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ABSTRACT

In Search of Neural Correlates of Social Comparisons: An Integrative Research Design*

We review the research questions that guided studies seeking to detect brain activity arising from engagement in upward social comparisons, in particular comparisons of a relative variable of interest and a variable-based rank. To streamline, and without loss of generality, we refer throughout this paper to income as the comparison variable. For close scrutiny, we choose two representative and influential studies, Fliessbach et al. (2007) and Zink et al. (2008). Each of these studies is representative of a family of studies conducted in the same vein, and each examined in isolation neural correlates, either of income-based relative deprivation, in short relative deprivation, or of income-based rank. We argue that a deeper research question than those to which the Fliessbach et al. and Zink et al. studies attended pertains to the interaction and tradeoffs between relative deprivation and income-based rank and, consequently, to the corresponding activity in areas of the brain. We propose a method for formulating an improved, integrative research design, and we remark on the expected corresponding gain.

JEL Classification: A12, A13, D01, D91

Keywords: social comparisons, brain activity, neural representation of social comparisons, neural correlates, integrative research design

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Preliminaries: **Definitions and clarifications of several terms used in this paper**

Relative deprivation.

The relative deprivation of an individual is quantified by aggregating the income excesses arising from comparisons with the higher incomes of other individuals in the individual's reference group (meaning the individual's comparison group) and upon dividing that aggregate by the size of the "population."

Formally, in population $N = \{1, 2, \ldots, n\}$, $n \geq 2$, let $y = (y_1, ..., y_n)$ be the vector of incomes of the members of the population. Let these incomes be ordered, $0 < y_1 < y_2 < \ldots < y_n$. RD_i - by which we denote the relative deprivation of individual *i*, $i = 1, 2, ..., n-1$, whose income is y_i - is defined as

$$RD_i \equiv \frac{1}{n} \sum_{j=i+1}^{n} (y_j - y_i),$$

where it is understood that $RD_n \equiv 0$.

The idea is to aggregate the income excesses (an income excess is the difference between an income that is higher than the income of individual *i* and the income of individual *i*) and normalize this sum, that is, divide it by the size of the population. A detailed derivation of this representation of an individual's "relative deprivation" appears in Appendix A of Stark and Budzinski (2021). An example of application of the RD_i formula for a case of $n = 3$ is in footnote 3.

The measure of relative deprivation used in this paper follows and aligns with a large body of literature on the subject of relative deprivation and reference (comparison) groups, spanning from the pioneering two-volume study of Stouffer et al. (1949), *Studies in Social Psychology in World War II: The American Soldier*, through Runciman (1966) and Akerlof (1997), all the way to recent writings, for example, those of Stark et al. (2017) and Stark (2020). By definition and construction, the concept of relative deprivation is complementary to the concept of reference group or comparison group. The work of Stouffer et al., which opened the door to research on relative deprivation and reference groups, documented the distress caused not by a low military rank and weak prospects of promotion (military police) but rather by the faster pace of promotion of others (air force). It also documented the lesser

dissatisfaction of Black soldiers stationed in the South who compared themselves with Black civilians in the South than the dissatisfaction of their counterparts stationed in the North who compared themselves with Black civilians in the North. Soldiers' pay was much closer to the incomes of Black civilians in the South and much lower than the incomes of Black civilians in the North. While not explicitly using the term relative deprivation, Sen (1973) refers to the stress that arises from having low relative income. In explaining the construction of the Gini coefficient, Sen (p. 33) writes: "the man with the lower income can be thought to be suffering from some depression on finding his income to be lower. Let this depression be proportional to the difference in income. The sum total of all such depressions . . ." takes us to a measure of aggregate relative deprivation.

Steady-state distribution.

In the case of location choices, a steady-state distribution obtains when all movements come to a halt as no individual can gain from moving between locations. In this paper, the initial distribution of people in locations is typically a transient state, although, as is shown subsequently, the initial distribution can constitute a steady-state distribution.

Types of preferences.

(i) *Cardinal preferences*. These preferences are expressed by a taste for lower income-based relative deprivation.

(ii) *Ordinal preferences*. These preferences are "operationalized" by a taste, in the hierarchy of incomes, for a higher income-based rank, called rank for short.

(iii) *Joint preferences*. These preferences obtain when behavior is motivated by ordinal and cardinal preferences combined. Preferences are joint when with regard to the variable of comparison (income) people concurrently exhibit (i) a preference for a smaller difference between the higher amounts (incomes) that others in their comparison group have and the amount (income) that they themselves have and (ii) a preference for occupying a higher position in the hierarchy of the incomes of their comparison group. We refer to a preference structure of this type as joint preferences.

