently connected. This set-up was constant across all the manipulation conditions in our experiments.

To track their emotional state over the 15 rounds, the subjects were asked to rate their feeling by a single-item five-scale measure: 'how do you feel right now: very bad, bad, neutral, good, and very good?'[80] and report it to us every round (this was our measure of SWB). In the main analysis below, we converted it into a continuous variable ranging from −2 to 2 (0 for neutral). The wording of the question is based on past literature on the day-reconstruction method[80], the General Social Survey[48] and the Hardy–Rejeski Feeling Scale[81]. The validity of a single-item measure of emotional well-being has been examined and confirmed by objective measures, including state-by-state quality-of-life ranking in the United States[82].

Session-level random assignment

We manipulated the visibility of local connected neighbours' wealth[20] and randomly assigned it to each of the sessions. In the sessions (networked groups) with the invisible wealth condition, subjects only knew their own accumulated wealth (25 sessions in which wealth was invisible for all subjects in the sessions). On the other hand, in those with the visible wealth condition, the accumulated wealth of directly connected neighbours was made available to subjects in addition to their own wealth (25 sessions). In both the invisible and visible wealth conditions, subjects did not have global knowledge beyond their immediate neighbours. The subjects were not informed that there was a network-level random assignment (that is, the visibility of others' wealth).

Statistical analysis

We used the R lme4 package[83] and constructed regression models that took into account the hierarchical structures of the data (observations clustered by individuals and sessions). We used the R lmerTest package[84] and calculated P values with the Satterthwaite approximation.

Replication data (experiment 2)

We also wanted to explore whether our results held in a more complex cooperation game (that allowed for 'punishment')[44]. We used the data from a second series of experiments to see if we could reproduce the main result with a different experimental set-up ($N = 745$ in 50 sessions, recruited from Mturk between March and December 2018) (G. Dewey et al., manuscript in preparation). The modification to our basic game is an addition of a third option in our cooperation game: the ability to harm neighbours (that is, reducing a subject's own wealth by 50 units per connecting neighbour to decrease the wealth of all connected neighbours by 100 units) in addition to the first option (cooperation) and second option (defection). Exploring the role of harming (punishment) in the evolution of cooperation[85,86] was the original purpose of this series of experiments (to be clear, the economic gradient of SWB was not examined there) (G. Dewey et al., manuscript in preparation). Briefly, the rate of execution of the harming option is as low as 5.7%. The low punishment rate may be explained by the high cost–harm ratio (that is, 50–100) in our experimental setting[87]. A total of 719 subjects remained for the first round of the experiment (26 drop-outs), who were used in the statistical analysis for replication. Again, the data from those who dropped out after the first round ($n = 101$) were used for the further analysis and they received a full payment (Extended Data Fig. 2).

Limitations

Our choice of subjects and methods had several limitations. First, we used the Mturk platform[70–72] to recruit our subjects. In fact, as shown in the Extended Data Table 1, the majority of people are 20–40 years old, male, and from the United States. Therefore, the external validity (generalizability) of our results is a concern. The other concern is a possible learning effect in the Mturk subject pool. Although we 'blacklisted' those who participated in our games in the past, some of them might join other experimental economics/psychology studies run by others, and might learn a good money-making strategy in the repeated public goods games there. Although some might argue that studies using Mturk are better than those recruiting subjects from the authors' college students (for example, refs. 85,88), Mturk is not perfect, and our experimental results must be carefully interpreted.

Second, our SWB measure was a −2-to-2 self-reported Likert scale (very bad to very good). This may explain why we detected an almost linear relationship between in-game wealth and SWB, but not a concave (or curvilinear) relationship (Supplementary Information Additional Analysis 2). The concave relationship has been reported elsewhere, for example, by Jebb et al.[2], which used the Gallup World Poll data and measured well-being (Cantril's Self-Anchoring Striving Scale[89]) on a 0-to-10 Likert scale. The resolution of the −2-to-2 scale that we used may not be sufficient to detect a concave relationship. For example, the −2-to-2 scale made it impossible for people to describe a feeling between good (1) and very good (2); and once subjects rated 'very good' (2), they had no room to rate higher in later rounds (ceiling effect). We were thus not able to examine the role of wealth invisibility in the context of a potential diminishing marginal SWB.

