**Status Invisibility Improves Emotional Well-being and Alleviates its Economic Gradient in Social Network Experiments**

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**Economic status (such as wealth and income) is positively associated with subjective well-being (SWB), happiness, and mental health, but debate persists about the determinants of SWB in circumstances involving limited resources and economic inequality. We implemented two series of online experiments involving a public goods game where subjects cooperate or defect financially, gain or lose wealth, and report their level of SWB across time. In one series of experiments, a total of 568 subjects were assigned to 50 networked groups with a high level of initial in-game economic inequality (Gini coefficient = 0.4) and we manipulated wealth visibility in the groups. In the visible wealth condition, we showed subjects the wealth of their immediate neighbors, thereby allowing social comparisons, while in the invisible wealth condition, we kept such information hidden. Results show that the invisible wealth condition achieved higher overall SWB. Furthermore, this condition disproportionally improves the SWB among poorer subjects and thus alleviated the economic gradient in happiness. These benefits can be explained by the increased magnitude of cooperativeness seen in the group. In the second series of experiments with modified cooperation conditions that allow subjects to punish each other (N = 719 in another 50 groups), we find similar results. We conclude that the visibility of wealth in conditions of wealth inequality is an important driver not only of SWB itself, but also of the economic gradient in SWB.**

Income and wealth 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], richer individuals are happier on average. *But what forces help alleviate the economic gradient in happiness? In what social setting might poorer individuals be as happy as richer individuals?* Adjusting the unequal income distribution itself within a group (e.g., by redistributing wealth) can of course have beneficial effects on the overall SWB of the group; however, the impact of such an adjustment on SWB is rarely examined (in part because the effect of resource redistribution may take a long time to appear) [10]. Distinctly, positive psychology interventions can make people happier; however, such interventions typically focus on alleviating depressive symptoms rather than increasing happiness [11].

Evidence from past observational studies suggests that a large portion of the wealth-well-being linkage comes from the existence of relative wealth (i.e., having higher/lower wealth than others in one’s social network) and not just absolute wealth (e.g., purchasing power) [12-14]. The impact of relative wealth comes from social comparison behavior, which is a process of comparing one’s social characteristics and outcomes to other people [15, 16]. The role of self-comparison to one’s peer group across a host of axes is of a longstanding interest in the social sciences [17-19]. 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; others earn $25,000) over B (your current yearly income is $100,000; others earn $200,000) [20]. The negative impact of social comparison on job satisfaction [21], income satisfaction [22], cooperativeness in social networks [23, 24], and economic inequality [23] has been reported. A series of neuroimaging studies also show that the brain regions related to a rewarding process (ventral striatum) are activated when there is a relatively lower monetary reward rather than an equal reward [25]. Social comparison is also observed among other animals (e.g. baboons) [26].

Regarding emotional well-being, observational studies have shown that, in regression models, individuals compare their income to others’ income, and, if others are richer, they feel less happy even given the same purchasing power [27-29]. Such effects are confirmed in country-level analyses, for instance in British, German, and Australian data separately [30]. It is known that social comparison alters one’s emotions because it induces a feeling of being left behind and of relative deprivation [31-33]. For example, evidence shows that relative income is at least twice as important for individual emotional well-being as absolute income [34, 35]. Feelings of relative deprivation and diminished emotional well-being from social comparison under an economically unequal condition have other negative consequences including poor health [36-43] and poor economic status and decision-making [44, 45].

Therefore, if there were a method to literally switch off social comparison between individuals in a group, we might successfully reduce the negative effect of “relative” income on emotional well-being, which has a larger impact on poorer individuals. In this sense, status *invisibility*, which is defined as the state where a focal individual can know his or her own status (such as income, wealth, or other attributes) but cannot know that of connecting neighbors’[46], could be an important factor in policies promoting emotional well-being. There are some real-world examples of both status invisibility (e.g., pay secrecy policy in firms [47, 48], and student uniform policy in schools [49, 50]) and status visibility (e.g., Forbes World’s Billionaires List [51] and the University of California’s policy on public disclosure of employee pay [21, 52]). The use of social media such as *Instagram*, *Facebook* is also an example of visibility of others’ status, and it can lead adolescents and others to compare themselves with rich individuals with a higher status since their position and belongings are visible and thus to experience poorer mental health [53, 54].

