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Short communication

Rank, stress, and risk: A conjecture ☆

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ABSTRACT

A perception at the core of studies that consider the link between social rank and stress (typically measured by the so-called stress hormone cortisol) is that the link is direct. Examples of such studies are Bartolomucci (2007), Beery and Kaufer (2015), and Koolhaas et al. (2017). A recent and stark representation of this body of work is a study by Smith-Osborne et al. (2023), who state that "social hierarchies *directly* influence stress status" (Smith-Osborne et al. p. 1537, italics added). In the present paper, we reflect on this "direct" perspective. We conjecture that the link between social rank and stress involves an intervening variable: an indirect relationship arises when the loss of rank triggers a behavioral response in the form of risk taking aimed at regaining rank, and it is the engagement in risk-taking behavior that is the cause of an elevated level of cortisol. Smith-Osborne et al., as well as others whose papers are cited by Smith-Osborne et al. and who, like Creel (2001) and Avitsur et al. (2006), conducted comprehensive research on the association between rank (social standing) and stress, do not refer to risk taking at all. We present four strands of research that lend support to our conjecture: evidence that in response to losing rank, individuals are stressed; evidence that in response to losing rank, individuals resort to risk-taking behavior aimed at regaining their lost rank; evidence that there exists a link between engagement in risky activities or exposure to risk and elevated levels of cortisol; and an analytical perspective on incidence and intensity, namely a perspective that shows how the willingness to take risks responds to a change in rank, specifically, how a loss of rank triggers a greater willingness to take risks and how this trigger is stronger for individuals whose rank is higher.

1. Introduction

The essence of studies that refer to the link between social rank and stress (typically measured by the so-called stress hormone cortisol) is that the social rank of individuals affects their level of stress, that loss of social rank increases the level of stress, and that occupying a higher social rank confers resilience to social stress. In humans, the level of social stress can be measured by the hormone cortisol (in rodents by the analogous hormone corticosterone). There is variation in the observed intensity of the hormonal response; rank indicates how an individual will respond to stress. In particular, the intensity of the response of an individual to a loss of rank depends on the rank held by the individual. A perception at the core of these studies is that the link is direct. Examples of such studies are Bartolomucci (2007), Beery and Kaufer (2015), and Koolhaas et al. (2017). A recent and stark representation of this body of work is a study by Smith-Osborne et al. (2023), who state that "social hierarchies *directly* influence stress status" (Smith-Osborne et al. p. 1537, italics added). In the present paper, we reflect on this "direct" perspective. We conjecture that the link between social rank and stress involves an intervening variable: an indirect relationship arises when the loss of rank triggers a behavioral response in the form of risk taking aimed at regaining rank, and it is the engagement in risk-taking behavior that is the cause of the elevated level of cortisol. Smith-Osborne et al., as well as others whose papers are cited by Smith-Osborne et al. and who, like Creel (2001) and Avitsur et al. (2006), conducted comprehensive research on the association between rank (social standing) and stress, do not refer to risk taking at all. Schematically, the novel chain of causality that we have in mind

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differs from loss of rank => elevated level of cortisol. Rather, it is loss of rank => risk-taking behavior => elevated level of cortisol.

We consider two hypotheses. The first hypothesis states that rank erosion induces individuals to resort to risk taking aimed at regaining their lost rank. The second hypothesis states that the intensity of risk taking is an increasing function of rank: a high-ranked individual will be more willing than a low-ranked individual to take the kinds of risks that might allow him to reverse his loss of rank. Measures of the levels of the hormone cortisol, which is secreted under stressful conditions, can be used to gauge the incidence and intensity of a risk-taking response.

Four strands of research lend support to our hypotheses.

(i) Evidence that in response to losing rank, individuals are stressed.
(ii) Evidence that in response to losing rank, individuals resort to risk-taking behavior aimed at regaining their lost rank.
(iii) Evidence that there exists a link between engagement in risky activities or exposure to risk and elevated levels of cortisol.
(iv) An analytical perspective on incidence and intensity, that is, a perspective that shows how the willingness to take risks is affected by a change in rank. In this part of the paper, we present, using a constructive example, a modeling framework of the manner in which rank preferences modulate risk preferences.

In the next four sections, we examine each of these strands of research in turn. We conclude the paper in Section 6.