Third, the SWB that we measured over the game rounds was short-lived and the wealth that we have measured was not actual wealth that each study participant maintained in the real world (though we paid our subjects modest real money based on their game play). Therefore, the generalizability of our experimental results is unclear. However, in both the real world and our experimental settings, a brief experience of economic inequality can accumulate over time as a stressor and such stress accumulation begins even at birth (or even before birth) and is embodied over time[1,3,13,90–96]. Nevertheless, the effect size of wealth invisibility in the real world is difficult to predict. Because the gap in absolute wealth observed in the real world is much larger than the gap we created and observed in our experimental setting (the gap that we created was at most one USD), the effect of making others' wealth invisible in the real world may also be larger than the one observed here. On the other hand, since people's well-being production function in the real world may be multifactorial (compared with our simplified setting), the effect of wealth invisibility may be smaller in the real world. Moreover, in many cases it may not be logistically possible to make the economic status of others completely invisible in non-experimental settings, which may be another reason for expecting a smaller effect.

Fourth, and finally, our treatment of making others' wealth invisible does not necessarily mean that we can remove all information that might lead subjects to infer the wealth of connected neighbours. Although the direct information about neighbours' in-game units can be made unavailable, the information that an individual continues to cooperate while his or her neighbours become uncooperative in later rounds may lead neighbours to predict that the subject is worse off. On the other hand, information that a subject has a large number of social ties may imply that the subject is building reciprocal cooperation in the subject's network and thus should gain wealth. Nevertheless, in our experimental setting, hiding the exact number of neighbours' in-game units (that is, the invisible wealth condition) may accomplish several things simultaneously. First, it may suppress subjects' innate desire to engage in social comparisons about in-game units. Second, it protects the right not to see one's neighbours' wealth levels (while depriving subjects of the right to status display). Both may contribute to SWB, but in different ways.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

The data for replicating the main results are available on A.N.'s GitHub page (https://github.com/akihironishi).

Code availability

The details of the analysis along with the R code are provided in our Supplementary Information Extended Data Methods and Results.

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Author contributions

A.N. designed the project. A.N. and N.A.C. secured funding. A.N. and C.A.G. conducted the experiment. A.N., S.K.I. and C.A.G. conducted the statistical analyses. A.N., C.A.G., S.K.I. and N.A.C. analysed the findings and wrote the manuscript.

Competing interests

A.N. is a consultant to Vacan, Inc. and obtained an honorarium from Taisho Pharmaceutical Co., Ltd., which had no role in the project. C.A.G. is an employee of 23andMe, which had no role in the project. The other authors declare no competing interests.

Additional information

Extended data is available for this paper at https://doi.org/10.1038/s44220-023-00159-0.

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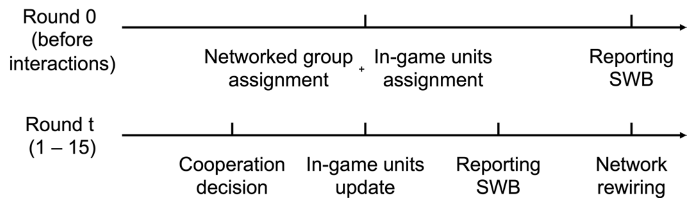

Extended Data Fig. 1 | The flow of our social network experiments. A session consisting of a networked group lasted 15 rounds. The timing of reporting subjective well-being (SWB) was different before the actual game rounds started.