Prior evidence from experimental social networks shows that making others’ wealth *invisible* promotes the construction of cooperative social interactions [55-57], and reduces the overall level of wealth inequality [46, 58, 59]. Making others’ wealth invisible can suppress all forms of social comparison in wealth (e.g., feelings of being exploited by richer individuals, last-place aversion, effort-reward imbalance); however, these studies [46, 55-58] have not investigated whether or not making others’ wealth invisible has a *positive impact on emotional well-being or the disparities therein*. The magnitude and the mechanisms with respect to the potential effect of status invisibility on emotional well-being have not been formally explored in an experimental manner.

Therefore, our experiments focus on a possible macrosocial determinant of mental health – namely, the *visibility* of others’ status (such as attributes, assets, income, and wealth). This factor may be increasingly important nowadays, but it has been relatively neglected in the literature on social determinants of mental health [60-62]. In more concrete terms, we shed light on this topic by using short-lived, online, dynamic social network experiments that 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 = 568 in 50 groups of people with 15 rounds of interaction 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) [63] to reproduce the results.

In our experiments, the subjects were given different amounts of wealth (which produced endowment heterogeneity [64-69] but was independent from their actual social standing in the real world); the Gini coefficient [70] before a game started was expected to be 0.4 (which is roughly equivalent to the 2019 Gini coefficient of the US [0.415] [71]); they interacted with one another financially through a cooperation game with two behavioral options (cooperate or defect) in the first series of experiments and with three options (cooperate, defect, or harm) in the second series of experiments; they updated their local social network ties based on their and their neighbors’ performance and position; and they reported their SWB every round of the game (see Materials and Methods). The wealth of the connecting neighbors was shown in the “visible wealth” condition while it was not shown in the “invisible wealth” condition; this was our primary experimental manipulation in order to explore the impact of 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. In-game wealth units were converted into USD as a participant’s reward and paid out at the end of the experiment (an average reward of USD 4.27 [SD: 1.65] in addition to a guaranteed participation fee of USD 3.00).

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| **Figure 1. The experimental social networks in our set-up (the first series of experiments). 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. **Right.** Sample social networks at the end of the experiment from six different sessions (chosen from the 50 sessions in the first series of the experiments). Circle size represents relative wealth; the color represents subjective well-being (light pink: bad, grey: neutral, light blue: good, and blue: very good). Lines represent a social tie between two subjects. In Sample 3, the subject on top right (colored blue) has no social ties at the end of the experiment. | |

**Results**

***Results of the first series of experiments.*** The visibility of wealth had several effects on game dynamics in the first series of the experiments. We begin by re-documenting the economic gradient in SWB that is usually observed in real-world interactions in the visible wealth condition in laboratory settings (**Fig. 2A, orange**). Subjects with the lowest wealth (-1.5 SD or lower) in the five categories rated their SWB at 0.38 (s.e. = 0.23; between neutral and good) over the course of the experiment, whereas those with the highest wealth (+1.5 SD or higher) rated their SWB at 1.29 (s.e. = 0.10; between good and very good). This means that, in our experimental setting, we could reproduce a setting resembling the real world in which richer individuals oftentimes feel better than the poorer individuals in the same groups. Since our experiments were 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 (i.e., the sum of in-game wealth in different rounds in different sessions), and, therefore, we statistically standardized it over the rounds across the sessions here.