Social space. The term social space denotes the set of individuals with whose income-based ranks an individual compares his own income-based rank. Social space, comparison group, and reference group can be used interchangeably.

1. Introduction

Two studies published at about the same time, Fliessbach et al. (2007) and Zink et al. (2008), use the technique of functional magnetic resonance imaging (fMRI) to detect brain activity arising from engagement in upward social comparisons. Each of these two studies, we hasten to add, can be considered as being representative of a family of studies conducted in the same vein. For studies of the Fliessbach et al. type, readers of this paper can consult Lindner et al. (2015) and references therein. For studies of the Zink et al. type, readers can consult Ligneul et al. (2017) and Munuera et al. (2018) and references therein. The Fliessbach et al. and Zink et al. studies share the same point of departure: given that it is already well established in social science, biological, medical, and health research that comparisons with others affect well-being and guide behavior,[1] it would be revealing to identify the corresponding neural representations (activation in particular brain areas). Turning to neuroscience in the study of social comparisons can bring a multitude of gains. We remark on this issue at the end of this paper.

The research questions posed in the two aforementioned representative studies are essentially the same: are brain areas active as a result of upward social comparisons? If so, which areas? And what can be inferred from the involvement or, for that matter, from the noninvolvement of particular brain areas? To facilitate a comparison of the two studies and to ease representation of the idea highlighted in this paper, we refer throughout, without loss of generality, to income as the variable of interest. Both studies emphasize the need to inquire about whether, by looking inside the brain, we can infer that the *relative* attribute of the variable of interest, say, relative income (meaning the income of an individual in comparison with the incomes of higher-income individuals) or income-based rank, rather than the *absolute* attribute of the variable of interest, say, absolute income, matter to people. And once we make such an inference, what is the use of this knowledge? Also common to the two studies is the notion that in the domain of satisfaction from having income, a comparison dimension needs to be introduced. In the Fliessbach et al. study, this comparison dimension is relative income, which, for the sake of clarity, could better be referred to in this paper as relative income deprivation or, in short, relative deprivation. In the Zink et al. study, the

[1] In the past five years alone, we have conducted research on how comparisons with others affect well-being and guide behavior in each of the disciplines of economics, sociology, biology, medicine, and public health. Our writings are listed under Publications in https://ostark.aau.at/ from where the writings can be easily downloaded.

comparison dimension is the rank that absolute income confers in a hierarchy of incomes, to which we refer in this paper as income-based rank.

The Fliessbach et al. study has as its base hypothesis the notion that relative deprivation matters. People assess the value of what they have, that is, the value of their absolute income by comparing this income with the incomes of comparators whose incomes are higher than theirs. When the absolute income of an individual is held constant and the income of a higher-income comparator increases, the individual's relative deprivation rises, and the individual is dismayed. The dismay does not stem from dissatisfaction with a given level of income or with a loss of own income; rather, the dismay arises from the income gain of a higher-income comparator. In the Fliessbach et al. study, receiving less than a comparator increases the expectation of a compensating "reward" and is found to be associated with a reduced blood-oxygen-level-dependent response signal in the ventral striatum, and the associated disappointment is taken as an incentive to select (as a motivation to change) goal-directed behavior. In concluding their study, Fliessbach et al. (p. 1308) write that "social comparisons affect activation levels in the ventral striatum." This brain region is known to be active in reward processing, which could suggest a pending decision to resort to remedial behavior (desirable action) aimed at alleviating the disappointment.

The Zink et al. study has as its base hypothesis the notion that placement in the hierarchy of incomes matters: people assess the value of what they have by the rank that it confers upon them in their social space. In the Zink et al. study, while people's absolute income is held constant, people are found to be dismayed when their position in the hierarchy of incomes deteriorates as others advance to positions higher than theirs. The dismay arising from the loss of income-based rank can give rise to specific neural correlates. The question of interest is to identify the neural representation of social hierarchies. Specific brain areas - occipital/parietal cortex, ventral striatum, and parahippocampal cortex - are found to be active in the neural encoding of rank, providing support for the notion that losing rank is emotionally painful and that the rank-related dismay "calls for" a mending goal-directed behavior. Zink et al. (p. 278) write that "[v]iewing a superior . . . player in [a] social unstable hierarchy setting [where a superior advances in the hierarchy] resulted in increases of activity in multiple areas linked with social emotional processing and social cognition."

