**Reproducibility, Objectivity, and Integrity: Insights from a Survey among Czech Scientists**

1. **Reproducibility**

Reproducibility, a cornerstone of scientific inquiry, is essential not only for the reliability but also the credibility of scientific research. A lack of reproducibility can precipitate a "crisis of confidence," eroding trust within the scientific community and among the public at large. Scientists and meta-scientists have long voiced concerns regarding the alarming rate of irreproducibility across various scientific disciplines, including biomedicine, pharmacology, neuroscience, and psychology, coining the term "reproducibility crisis" to characterize this phenomenon. Some, however, argue that while the issue is serious, the crisis narrative may be overstated, as the overall irreproducibility rate allegedly remains stable. Others even contend that irreproducibility can, to some extent, serve as a natural driver of scientific discovery.

These concerns have triggered a reflection on the subject and sparked initiatives aimed at improving research practices and reproducibility. These initiatives include projects like the Center for Open Science's Reproducibility Project in Cancer Biology, the Reproducibility Project in Psychology, and the National Academies' Reproducibility and Replicability in Science. However, these efforts sometimes encounter disagreements concerning experimental design, outcome measures, and their interpretation.

1. **Scope of Irreproducibility**

Empirical studies seeking to quantify the extent of irreproducibility fall into two categories. The first category entails rigorous attempts to replicate experiments, providing discipline-specific estimates of reproducibility (e.g., OSF, Nosek, Cancer). While invaluable, these controlled studies are resource-intensive. The second category relies on reported or self-reported estimates, employing surveys that enable direct comparisons among more disciplines.

One such comprehensive survey, conducted by Baker, aimed to determine reproducibility rates across major scientific disciplines. Baker distinguished between replication (exact repetition) and reproduction (confirmation of findings in similar experimental systems), allowing for some methodological flexibility. Our survey, following Baker's definitions, sought to gauge scientists' opinions on the reproducibility crisis. In a sample of 1,576 scientists, 52% considered it a "significant" crisis, while 38% perceived it as "slight." This study also estimated reproducibility rates across disciplines, ranging from 55% in medicine to 73% in physics. To facilitate an exact comparison of these results with our own survey, we adopted identical questions.

1. **Factors Influencing Reproducibility**

Irreproducibility arises from a diverse array of internal and external factors that manifest at various stages of the research process. These factors encompass theoretical foundations, methodological limitations, and an array of psychological, social, economic, political, and cultural influences, which can operate on individual, group, national, or supranational levels. This diversity complicates efforts to develop a universal and coherent analytical framework for studying reproducibility.

These influencing factors can be categorized into several groups: the maturity of the discipline, complexity of phenomena, methodological challenges, laboratory practices, publication pressures, reporting biases, questionable research practices, personal integrity, biases, organizational norms, and broader cultural and political systems. Notably, these factors interact in complex ways, making it challenging to dissect their individual impacts.

The diverse factors influencing reproducibility can be approached from various angles, making it challenging to establish a universal and coherent analytical framework for their study. One helpful typology, proposed by Laraway, categorizes these factors into three broad categories: those rooted in the nature of the research, those associated with the researcher, and those pertaining to the publication process. Causes originating in the nature of the research encompass aspects such as control over experimental conditions, uncontrollable variables, sampling errors, and the inherent messiness of the world. Researcher-related factors encompass questionable research practices (QRPs), reflecting researchers' integrity, honesty, and adherence to norms. These factors influence reproducibility by encompassing a range of individual and communal values, norms, and contextual factors. Lastly, publication-related factors encompass issues like publication bias and the preference for publishing 'exciting' or 'interesting' results, which can compromise scientific rigor and the integrity of reporting."

Other notable concept, introduced by Goodman et al., is "multiplicity," which provides fertile ground for irreproducibility. Multiplicity encompasses practices like testing numerous hypotheses within a single experiment, repeating a single hypothesis multiple times, and employing various strategies that can lead to statistically significant results through repeated testing. Such practices compromise scientific rigor and reproducibility.

Reproducibility can be undermined at any stage of research, whether due to natural, technical, or ethical factors. Challenges such as substance purity, heterogeneous cell line populations, model organism variability, and population diversity in psychology and social sciences exemplify natural sources of irreproducibility.

Researcher-related factors predominantly relate to questionable research practices (QRPs) and researchers' integrity, influenced by individual and communal values, organizational rules, and broader contextual factors. Scientific integrity embodies virtues like honesty, reliability, impartiality, objectivity, fairness, accountability, transparency, and trustworthiness. Upholding scientific integrity ensures the production of objective, unbiased, accurate, and reproducible knowledge, guarding against undesirable behaviors such as fabrication, falsification, plagiarism, and external interference.