In the invisible wealth condition, subjects in the lower wealth category were also less happy than those in the higher wealth category **(Fig. 2A, blue)**. However, the slope in the invisible wealth condition (slope = 0.056 [P = 0.009]) – that is, the magnitude of the economic gradient of SWB – is almost one fourth as steep as that in the visible wealth condition (slope = 0.21 [P < 0.001]) (interaction P < 0.001) under a linear assumption. Indeed, in the invisible wealth condition, subjects in the lowest wealth category (-1.5 SD or lower) rated their SWB at 1.01 (s.e. = 0.19; between good and very good), while those in the highest wealth category (+1.5 SD or higher) rated their SWB at 1.25 (s.e. = 0.10; between good and very good). This means that richer individuals did not benefit a lot from making wealth invisible in terms of SWB, while poorer individuals did substantially benefit.

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| **A. Result (first series)** | **B. Result (second series)** |
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| **Figure 2. Wealth visibility decreases SWB and exacerbates the economic gradient in SWB. A. the first series of experiments; B. the second series of experiments.** Study participants’ wealth in each round was classified into one of the five categories based on standardized wealth (Poorest: -1.5 SD or less and placed at -2; Poorer: -1.49 SD to -0.5 SD and placed at -1; Middle: -0.49 SD to 0.49 SD and placed at 0; Richer: 0.5 SD to 1.5 SD and placed at 1; and Richest: 1.5 SD or more and placed at 2) for visualization. The area of the circle in each category represents the relative sample size in each category. | |

Using our data, we can evaluate the following hypothetical change: if a subject in the lowest wealth category (-1.5 SD or lower) in the visible wealth condition transitions to the highest wealth category (+1.5 SD or higher) in the same condition, the subject could improve his or her SWB by 0.91 (almost one category shift from the neutral to the good range). On the other hand, if the same subject with the lowest wealth in the visible wealth condition moves to the invisible wealth condition, the subject can improve his or her SWB by 0.63. These results benchmark the adverse impact of wealth visibility on SWB.

In addition to the above-mentioned interaction effect (the slope in the invisible wealth condition is shallower), making the wealth of connecting neighbors invisible can improve the level of SWB as a whole (the line for the invisible wealth condition is generally higher than that in the visible wealth condition) (beta = -0.31; P = 0.001). This means that while the poorest individuals would benefit the most from making the wealth of connecting neighbors invisible, individuals in other regions of the wealth distribution could also benefit from such a change **(Fig. 2A)**. This effect on SWB has been generally observed over the entire temporal course of the experiments **(Fig. 3A)**.

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| **A. SWB trend (first series)** | **B. Cooperation trend (first series)** |
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| **C. SWB trend (second series)** | **D. Cooperation trend (second series)** |
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| **Figure 3. The trends of subjective well-being (SWB) and cooperation rate over the 15 rounds in the first and second series of experiments.** The shades represent the means ± standard errors estimated from multilevel regression models. | |

***Mediation analysis.*** We further investigated a mediating role of the magnitude of cooperativeness in each group with respect to how wealth invisibility could produce the increments in SWB. As in past experiments [23], study participants received higher levels of cooperation from their social networks in the invisible wealth condition (the group-level cooperation rate of 78.4%; s.e = 0.029) than in the visible wealth condition (71.5%; s.e = 0.027) (P = 0.083) in the present experimental setting (see also **Fig. 3B**). In addition, other studies reported that people who receive higher levels of cooperation (or social support) from their social networks feel less conflicted [72] and mentally healthier [73, 74]. Therefore, we hypothesized that the proportion of cooperative individuals among the connecting neighbors of each study participant (i.e., neighbors’ cooperativeness) mediated a path from wealth visibility to SWB. A causal mediation analysis [75] (see Material and Methods) shows that the total effect of invisible wealth on SWB is mediated by the neighbors’ cooperativeness in social networks (average causal mediation effect) by 17.1% (P < 0.001) **(Fig. 4A)**.