2. Our core argument: A rationale for an integrative research design

The strength and appeal of Fliessbach et al. and the Zink et al. studies notwithstanding, a deeper research question than those to which these studies attend pertains to the interaction and tradeoffs between relative deprivation and income-based rank and the corresponding encodings in areas of the brain. Neither study examined the neural correlates of a concurrent (joint or composite) change of relative deprivation and income-based rank. It is our view that in the search for fundamental determinants of social-based human behavior, rather than a determinant of one type alone, the nexus between cardinal and ordinal determinants needs to form the basis of inquiry. This perspective carries over to research on neurological correlates. After all, ordinal preferences can give rise to distinctly different behaviors than cardinal preferences, so it could be expected that the processing in the brain of cardinal relative deprivation and ordinal income-based rank will be carried out in distinct areas.[2]

It is worth noting the sharp difference between extreme versions of the types of social comparisons studied by Fliessbach et al. and Zink et al. If income-based rank is the only attribute that matters, that is, if social preferences are purely ordinal, then to individual *i* who occupies a given rank, an increase of the income of any individual *j* who occupies a rank that is higher than *i*'s rank is immaterial; *i*'s rank is not affected, and the deterioration of *i*'s relative deprivation does not count. Conversely, if relative deprivation is the attribute that matters, that is, if social preferences are purely cardinal, then the opposite holds: the increase of *i*'s relative deprivation counts, a retention of *i*'s income-based rank notwithstanding.

Suppose that initially the income of individual *j* is lower than that of individual *i*. Suppose that the income of individual *j* increases and surpasses that of individual *i*. Fliessbach et al. consider the consequent increase of *i*'s relative deprivation, but they do not account for the concurrent decrease of *i*'s rank. An increase of relative deprivation not accompanied by a decrease of rank is less painful to an individual who cares about both than an increase of relative deprivation combined with a decrease of rank, and this difference can be expected to give rise to different brain activations. Zink et al. consider the consequent decrease of *i*'s rank, but they do not account for the concurrent increase of *i*'s relative deprivation. The rank gain

[2] By means of an example, in Remark 1 below, we illustrate how observing behavior can enable us to ascertain whether the preferences that underlie behavior are cardinal or ordinal.

of individual *j* can be such that his income is slightly higher than that of individual *i* or such that his income is much higher than that of individual *i*. A decrease of rank accompanied by a small increase of relative deprivation is less painful to an individual who cares about both than a decrease of rank accompanied by a sizeable increase of relative deprivation, and this difference can be expected to give rise to different brain activations.

A similar scenario is one in which the income of individual *i* increases: while this increase results in lower relative deprivation, it may or may not bring about a rank gain. Indeed, because a given increase of income that brings about lower relative deprivation and higher rank is worth more to an individual who cares about both than to an individual who cares about only one, searching for brain activation on account of just one can miss the chance of documenting the complete neural representation of social comparisons. We complement this discussion with an example.

Example 1. Consider population $N = \{1,2,...,n\}$, $n \geq 2$, with an initial income vector $y = (y_1, y_2, ..., y_n)$ such that $0 < y_1 < y_2 < ... < y_n$. We refer to individuals by their incomes, so individual 1 is the individual whose income is y_1, and so on. We consider the case of $n = 3$. Holding the income of individual 1 constant, we let two changes occur simultaneously: the income of individual 2 is reduced to below the income of individual 1, and the income of individual 3 rises by more than the amount $y_2 - y_1$.[3] Thus, at the same time, individual 1 experiences a gain on account of income-based rank and a loss on account of relative deprivation. How will this dual occurrence be encoded in the brain? Suppose that area A in the brain is "in charge of" relative deprivation events and that area B in the brain is "in charge" of income-based rank events. In the case just described, are both these areas active? If so, how do they communicate with each other? Or is only one area active? If so, which one? And is it correct to infer that if only a particular area is active, then the corresponding income variable is the dominant one in a person's sense of well-being, as modulated by social

[3] A numerical example of this scenario can be useful. Let the initial incomes of the three individuals be (2, 4, 5). We refer to these three individuals as first, second, and third, respectively, and we retain these names throughout. The relative deprivation of the first individual is $\frac{5}{3}$. If the income of the second individual is reduced by 3 to become 1, and if at the same time the income of the third individual rises by $4 - 2 = 2$ to become 7, then in the income distribution (1, 2, 7), the relative deprivation of the first individual (who is now placed in the middle of the income distribution) is $\frac{5}{3}$. Thus, for the relative deprivation of this first individual to rise, the income of the third individual needs to increase by more than 2.

comparisons? We are aware that these questions can be perceived as unconstrained ideals. We say this for two reasons. First, neural representations in the brain can blur the boundary between areas. Second, the brain's practice of "cardinalization" can obfuscate ordinal representations in that it approximates them as cardinal.