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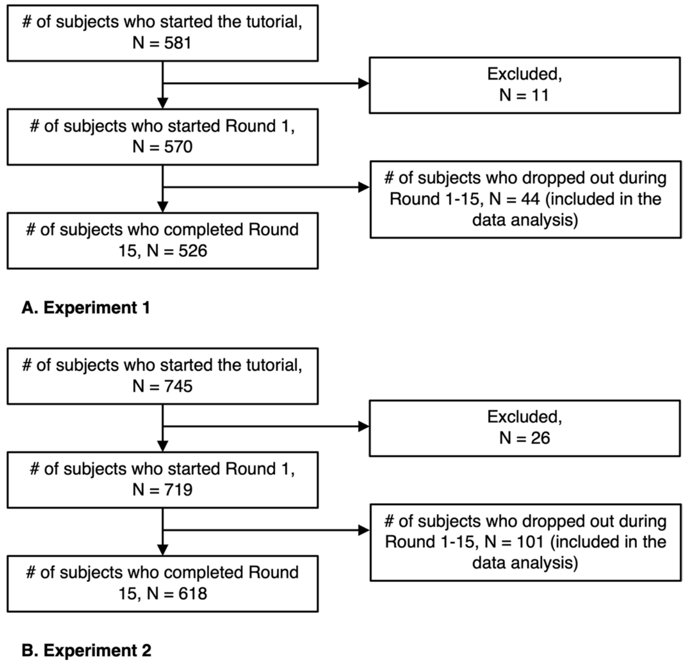
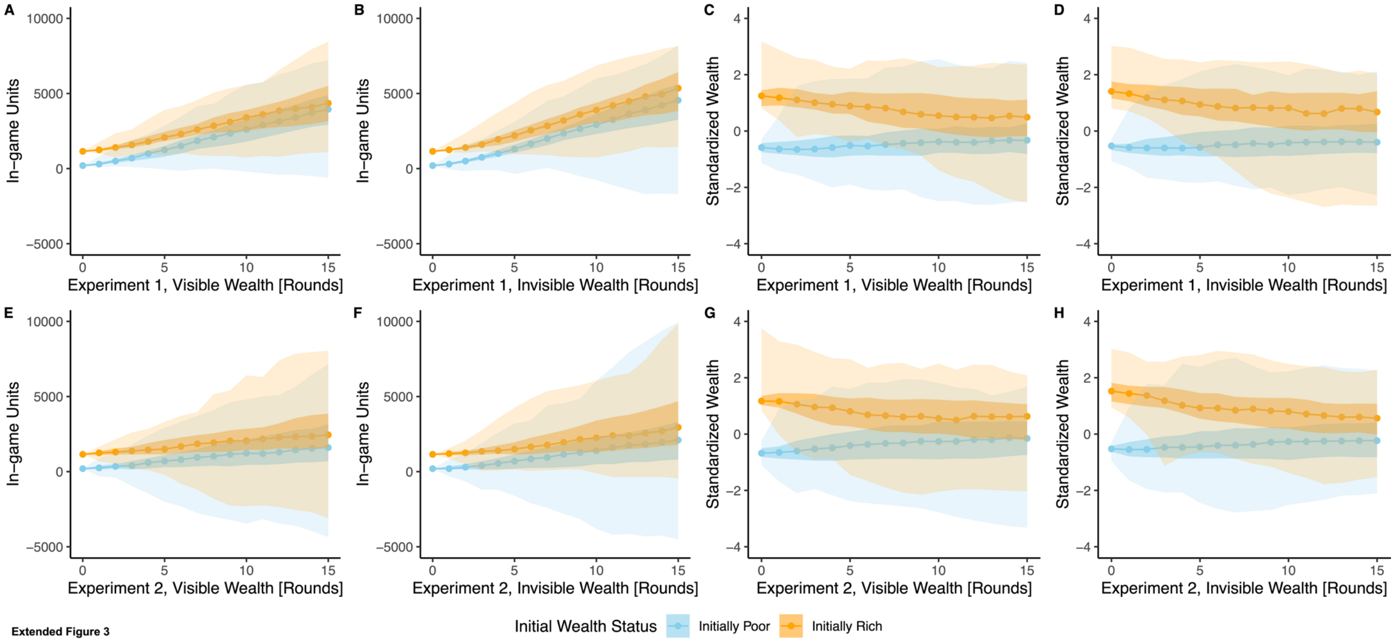


Extended Data Fig. 2 | CONSORT participant flow diagram. A, Experiment 1. B, Experiment 2.