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| **Figure 4. Mediation analysis.** An indirect path from wealth invisibility to subjective well-being (SWB) through neighbors’ cooperativeness (average causal mediation effect) was examined simultaneously with a direct path from wealth invisibility to SWB (average direct effect). |

***Results of the second series of experiments (the replication dataset).*** Results of a further series of experiments, which added a third option in the cooperation decision-making, namely the option to punish or harm others in one’s group (e.g., if they were not cooperating) [63], reproduced the disproportionate effect of invisible wealth on SWB among poorer individuals. In the visible wealth condition, subjects in the lower wealth category were less happy than those in the higher wealth category **(Fig. 2B, orange)**. A modest difference from the results of the first experiment is that the slope in the invisible wealth condition (slope = 0.30 [P < 0.001]) is nearly half as steep as that in the visible wealth condition (slope = 0.16 [P < 0.001]) (interaction P < 0.001) – not one fourth. The gross happiness in the invisible wealth condition is higher than that in the visible wealth condition (difference of 0.18 [P = 0.06]) over the course of experiment **(Fig. 3C)**. The gross SWB in the second series of the experiments is slightly lower than that in the first series of the experiments (difference of –0.20 [P = 0.006]). The mediation analysis shows that there is a large mediation effect (38.0% [P < 0.001]) again **(Fig. 4B)**.

**Discussion**

In sum, we find that making the wealth of connecting neighbors in people’s social groups invisible can improve SWB in a group as a whole and essentially attenuate the impact of an economic gradient upon SWB, compared to identical circumstances where wealth is visible. That is, we could successfully reduce the rich-poor gap in happiness in our experimental setting by making wealth invisible. 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 invisibility on SWB, and on the *gradient* in well-being, here demonstrated experimentally. Furthermore, we have also shown the hidden role of cooperative social networks which can enhance emotional well-being and be boosted by wealth invisibility.

The negative consequence of wealth visibility offers a sharp contrast with positive roles of visibility on enhancing behavioral cascades over people’s social networks [76]. For example, making reputation (the record of subjects’ cooperative behavior in the past) visible can nurture cooperative social networks [77-80]; and voting behavior of others can enhance connecting neighbors’ (e.g., *Facebook* friends’) voting behavior [81]. The contrast may come from a difference of characteristics between visibility of behaviors, 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 [82]. Therefore, making something visible may not always be good even if visibility may be promoted and implemented for promoting transparency, public accountability, or other reasons.

*Why does wealth invisibility improve SWB especially among poorer individuals?* Although detailed mechanistic elucidation is one of the directions of future experiments, there are at least two possible major explanations. First, in the invisible wealth condition, individuals cannot engage in social comparisons that produce a sense of inferiority [83] and relative deprivation [14], both of which may provoke a negative emotional impact, especially if people witness richer individuals in their immediate social networks (hypothesis 1). Second, wealth invisibility can enhance people’s cooperativeness, which itself has a positive emotional impact [72-74] (hypothesis 2). Our results support both hypotheses 1 and 2 and especially reveal that the importance of the neighbors’ cooperativeness on a person’s emotional well-being, which wealth invisibility can improve.

Our work has limitations. The SWB that we have measured over the experiment is short-lived and that the wealth that we have measured and calculated is not actual wealth that each study participant maintains in the real world (though we paid our subjects real money based on their game play). Therefore, the generalizability of our experimental results is unclear. However, a short-lived experience of economic inequality in people’s daily life may be cumulated over time as a stressor and eventually cause mental illness [1, 3, 14, 17, 84-97].

Our results may contribute to the understanding of the mutual, dynamic relationships between cooperation (social support), economic inequality, and emotional well-being (mental health). Especially, in dynamic social networks in our experiments, we discovered that the cooperativeness experimentally boosted by making others’ wealth invisible can improve SWB among people within networked social groups. The results shed light on longstanding concerns in social epidemiology [98] regarding the social determinants of mental health, and their mechanisms.