At the beginning of this paper we wrote that turning to neuroscience in the study of social comparisons can yield many gains. Rather than discussing this issue ourselves, we cite Kedia et al. (2014, p. 1264): "The discovery of the neural correlates of social comparison would enable researchers to evaluate the role played by comparison in social cognitive processes and as a consequence to further elucidate the neural mechanisms of social cognition." Perhaps, as a complementary note, we could say that an obvious gain is identification of activity in a brain area that plays a role in the selection of the subjective desirability of actions / "movements for execution," borrowing from Dorris and Glimcher (2004).

3. Complementary remarks

We supplement the preceding discussion with two remarks.

Remark 1. Inferring by observing behavior whether preferences are cardinal or ordinal

In social science research, the need to ascertain whether preferences are cardinal or ordinal can be met by observing behavior. The following example illustrates this point.

Example 2. Suppose that, to begin with, three individuals whose incomes are 3, 2, and 1 and to whom we refer respectively as individuals 3, 2, and 1 are in one room, room A, and that, subsequently, any of these individuals can at no cost to himself move to another room, room B, which in all relevant respects (amenities) is identical to room A. When an individual moves, he takes his income with him, so to speak. An individual compares his income only with the incomes of other individuals in his room, that is, the room in which an individual is located is the individual's exclusive sphere of comparison. When there is nothing to be gained from moving, no move takes place. This is tantamount to stating that an individual in room A will move to room B only if he is strictly better off in room B. This assumption can be supported by saying that there exists an infinitesimal cost of moving. The individuals are "far-sighted" in the sense that when they consider a move between rooms, they take into account the decisions about moving that will be taken by other individuals who are higher up in the hierarchy of the income distribution. What governs the individuals' location choice is a desire

to obtain the highest possible level of well-being. Obviously, "room" is a metaphor; we can likewise think of two islands, two banks of a river, two adjacent villages, and so on. Moreover, we could replace room location with group formation, in which case we would infer people's preferences from how they sorted themselves into groups.

It is not the purpose of this paper to account for the menu of behaviors that could arise from interpersonal comparisons. We abstract from other possible types of behavior, such as people exerting effort to obtain higher income when positioned less favorably in an income distribution. Further, when we measure relative deprivation, we assume that comparisons with others who are positioned to the right of the individual in the income distribution count equally: the income excesses of those who are close by and the income excesses of those who are farther away are accorded equal importance. We can think, though, about a flexible weighting protocol based on the notion that the same importance need not be attached to the incomes of individuals who are placed at different distances from the individual whose relative deprivation is being measured. (A model of this possibility is in Stark et al., 2017.)

(i) If behavior is motivated by ordinal preferences (a preference for a higher rank), that is, if individuals are concerned about their position in the hierarchy of incomes so that improvement in rank is the sole reason for considering moving from one room to another, then a steady-state distribution between the two rooms is reached such that individuals 3 and 1 are in room A, and individual 2 is in room B. This is so because individual 2 will enjoy a rank gain from moving to room B, and because individual 1 knows that individual 2 will move to room B, there is no rank gain awaiting individual 1 from moving to room B. (Recall our assumption that when there is nothing to be gained from moving, no move takes place.)

(ii) Suppose, alternatively, that behavior is motivated by cardinal preferences, that is, that individuals are concerned about relative deprivation so that reducing relative deprivation is the sole reason for considering moving from one room to another. Then, a steady-state distribution between the two rooms is reached such that individual 3 is in room A and individuals 2 and 1 are in room B. This is so because by moving to room B, individual 2 frees himself completely from relative deprivation, and individual 1 experiences less relative deprivation when he is with individual 2 in room B than when he is with individual 3 in room A.

Thus, steady-state distribution $A = \{3,1\}, B = \{2\}$ implies rank preferences, and steady-state distribution $A = \{3\}, B = \{2,1\}$ implies relative deprivation preferences.