https://doi.org/10.1038/s44220-023-00159-0



Extended Data Fig. 3 | Trajectories of standardized and actual in-game units for the initially poor and rich subjects. a–d. Experiment 1 (n = 570). **e–h**. Experiment 2 (n = 719). Lines with dots represent medians, light shading represents range between minimum and maximum, dark shading represents interquartile range (IQR).

https://doi.org/10.1038/s44220-023-00159-0

Extended Data Table 1 | Socio-demographic factors of the Amazon Mechanical Turk (Mturk) study participants

Experiment 1	Invisible wealth condition		Visible wealth condition		p value
n	286		284		
age, mean, SD	32.73	8.46	34.27	9.87	0.057
Sex (male), n, %	160	62.5	161	60.1	0.631
Country, n, %					0.075
US	204	71.3	225	79.2	
India	65	22.7	44	15.5	
Other	17	5.9	15	5.3	
# Cooperations in the tutorial, mean, SD	1.61	0.63	1.56	0.63	0.327
Initial network size, mean, SD	12.07	1.93	11.88	2.07	0.268
Initial degree, mean, SD	3.47	1.63	3.43	1.59	0.783
Final in-game units, mean, SD	4612.8	1676.3	3934.0	1564.0	<0.001
Final subjective well-being, mean, SD	1.0311	0.9995	0.7918	1.0865	0.009

Experiment 2	Invisible wealth condition		Visible wealth condition		p value
n	351		368		
age, mean, SD	33.31	15.69	32.41	9.93	0.401
Sex (male), n, %	196	65.8	196	65.3	0.979
Country, n, %					0.86
US	201	57.3	204	55.4	
India	125	35.6	135	36.7	
Other	25	7.1	29	7.9	
# Cooperations in the tutorial, mean, SD	1.15	0.81	1.11	0.79	0.509
Initial network size, mean, SD	15.67	4.36	16.42	4.37	0.022
Initial degree, mean, SD	4.29	2.19	4.71	2.25	0.014
Final in-game units, mean, SD	2351.2	2176.3	2094.8	2043.6	0.1321
Final subjective well-being, mean, SD	1.0565	1.0199	0.7382	1.2029	<0.001

Visible wealth condition in Experiment 1	Initially poor (200 in-game units)		Initially rich (1150 in-game units)		p value
n	192		92		
age, mean, SD	34.33	9.77	34.14	10.14	0.882
Sex (male), n, %	106	58.2	55	64	0.449
Country, n, %					0.732
US	150	78.1	75	81.5	
India	32	16.7	12	13	
Other	10	5.2	5	5.4	
# Cooperations in the tutorial, mean, SD	1.52	0.66	1.65	0.58	0.09
Initial network size, mean, SD	11.77	2.08	12.12	2.05	0.185
Initial degree, mean, SD	3.37	1.59	3.58	1.59	0.298
Final in-game units, mean, SD	3762.3	1525.0	4299.4	1592.0	0.009
Final subjective well-being, mean, SD	0.8251	1.0546	0.7209	1.1545	0.4791

Visible wealth condition in Experiment 2	Initially poor (200 in-game units)		Initially rich (1150 in-game units)		p value
n	243		125		
age, mean, SD	32.45	9.59	32.32	10.65	0.919
Sex (male), n, %	128	63.7	68	68.7	0.467
Country, n, %					0.135
US	133	54.7	71	56.8	
India	86	35.4	49	39.2	
Other	24	9.9	5	4	
# Cooperations in the tutorial, mean, SD	1.13	0.81	1.07	0.77	0.526
Initial network size, mean, SD	16.3	4.29	16.64	4.52	0.486
Initial degree, mean, SD	4.73	2.18	4.65	2.38	0.738
Final in-game units, mean, SD	1803.1	1989.5	2659.3	2037.5	<0.001
Final subjective well-being, mean, SD	0.7416	1.1809	0.7315	1.2501	0.9444