2. Evidence that in response to losing rank, individuals are stressed

Knight and Mehta (2017) present causal evidence that high social status reduces stress responses in a stable hierarchy, whereas in an unstable hierarchy, high social status brings about increased stress.[1] High-ranked individuals are particularly vulnerable to rank erosion. In a similar vein, Larrieu and Sandi (2018) conclude that losing rank (and the associated resources) is more prominent as a cause of stress-induced behavior than subordination. They note that higher-ranked individuals "are at higher risk of developing depression-like symptoms when confronted [with] chronic situations implying loss of rank and resources" (Larrieu and Sandi, 2018, p. 6). Korzan and Summers (2021) echo the findings of Larrieu and Sandi (2018): stress is more closely linked to loss of social rank and access to resources than to the absence of a dominant status, and the penalty for a decline in rank can be as harsh as a higher risk of mortality. Korzan and Summers (2021) note that "rank relationships are stressful by the nature of status interactions" (Korzan and Summers, 2021, p. 2).

The preceding observations are in line with a social rank theory in psychopathology, where it is argued that individuals who lose status (or individuals with involuntary subordinate self-perception) are at greater risk of pathology than individuals who do not lose status and that the loss of status is a cause of increased propensity for social anxiety (Gilbert and Allan, 1998; Gilbert, 2000). In particular, Gilbert (2000) shows that unfavorable social comparisons are highly correlated with social anxiety.

Troop and Hiskey (2013) and Troop (2016) identify stress-related ill-health consequences of the loss of social rank. Troop and Hiskey (2013) link social defeat (failed struggle and loss of rank) with post-traumatic stress disorder (PTSD). Troop (2016) finds that loss of social rank is the main cause of eating pathologies.

[1] Similar observations for olive baboons had been made much earlier by Sapolsky (1992), who noted that (p. 701) "it was the stability of interactions with males close in rank (within three steps in the hierarchy of the individual) which predicted cortisol concentrations: the greater the percentage of interactions that were reversals with the three nearest lower-ranking males, the higher the basal cortisol concentrations in an individual."

3. Evidence that in response to losing rank, individuals resort to risk-taking behavior aimed at regaining their lost rank

A large body of literature links changes in social hierarchies with risk-taking behavior. A persistent finding is that lowered social rank correlates positively with a higher propensity to engage in risk-taking behavior.

Hill and Buss (2010, p. 219) reaffirm "the important role played by social comparisons in individual decision-making and preferences for risk." In particular, they conclude (p. 221) that the "concern with relative position will lead to increased risk when the higher variance outcome offers the potential to render one better off than social competitors, but the lower variance outcome would not." Hill and Buss (2010, pp. 224 and 225) add that "individuals are increasingly willing to choose risky outcomes when doing so offers the possibility of outperforming their social competitors." Thus "risk-seeking in the face of being outperformed by rivals is cogently understood as a functional response to social competitive forces."

Genakos and Pagliero (2012), who study the risk-taking behavior of professional athletes in a dynamic tournament, show that exposure to information on relative performance motivates athletes who lag behind the tournament's interim leaders to take greater risks. Similar results are reported by Grund et al. (2013), who document greater risk taking among trailing sport teams.

Increased risk taking in the presence of a disparity between a desired state and an actual state is predicted in the risk-sensitivity theory articulated by Mishra et al. (2014, 2015). According to this theory, risk-taking behavior is adaptive in some circumstances, especially when lower-risk options are unlikely to meet the needs of an individual.

The propensity to resort to risky behavior is significantly affected by the social context. Grimm et al. (2021) experimentally find that individuals occupying disadvantageous positions relative to others are much more likely to resort to risk-laden behavior than isolated individuals.

Ager et al. (2022) provide evidence of increased risk taking in response to the loss of rank, analyzing data on German air force fighter pilots during World War II whose peers were praised - received public recognition via citations in the armed forces bulletin - for outstanding accomplishments. Such citations were considered a great honor. For a pilot whose peers were praised, "risk taking increased substantially after a peer's mention" (Ager et al., p. 2284). Specifically, Ager et al. find that these pilots took greater risk in combat missions ("going after 'marginal' and more dangerous and difficult victories," p. 2260) as a means of restoring their standing. The effect of increased risk taking by fighter pilots was more pronounced the closer their birthplace was to that of the praised pilots, a finding that is in agreement with our perception that rank is social, in the sense that it is determined in "social space." (The term "social space" is the set of individuals with whose standing or rank an individual compares his own standing or rank. Because this set constitutes a social environment, we use the word "social.")