**Materials and Methods**

***Experiment set-up (the first series of experiments).*** 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 [23], but we modified this set-up in an important way: we added the additional step of measuring SWB at each round. In the experiment, we recruited 581 subjects from Amazon Mechanical Turk [99, 100] between July and October 2017 and divided them among 50 sessions (social networks). Among the 581 recruited subjects, 321 were male (55.2%), 203 were female (34.9%), and 57 did not report their gender (9.8%); the median age is 31 years (interquartile range = 27 – 38 with the minimum of 19 and maximum of 71). 568 subjects remained for the first round of the experiment (13 drop-outs).

Each session typically lasted one hour. Subjects were 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 [23, 101-103]. Subjects were initially connected to an average of 4.5 neighbors (s.e. = 0.14). To artificially generate a rich-poor gap, we randomly assigned subjects to either an initial endowment of 1,150 “units” (the in-game wealth of the initially rich subjects) or that of 200 units (that of the initially poor subjects) [23]. 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 [70] before a game started (at round 0) was 0.4 [71]). Each subject was also randomly assigned to one of the nodes in the social network regardless of their in-game wealth units.

Subjects played a cooperation game lasting 15 rounds with their neighbors [102]. Empirically, the level of cooperation over experimental social networks reaches a plateau at around the tenth round or so [104]. In each round, all the subjects decided to choose whether to cooperate (i.e., reducing their own wealth by 50 units per connecting neighbor to increase the wealth of all the connecting neighbors by 100 units per connecting neighbor) or to defect (i.e., paying zero units and providing connecting neighbors with zero units). Subjects were required to make the same choice with all their connecting neighbors, which was similar to a conventional public goods game [102, 103, 105]. For example, a subject might want to cooperate with connecting neighbors 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 (USD 1 = 1,000 units). These financial interactions with connecting neighbors through a cooperation game allowed us to observe the dynamics of individuals’ cooperation behavior, wealth, and SWB. In addition, USD 3 was paid as a participation fee.

Subjects were informed of their connecting neighbors’ choices and their updated wealth (units) after they made their cooperation choice [78, 79, 106, 107]. 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 [102]). In more concrete terms, 30% of all the ties (pairs) 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 5-scale measure: “how do you feel right now: very bad, bad, neutral, good, and very good?” [108] 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 [108], the General Social Survey [10], and the Hardy-Rejeski Feeling Scale [109]. 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 US [110].

***Random assignment.*** We manipulated the visibility of local connecting neighbors’ wealth [23] and randomly assigned it to each of the sessions. In the sessions (social network) 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 neighbors 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 neighbors.

***Statistical analysis.*** We used the R lme4 package [111] and constructedregression models that took into account the hierarchical structures of the data (observations clustered by individuals and sessions). We used the R lmerTest package [112] and calculated P values with the Satterthwaite approximation. We also used the R mediation package [75] and implemented causal mediation analysis, which could distinguish an indirect effect (via an intermediate factor) from a direct effect (not via an intermediate factor). Since two or more levels of clusters have not yet been supported, we used individuals as a specified level of cluster; the results did not substantially change when we used sessions (social networks) as a specified level of cluster. The details of the analysis along with the R code are provided in our *SI Appendix, Extended Methods.* The data for replicating the main results will be published and available on AN’s Github page (https://github.com/akihironishi) upon acceptance.

***Replication (the second series of experiments).*** We also wanted to explore whether our results held in a more complex cooperation game (that allowed for “punishment”) [59]. 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, recruited from Amazon Mechanical Turk between March and December 2018) [63]. The modification to our basic game is an addition of a third option in our cooperation game: the ability to harm neighbors (i.e., reducing a subject’s own wealth by 50 units per connecting neighbor to decrease the wealth of all connecting neighbors 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 [113, 114] was the original purpose of this series of experiments, which primary results will be placed elsewhere [63] (to be clear, the economic gradient of SWB was not examined or reported). Briefly, the rate of execution of the harming option is as low as 5.7%. 719 subjects remained for the first round of the experiment (26 drop-outs), who were used in the statistical analysis for replication.

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