Our ability to distinguish between rank preferences and relative deprivation preferences by observing the behavior to which preferences give rise is not specific to the example of three individuals. It holds for any $n \geq 2$ individuals. This can be reasoned heuristically. First, we consider the case of Example 2(i). Second, we consider the case of Example 2(ii).

Let there be in room A $n \geq 2$ individuals whose location choices are motivated by a preference for higher rank, and let *n* be an odd number. (The case of *n* being an even number is similar.) For a reason that is similar to that in Example 2(i), a steady-state distribution is obtained such that the odd-numbered individuals $n,\ n-2,\ n-4,...,\ 1$ are in room A, and the even-numbered individuals $n-1,\ n-3,\ n-5,...,\ 2$ are in room B.

Let there be $n \geq 2$ individuals whose location choices are motivated by a preference for lower relative deprivation be in room A. A steady-state distribution is reached such that individual *n* stays in room A and individuals $n-1,\ n-2,...,\ 1$ move to and stay in room B. A heuristic account is as follows. Each of the $n-1$ individuals knows that individual *n* will stay in room A, and each of them will be happier staying alone in room B. Given that the individuals are "farsighted," each of the $n-1$ individuals knows that each of the other $n-2$ individuals will also prefer not to stay with individual *n* in room A, so the possibility of being alone in room B turns out to be a figment of imagination. Thus, aware that all $n-1$ individuals are in room B, each of them will ponder whether staying in room B with the other $n-2$ individuals would be better than returning to room A so as to be there with individual *n*. To demonstrate that individual *n* staying in room A and individuals $n-1,\ n-2,...,\ 1$ staying in room B is the steady-state outcome (that is, to demonstrate that this distribution constitutes a steady state), we can show that no individual $k = n-1,\ n-2,...,\ 1$ will prefer to return to room A as opposed to staying in room B: given the location moves of the other $n-2$ individuals, no individual out of the $n-1$ individuals can (unilaterally) gain by changing his location from room B to room A. A proof of this claim is available from the author on request.

The ability to identify the difference between a steady-state distribution arising from rank preferences and a steady-state distribution arising from relative deprivation preferences

is robust to an alternative characterization of rank preferences. To see this, suppose that individuals engage in both upward and downward rank comparisons (Swencionis and Fiske, 2014; Luo et al., 2018; Yaple and Yu, 2020): the individuals are dismayed by observing higher-ranked individuals, they derive satisfaction from observing that other individuals are ranked below themselves, and they accord equal weights to the dismay and satisfaction. In this setting and to begin with, we once again let the three individuals 3, 2, and 1 be located in room A. Then, *seemingly*, individual 1, who is the most disadvantaged individual in room A, moves to room B. Individual 2 will then move to room B too, where he will be with no one ranked higher than himself and where he will gain satisfaction from the presence in room B of individual 1, who is ranked below him. But then, individual 3 will also move to room B, where he will gain from seeing the two individuals ranked below him. There is no incentive for individual 2 to move back to room A because there, he would also be ranked second, while he will have no one positioned below him. Therefore, *seemingly*, all three individuals end up in room B, experiencing exactly the same dismay and satisfaction as if they never moved from room A. Note that we wrote "*seemingly*" because given our assumption that the individuals are "farsighted," they know that the moves described earlier will amount to no gain, so they will all remain in room A. Thus, the initial allocation $A = \{3,2,1\}$ is a steady-state distribution, and this rank-based distribution is different from the steady-state distribution $A = \{3\}, B = \{2,1\}$ rendered by relative deprivation preferences as in Example 2, part (ii).

(iii) Suppose now that behavior is motivated by ordinal and cardinal preferences combined. We refer to a preference structure of this type as joint preferences. In this case, the steady-state distribution is $A = \{3\}, B = \{2,1\}$. This is so because individual 2 moves to room B, a move that confers upon him both a relative deprivation gain and a rank gain, and individual 1 moves to room B because his relative deprivation there, where he will be with individual 2, will be lower than his relative deprivation would be if he stayed with individual 3 in room A. Needless to add, individual 1's rank is the same when he is with individual 2 in room B as when he is with individual 3 in room A. The steady-state distribution in this case is the same as the steady-state distribution when behavior is motivated by preferences that are exclusively for low relative deprivation.

Thus, in the case of joint preferences, observing the steady-state outcome does not enable us to distinguish between types of preferences in the same manner as we could when

preferences are of the single type. What we can say, though, is that the $A = \{3\}, B = \{2,1\}$ steady-state distribution informs us that preferences are not solely of the rank type.