All in all, then, what the existing literature seems to suggest is that risk taking is a natural response to adverse disruptions in the social hierarchy.

4. Evidence that there exists a link between engagement in risky activities or exposure to risk, and elevated levels of cortisol

It is not easy to line up evidence supporting the notion that engagement in risk-taking activities causes increases in cortisol levels. A reason for this difficulty is that, typically, these two indicators are measured simultaneously, not sequentially. Ideally, we would want to be able to draw on experiments in which the level of cortisol is monitored regularly; initially, risk taking is absent or low, and then individuals are subjected to a risk-laden environment or are assigned risk-taking tasks, at which time measures of cortisol are found to register an increase. Corresponding striking evidence is provided by studies on athletic competitions. Filaire et al. (2007a, p. 1271) report that in eight consecutive collections of saliva among paragliding competitors, “cortisol values showed a significant increase early on the day of the competition and remained elevated all the day, with highest concentrations at the start.” Comparable results are provided by Filaire et al. (2007b) for motorcycling competitors (in this case, the highest concentration of cortisol was recorded ten minutes after the race). In a similar vein, using three collections of saliva among BASE (building, antenna, span, and earth) jumpers, Monasterio et al. (2016) report that salivary cortisol increased from the baseline to the pre-jump and then decreased after the jump (while still remaining above the baseline).

Dickerson and Kemeny (2004), in a meta-analysis, report (p. 377) that “the cortisol system is activated in goal-relevant situations (motivated performance tasks) when a central goal is saliently threatened (social-evaluative threat) and the process for attaining this goal is impeded (uncontrollability).” This “uncontrollability” is an inherent characteristic of a risk-laden environment. Dickerson and Kemeny remark (p. 379) that “social-evaluative contexts with uncontrollable outcomes would elicit the *largest* cortisol increases” (italics added).

In line with the dual-hormone hypothesis, Mehta et al. (2008) present evidence that cortisol reactivity depends on testosterone levels. In particular, high-testosterone individuals who participate in a competition - a risk-laden activity - and who are exposed to the brunt of a downside risk (losing in a competition) experience a rise in their level of cortisol.

Coates et al. (2010, p. 338), in a study on financial market traders, document “a very high and significant correlation between the traders’ daily cortisol levels, averaged from all traders, and the market’s uncertainty regarding upcoming market moves.” The traders studied by Coates et al. engage in high-frequency stock (equity) trading. With regard to the hormones testosterone and cortisol, Coates et al. hypothesize that levels of testosterone are correlated with reward and that levels of cortisol are correlated with risk. Coates et al. add (p. 339) that “a trader’s interpretation of information may not be stable: a trader with high levels of testosterone may see only opportunity in a set of facts; while the same trader with chronically elevated cortisol may find only risk.” In a similar vein, a link between financial risk taking and an elevated level of cortisol is identified by Herbert (2018).

Knight and Mehta (2014) draw attention to studies that link risky health behavior (such as alcohol and tobacco use) with increased basal cortisol concentrations. They note that losers (or supporters of a losing party) in sports, in laboratory competitions, and in political elections experience a rise in their level of cortisol. Knight and Mehta (2014, p. 281) write that “being relegated to low-status positions [once again, losing in a competition] may cause cortisol to increase … for … individuals motivated to achieve high status.” (This observation happens to align nicely with the theme of our next section.)

Casto and Edwards (2016), who conduct a review of research on the testosterone and cortisol response to social competition in humans, find that, typically, athletic competitions are associated with an increase in the levels of both hormones, while other types of competition may yield more diverse responses.

Kusev et al. (2017) present an overview of the hormonal predictors of and hormonal response to risk taking. They provide evidence that preference formation and risk-taking behavior depend on contextual, emotional, and hormonal factors, and they claim that “a critical area that, until recently, has been relatively neglected by psychologists and economists is the hormonal underpinning of risk. Hormones are particularly relevant to understanding context-specificity, given that some of their blood levels can vary according to context and some of their effects are transient and short-lasting” (Kusev et al., 2017, p. 4).