Invisible wealth condition in Experiment 1	Initially poor (200 in-game units)		Initially rich (1150 in-game units)		p value
n	204		82		
age, mean, SD	32.81	8.84	32.55	7.5	0.829
Sex (male), n, %	106	58.6	54	72	0.06
Country, n, %					0.751
US	148	72.5	56	68.3	
India	44	21.6	21	25.6	
Other	12	5.9	5	6.1	
# Cooperations in the tutorial, mean, SD	1.6	0.65	1.65	0.6	0.56
Initial network size, mean, SD	12.13	1.87	11.93	2.08	0.428
Initial degree, mean, SD	3.5	1.63	3.41	1.63	0.671
Final in-game units, mean, SD	4366.5	1637.0	5210.7	1629.4	<0.001
Final subjective well-being, mean, SD	1.022	1.0189	1.0533	0.9571	0.8151

Invisible wealth condition in Experiment 2	Initially poor (200 in-game units)		Initially rich (1150 in-game units)		p value
n	258		93		
age, mean, SD	33.43	17.36	32.97	9.71	0.826
Sex (male), n, %	144	65.8	52	65.8	1
Country, n, %					0.807
US	149	57.8	52	55.9	
India	92	35.7	33	35.5	
Other	17	6.6	8	8.6	
# Cooperations in the tutorial, mean, SD	1.18	0.81	1.06	0.8	0.245
Initial network size, mean, SD	15.67	4.23	15.69	4.72	0.968
Initial degree, mean, SD	4.31	2.22	4.24	2.13	0.785
Final in-game units, mean, SD	2051.8	2136.1	3178.1	2082.1	<0.001
Final subjective well-being, mean, SD	1.0452	1.0259	1.0875	1.0087	0.7498

The p values were calculated based on chi-square test (for categorical variables) or t test (for continuous and discrete variables). Extended Table 1. Social-demographic factors and end-point values of the Amazon Mechanical Turk (Mturk) study participants.

Extended Data Table 2 | Regression results with various models using the data of Experiment 1 (n=570) and Experiment 2 (n=719)