Scientific misconduct, including fabrication, falsification, and plagiarism (FFP), represents a severe breach of integrity. Questionable research practices (QRPs), on the other hand, operate in a "gray zone" and encompass practices like data manipulation, statistical errors, and flawed analysis. While QRPs may sometimes be deemed acceptable under certain circumstances, they can collectively undermine the objectivity and reproducibility of scientific research.

Publication-related factors, such as publication bias and the pursuit of "exciting" or "flashy" results, also contribute to irreproducibility. The use of various techniques, including QRPs, at multiple stages of research, has led to what is termed the "chrysalis effect," a phenomenon that boosts publication success but erodes scientific rigor and reproducibility.

1. **Factors in the Nature Survey**

The Nature survey identified numerous factors and challenges contributing to low reproducibility, spanning methodological, technical, organizational, publishing, and ethical realms. Among the most cited factors were selective reporting (69.7%) and publication pressures (65.7%), followed by issues related to low statistical power, poor analysis, poor experimental design, and deficiencies in laboratory oversight and mentoring. Transparency issues, such as unavailability of methods and raw data, also featured prominently. Technical factors, like reagent variability, scored lower in terms of perceived impact. Fraud, a severe breach of scientific integrity, garnered a relatively low score of 42.9%.

In our effort to comprehensively examine the landscape of factors influencing irreproducibility, we conducted qualitative research as part of our methodology (see Methodology section for details). This research led us to identify additional problematic practices that complemented and expanded upon those found in the Nature survey. Our extended list of factors encompasses practices that can impact research integrity and reproducibility at various stages of the research process, ranging from grant applications to the reporting of research outcomes. Recognizing that these practices could potentially skew research and compromise scientific objectivity over the long term, we incorporated them into our questionnaire. Unlike the Nature survey, which primarily used a one-dimensional scale to assess "factors contributing to irreproducibility," we sought to enhance clarity in our analysis. To achieve this, our questionnaire included questions that addressed both the prevalence and the perceived severity of these factors. By capturing nuanced perceptions of these issues, our survey aimed to provide a more comprehensive understanding of their impact on scientific objectivity and reproducibility.

Within our compiled list of factors, we identified a range of typical questionable research practices (QRPs) that researchers employ, which can compromise scientific objectivity and reproducibility. These QRPs include practices like "P-hacking" and similar strategies (e.g., data-dredging, significance-chasing, and "harking"), as well as various factors associated with the publication process and reporting strategies. Researchers may engage in practices such as publishing only positive or statistically relevant results or employing the "salami method," where results are divided and published across multiple papers, potentially leading to duplication and selective reporting.

Furthermore, our list encompasses issues related to result interpretation, such as unjustified generalization of findings, where data are applied in contexts that exceed the sample's size or representativeness. Deliberate exaggeration of scientific results, a practice known as "overselling," is another challenge we identified. Additionally, we noted the publication of studies with questionable scientific contributions, often driven by factors such as inserting "popular" terms into texts or papers solely to enhance the likelihood of publication. Researchers may also resort to using "fashionable" methods in their research, even in grant applications, without rigorous scientific justification.

These practices, as perceived by survey participants, collectively contribute to unobjective science and align with other dubious strategies intended to enhance the likelihood of publication or securing research funding. Understanding and addressing these practices are crucial for fostering scientific objectivity and enhancing reproducibility.

1. **Effect of the Discipline**

Previous studies have explored the relationship between reproducibility and scientific disciplines, uncovering differences in determinism, signal-to-noise ratios, complexity, research standards, and publication practices. Fanelli proposed a hypothesis linking reproducibility to the complexity of scientific disciplines, arranging them hierarchically, with physics at the foundation, biology in the middle, and soft sciences like psychology and sociology at the top. Complex disciplines, characterized by greater degrees of freedom and less stringent research standards, may exhibit lower reproducibility rates. This hypothesis finds partial support in the Nature survey, which revealed discipline-dependent reproducibility rates, aligning with the hierarchy of sciences model.

1. **Geographical Distribution**

Studies indicate that non-reproducible findings are not uniformly distributed across the global scientific community, often linked to a higher prevalence of scientific integrity breaches (FFP or QRPs) in certain regions, notably some Asian and African countries, such as China and India. This disparity is associated with various factors, including financial constraints, unobjective grant systems, publication incentivization, and a complex interplay of structural, organizational, individual, and situational factors.

Our quantitative survey highlights a perceived bias against specific territories, which we term "Less Scientifically Developed Cultures" (LSDC). Scientists pointed to multifaceted factors contributing to irreproducibility in these regions, including regulatory and ethical standards, competition, reward systems, organizational hierarchies, and criticism suppression. We further explored the existence of this bias through our survey, inquiring about scientists' coping strategies when confronted with irreproducible research.