Remark 2. **The fMRI technique in the service of concurrent changes of relative deprivation and income-based rank**

Current fMRI studies often a resort to a linear regression framework, in particular the use of general linear models (GLMs). An application of this tool kit could inform an inquiry aimed at examining the neural correlates of multiple variables, here the concurrent (joint or composite) changes of relative deprivation and income-based rank.

The sole intent of this paper is to induce researchers in the evolving field of neuroscience of social comparisons to think out of the box of stress that arises from having less than what comparators have, and out of the box of stress that arises from being placed low in the hierarchy of comparators. There is more to social comparisons than that. Insights yielded by this paper are that joint preferences exist and that there is a distinction between behavior that joint preferences give rise to and behavior that results from preferences that are purely ordinal or purely cardinal. It is up to neuroscientists to take our call for an integrative approach to the design and execution of experimental work.

References

Akerlof, George A. (1997). "Social distance and social decisions." *Econometrica* 65: 1005-1027.

Dorris, Michael C. and Glimcher, Paul W. (2004). "Activity in posterior parietal cortex is correlated with the relative subjective desirability of action." *Neuron* 44: 365-378.

Fliessbach, K., Weber, B., Trautner, P., Dohmen, T., Sunde, U., Elger, C. E., and Falk, A. (2007). "Social comparison affects reward-related brain activity in the human ventral striatum." *Science* 318: 1305-1308.

Kedia, Gayannee, Mussweiler, Thomas, and Linden, David E.J. (2014). "Brain mechanisms of social comparison and their influence on the reward system." *NeuroReport* 25(16):1255-1265.

Ligneul, Romain, Girard, Romuald, and Dreher, Jean-Claude (2017). "Social brains and divides: The interplay between social dominance orientation and the neural sensitivity to hierarchical ranks." *Scientific Reports* 7: 45920.

Lindner, Michael, Rudorf, Sarah, Birg, Robert, Falk, Armin, Weber, Bernd, and Fliessbach, Klaus (2015). "Neural patterns underlying social comparisons of personal performance." *SCAN* 10: 569-576.

Luo, Yi, Eickhoff, Simon B., Hetu, Sebastien, and Feng, Chunliang (2018). "Social comparison in the brain: A coordinate-based meta-analysis of functional brain imaging studies on the downward and upward comparisons." *Human Brain Mapping* 39: 440-458.

Munuera, Jerome, Rigotti, Mattia, and Salzman C. Daniel (2018). "Shared neural coding for social hierarchy and reward value in primate amygdale." *Nature Neuroscience* 21: 415-423.

Runciman, Walter G. (1966). *Relative Deprivation and Social Justice*. Berkeley: University of California Press.

Sen, Amartya (1973). *On Economic Inequality*. Oxford: Clarendon Press.

Stark, Oded (2020). "Relative deprivation as a cause of risky behaviors." *Journal of Mathematical Sociology* 44(3): 138-146.

Stark, Oded, Bielawski, Jakub, and Falniowski, Fryderyk (2017). "A class of proximity-sensitive measures of relative deprivation." *Economics Letters* 160: 105-110.

Stark, Oded and Budzinski, Wiktor (2021). "A social-psychological reconstruction of Amartya Sen's measures of inequality and social welfare." *Kyklos* 74: 552-566.

Stouffer, Samuel A., Suchman, Edward A., DeVinney, Leland C., Star, Shirley A., and Williams Jr., Robin M. (1949). *The American Soldier*: *Adjustment During Army Life*, Vol. I. Stouffer, Samuel A., Lumsdaine, Arthur A., Lumsdaine, Marion Harper, Williams Jr., Robin M., Smith, M. Brewster, Janis, Irving L., Star, Shirley A., and Cottrell Jr., Leonard S. (1949). *The American Soldier*: *Combat and Its Aftermath*, Vol. II. *Studies in Social Psychology in World War II*. Princeton: Princeton University Press.

Swencionis, Jillian K. and Fiske, Susan T. (2014). "How social neuroscience can inform theories of social comparison." *Neuropsychologia* 56: 140-146.

Yaple, Zachary A. and Yu, Rongjun (2020). "Upward and downward comparisons across monetary and status domains." *Human Brain Mapping* 41(16): 4662-4675.

Zink, Caroline F., Tong, Yunxia, Chen, Qiang, Bassett, Danielle S., Stein, Jason L., and Meyer-Lindenberg, Andreas (2008). "Know your place: Neural processing of social hierarchy in humans." *Neuron* 58(2): 273-283.