	Experiment 1 (without a harming option)					Experiment 2 (with a harming option)				
	Model 1$	Model 2$	Model 3$	Model 4$	Model 5$	Model 6$	Model 7$	Model 8$	Model 9$	Model 10
	Standardized wealth	Yitzhaki index	Relative rank	Relative rank + last place	Standardized wealth + square term	Standardized wealth	Yitzhaki index	Relative rank	Relative rank + last place	Standardized wealth + square term
(Intercept)	-0.19	-0.18	-0.14	-0.13	-0.17	0.22	0.24	0.14	0.18	0.21
	[0.20]	[0.21]	[0.21]	[0.21]	[0.20]	[0.14]	[0.14]	[0.15]	[0.15]	[0.14]
Wealth visibility	-0.14 *	-0.01	-0.36 ***	-0.35 ***	-0.16 *	-0.16 *	-0.01	-0.37 ***	-0.38 ***	-0.12
	[0.07]	[0.08]	[0.08]	[0.08]	[0.07]	[0.07]	[0.08]	[0.08]	[0.08]	[0.07]
Standardized wealth	-0.02				-0.02	0.05 *				0.05
	[0.03]				[0.03]	[0.03]				[0.03]
Absolute wealth (per 10,000)	-0.35 *	-0.30	-0.30	-0.30	-0.35 *	-0.39 **	-0.33 *	-0.35 *	-0.36 **	-0.39 **
	[0.16]	[0.16]	[0.16]	[0.16]	[0.16]	[0.14]	[0.14]	[0.14]	[0.14]	[0.14]
In-game units gain (per 10,000)	14.96 ***	14.93 ***	15.07 ***	15.11 ***	14.95 ***	6.37 ***	6.51 ***	6.54 ***	6.45 ***	6.44 ***
	[1.38]	[1.38]	[1.38]	[1.38]	[1.38]	[1.04]	[1.04]	[1.04]	[1.04]	[1.04]
Initial wealth (ref: 200)	0.05	0.07	0.06	0.07	0.06	-0.01	0.04	0.00	0.01	0.00
	[0.06]	[0.06]	[0.06]	[0.06]	[0.06]	[0.06]	[0.06]	[0.06]	[0.06]	[0.06]
Initial degree	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]
Initial network size	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Age	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Sex (ref: female)	-0.07	-0.07	-0.07	-0.07	-0.07	-0.16 **	-0.16 **	-0.15 *	-0.16 **	-0.15 **
	[0.05]	[0.05]	[0.05]	[0.05]	[0.05]	[0.06]	[0.06]	[0.06]	[0.06]	[0.06]
Country, India (ref: US)	0.36 ***	0.36 ***	0.36 ***	0.36 ***	0.36 ***	0.51 ***	0.51 ***	0.51 ***	0.51 ***	0.51 ***
	[0.07]	[0.07]	[0.07]	[0.07]	[0.07]	[0.06]	[0.06]	[0.06]	[0.06]	[0.06]
Country, Other (ref:US)	0.17	0.17	0.18	0.18	0.17	-0.01	-0.01	-0.01	0.00	-0.01
	[0.11]	[0.11]	[0.11]	[0.11]	[0.11]	[0.11]	[0.11]	[0.11]	[0.11]	[0.11]
Cooperation at practice rounds	-0.15 ***	-0.16 ***	-0.16 ***	-0.16 ***	-0.15 ***	-0.10 **	-0.11 **	-0.11 **	-0.11 **	-0.11 **
	[0.04]	[0.04]	[0.04]	[0.04]	[0.04]	[0.04]	[0.04]	[0.04]	[0.04]	[0.04]
Cooperation at the round	0.40 ***	0.40 ***	0.40 ***	0.41 ***	0.40 ***	-0.01	-0.01	0.00	0.00	-0.01
	[0.04]	[0.04]	[0.04]	[0.04]	[0.04]	[0.03]	[0.03]	[0.03]	[0.03]	[0.03]
Cooperation rate of connecting neighbors at the round	1.45 ***	1.45 ***	1.44 ***	1.43 ***	1.45 ***	1.07 ***	1.07 ***	1.06 ***	1.06 ***	1.07 ***
	[0.07]	[0.07]	[0.07]	[0.07]	[0.07]	[0.05]	[0.05]	[0.05]	[0.05]	[0.05]
Degree	-0.05 ***	-0.05 ***	-0.05 ***	-0.05 ***	-0.05 ***	0.02 ***	0.02 ***	0.02 ***	0.02 ***	0.02 ***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Wealth visibility x Standardized wealth	**0.18 *****				**0.17 *****	**0.13 *****				**0.14 *****
	[0.03]				[0.03]	[0.04]				[0.04]
Wealth visibility x Absolute wealth	-0.01	0.05	0.05	0.05	-0.01	-0.04	-0.09	-0.01	-0.02	-0.07
	[0.13]	[0.12]	[0.12]	[0.12]	[0.13]	[0.18]	[0.18]	[0.18]	[0.18]	[0.19]
Wealth visibility x in-game units gain	-0.16	0.14	-0.06	-0.07	-0.12	-0.53	-0.51	-0.59	-0.53	-0.58
	[1.08]	[1.08]	[1.09]	[1.09]	[1.08]	[1.00]	[1.00]	[1.00]	[1.00]	[1.00]
Yitzhaki index (scaled to 0-1)		0.03					-0.05			
		[0.05]					[0.05]			
Wealth visibility x Yitzhaki index		**-0.29 *****					**-0.29 *****			
		[0.07]					[0.07]			
Relative rank (scaled to 0-1)			-0.03	-0.04				0.15 *	0.11	
			[0.08]	[0.08]				[0.08]	[0.08]	
Wealth visibility x Relative rank			**0.40 *****	**0.38 *****				**0.42 *****	**0.42 *****	
			[0.10]	[0.10]				[0.11]	[0.11]	
Last-place indicator				-0.03					-0.11	
				[0.07]					[0.06]	
Wealth visibility x Last-place indicator				**-0.04**					**-0.01**	
				[0.09]					[0.09]	
Standardized wealth squared					-0.02					0.02
					[0.02]					[0.01]
Wealth visibility x Standardized wealth squared					**0.01**					**-0.04**
					[0.02]					[0.02]
Harming at the round						-0.19 ***	-0.19 ***	-0.18 ***	-0.18 ***	-0.18 ***
						[0.05]	[0.05]	[0.05]	[0.05]	[0.05]
Harming rate of connecting neighbors at the round						-0.53 ***	-0.53 ***	-0.52 ***	-0.52 ***	-0.53 ***
						[0.08]	[0.08]	[0.08]	[0.08]	[0.08]
N	7566	7566	7566	7566	7566	8646	8646	8646	8646	8646
N (individual)	506	506	506	506	506	588	588	588	588	588
N (game)	50	50	50	50	50	49$	49$	49$	49$	49$
Conditional log-likelihood	-7375.06	-7382.01	-7382.71	-7382.09	-7375.44	-8700.27	-8699.08	-8696.51	-8691.54	-8698.22
Degrees of freedom	482.87	482.94	482.83	484.65	484.77	572.2	572.54	572.4	574.47	574.04
Conditional Akaike information criterion (AIC)	15717.46	15729.91	15731.09	15733.48	15720.41	18544.94	18543.24	18537.82	18532.02	18544.52