Kusev et al. (2017) share the view that stress is triggered when there is a disparity between individual goals and reality. Threats to one’s survival, safety, or other goals activate the adrenocortical system and elicit a release of cortisol. Von Helversen and Rieskamp (2020, p. 13) provide evidence “that stress-related physiological changes such as increases in cortisol and affective states interact in shaping risky decision making. Only when people were stressed and in a negative affective state did stress lead to increases in risk taking. These results show that when aiming to understand the influence of stress on risky decision making, it is necessary to consider not only single measures of stress responses but also the complex interplay of different response types.”

Sherman and Mehta (2020), who analyze the complexity of the links between stress, behavior, and hormonal changes, write (p. 227) that “cortisol is both an output (stress indicator) and input (cause of behavioral inhibition)” and that “low cortisol may be both a cause and consequence of stable status.” This latter observation comes quite close to the notion that an elevated level of cortisol is associated with loss of rank and risk taking.

In yet another piece of illuminating evidence, Turan et al. (2022) write that public performances by aspiring young musicians (these performances can be perceived as somewhat risky endeavors) are associated with anxiety and increased levels of cortisol.

The phenomena identified in the works presented in Sections 2 through 4 are closely interrelated. Korzan and Summers (2021, p. 2) state this eloquently: “inter-individual rank relationships are formed and shaped by environmental and socially stressful conditions, and mediated by the neurocircuitries that regulate stress and aggressive responsiveness.”

5. Modeling the manner in which rank preferences modulate risk-taking preferences: A constructive example

Consider a population of measure 1 in which we index the individuals by a number $\rho \in [0,1]$. We assume that the population is characterized by some continuous distribution of wealth or of income or of some other relevant variable. (Henceforth, wealth can be used interchangeably with income or any other relevant variable.) Without loss of generality, we equate the index number of an individual with the fraction of those in the population whose levels of wealth are smaller than or equal to the level of wealth of the individual. The index ρ then represents the individual’s continuous rank measure, and $1-\rho$, which is the fraction of those in the population whose levels of wealth are higher than the level of wealth of the given individual, represents the individual’s continuous rank deprivation measure.

A natural step in constructing the utility function of the individual is to combine the individual’s concern for rank with a concern for absolute wealth.[2] To this end, we let

$$U(\rho, w) \equiv f(w) - [1 + (1-\rho)]^{\beta} = f(w) - (2-\rho)^{\beta}, \tag{1}$$

where $\beta > 1$. The individual’s utility depends positively on the level of his wealth, w, and negatively on the fraction of the individuals who occupy ranks higher than his. To express the individual’s preference for wealth, we employ a real function, $f(w)$, that is strictly increasing and strictly concave. For the individual who occupies the top rank, we have that $1-\rho = 0$, so the second component of his utility function is at a minimum of 1. For the individual who occupies the bottom rank, we have that $1-\rho = 1$, so the second component of his utility function is at the maximum of 2^{β}. [3]

When considering $U(\rho, w)$ as a function of ρ for a given level of wealth, we write U_{ρ}.

[2] The utility of an individual is a measure of the individual’s well-being; the individual’s well-being is determined or conferred by income, wealth, and position in a hierarchy; and the individual’s behavior or choice is governed by a preference for higher utility.

[3] Although from a theoretical perspective there is nothing preventing $U(\rho, w) = f(w) - (2-\rho)^{\beta}$ from taking negative values, this can be forestalled by simply assuming that $f(w) > 2^{\beta}$.

To assess how an individual's willingness to take risks responds to a change in the individual's rank, we draw on a measure of risk aversion. To this end, we employ the Arrow-Pratt index of relative risk aversion (Pratt, 1964; Arrow, 1965, 1970). In the case of (1), the index of relative risk aversion with respect to rank is

$$r(\rho) \equiv \frac{-\rho U_\rho''(\rho)}{U_\rho'(\rho)}.$$

As will become evident, employing the Arrow-Pratt index of absolute risk aversion, $R(\rho) \equiv \frac{-U_\rho''(\rho)}{U_\rho'(\rho)}$, will yield the same insight as that yielded when employing the Arrow-Pratt index of relative risk aversion.

From (1) we obtain the derivatives

$$U_\rho'(\rho) = \beta(2-\rho)^{\beta-1}$$

and

$$U_\rho''(\rho) = -\beta(\beta-1)(2-\rho)^{\beta-2}.$$

Remark 1. Because $U_\rho'(\rho) > 0$ and $U_\rho''(\rho) < 0$, then, as a nice "side effect," the utility function U_ρ satisfies Gossen's First Law of marginal utility.