*** p < 0.001; ** p < 0.01; * p < 0.05.

Since one of the sessions in the second series of the exepriment missed some socio-demographic variables, the session was excluded from the regression analysis (N of the games is 50 - 1 = 49).

$ Regression models (Models 1-10) also had 14 indicator variables representing the geenral difference between each round and round 1, which were omitted from the result table.

*** p<0.001; ** p<0.01; * p<0.05. # Since one of the sessions in the second series of the exepriment missed some socio-demographic variables, the session was excluded from the regression analysis (N of the games is 50 - 1=49). $ Regression models (Models 1–10) also had 14 indicator variables representing the geenral difference between each round and round 1, which were omitted from the result table.

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Last updated by author(s): 9/27/2023

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☐	☒	For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☐	☒	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	We used the breadboard.yale.edu (publicly available) platform to collect experiment data.
Data analysis	We used R 4.2.3. (pubicly available), dplyr package (ver. 1.1.1), lme4 package (ver. 1.1.32), lmerTest package (ver. 3.1.3), and cAIC4 package (ver. 1.0) for data analysis. The details of the analysis along with the R code are provided in our SI Appendix, Extended Methods.

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The data for replicating the main results are published and available on AN’s Github page (https://github.com/akihironishi) upon publication.

Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

Reporting on sex and gender	Among the 570 recruited subjects in Experiment 1, 321 were male (56.3%) and among the 719 recruited subjects in Experiment 2, 392 were male (54.5%).
Population characteristics	The median age was 31 years in Experiment 1 and 29 years in Experiment 2.
Recruitment	We used Amazon Mechanical Turk for the recruitment platform. Self-selection bias may be minimized since the study participants or those who considered to participate in our research project were not aware of the purpose of the project.
Ethics oversight	UCLA IRB#16-001920

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

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Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Quantitative data analysis of online network-based behavioral experiments
Research sample	Amazon mechanical turk workers (see Extended Table 1 for the demographic information)
Sampling strategy	Convenience sampling
Data collection	We posted job posts at the Amazon mechanical turk website to recruit study participants. The experiment platform, breadboard.yale.edu was used for data collection. No one was present besides the participants and us (researcher team). None of the participants or us were blinded to experimental condition.
Timing	We implemented Experiment 1 between 7/19/2017 and 10/20/2017 and Experiment 2 between 3/19/2018 and 12/27/2018 (there is a gap between the Experiment 1 and Experiment 2 periods).
Data exclusions	No data were excluded.
Non-participation	11 participants (out of 581) dropped out before the first round of the game in the first series of the experiment; 26 participants (out of 745) dropped out before the first round of the game in the second series of the experiment. Most of the drop-outs might happen due to an internet connectivity issue.
Randomization	For both the first and second series of the experiments, there were two treatment arms (visible wealth and invisible wealth), and each of the sessions (a group of people in one social network or session) was assigned to either the visible or invisible wealth arm.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
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