The index of relative risk aversion as a function of ρ is

$$r(\rho) = (\beta-1)\frac{\rho}{2-\rho}.$$

Therefore,

$$r'(\rho) = (\beta-1)\frac{2}{(2-\rho)^2} > 0.$$

Thus, when the fraction of lower-ranked individuals, ρ, is lower, which is tantamount to the reference individual occupying a lower rank and thereby experiencing higher rank deprivation, the reluctance of the reference individual to take risks is lower. Put somewhat differently, when the reference individual loses rank, he becomes more willing to take risks.

Remark 2. From differentiating $r(\rho)$ twice, we get

$$r''(\rho) = (\beta-1)\frac{4}{(2-\rho)^3} > 0.$$

We see that the Arrow-Pratt index of relative risk aversion is convex with respect to ρ. This means that when the fraction of lower-ranked individuals is higher (which is equivalent to the rank of the reference individual being higher), the impact of a given loss of rank on the risk-taking response of the reference individual is stronger. For example, when an individual is surpassed by 10 percent of his comparison group (that is, when his coefficient ρ decreases by 0.1), his risk aversion as measured by the Arrow-Pratt index of relative risk aversion decreases by more when he is close to the top rank (for example, when the decrease of ρ is from 0.9 to 0.8) than when he is low ranked (for example, when the decrease of ρ is from 0.4 to 0.3). In short, an individual increases his willingness to take risks as a response to a loss of rank of a given magnitude by more when prior to the loss he occupied a higher rank.

Remark 3. The result alluded to in Remark 2 is in tandem with the "Killer incentives" evidence provided by Ager et al. (2022), and, as such, it complements the painstaking effort of Ager et al. to document the effect of loss of rank on risk taking. That effort was not preceded or accompanied by an articulation of an underlying theory, which could have provided analytical support for the empirically observed patterns. Here we outlined a simple example of such a theory. Doing this adds to the appeal of the study by Ager et al., and it can serve as a rigorously formulated hypothesis for undertaking additional inquiries of the manner in which rank preferences translate into risk preferences.

6. Conclusions

Social rank matters greatly. Centuries ago, Adam Smith remarked that "the desire of … obtaining rank among our equals, is, perhaps, the strongest of all our desires" (Smith, 1759, Part VI, Section I, Paragraph 4). When something matters greatly, we should expect a significant corresponding behavioral response.[4] The cumulative evidence presented in Section 3 that a search for a response is to be found in the domain of risk taking is powerful, especially because it is reported by studies in a wide range of disciplines. Biology had its say, but as this paper suggests, it could do more: refine our knowledge of the mechanism that converts loss of rank to elevated levels of cortisol by conducting well-designed inquiries aimed at ascertaining whether risk-taking behavior is an intervening variable.

The health of an individual is affected by his psychological condition. In particular, psychological stress can cause physical and mental harm. A standard measure of stress is the level of the stress hormone cortisol. Research in social psychology, biology, physiology, neurobiology, and related disciplines suggests that people care about their social rank, that they compare their rank with the ranks of others in their comparison group, and that when this comparison reveals a decline in their rank, their level of stress rises. The existing literature postulates a direct link between increased rank deprivation and increased stress. From this premise it follows that the time for intervention motivated by a health-inspired concern for the well-being of individuals is when increased rank deprivation is perceived. This prescription will gain traction if the level of cortisol registers an elevation immediately upon the experience of a negative rank comparison. Our conjecture is that the link between social rank and stress is not direct but rather involves an intervening variable: that is to say, an indirect relationship arises when a loss of rank triggers a behavioral response in the form of risk taking that is aimed at regaining rank, and it is the engagement in risk-taking behavior that is the cause of the elevated level of cortisol. Based on this premise, the time for intervention motivated by a health-inspired concern for the well-being of individuals is when risk-taking behavior is exhibited. To put it slightly differently, an intervention aimed at countering an increase in the level of cortisol will be timed differently if our conjecture is true versus if it is not true.

Declaration of no competing interest

No conflict of interest of any type.

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[4] For example, Stark (2017) and Stark and Kosiorowski (2023) conduct comprehensive analyses showing how the preference of individuals to be in a space in which their income-based rank is higher can give rise to complex patterns of migration and an equilibrium, socially optimal, spatial distribution of a population.

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