Theoretical and empirical perspectives on objectivity: Transforming a historical account into an investigative tool

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Introduction: Integrated H(E)PS

First we would like to situate our research within the context of history and the philosophy of science. Several authors advocated for a larger deployment of methods from the cognitive sciences and sociology in the philosophy of science as they understood their importance as other empirical sources besides those from the history of science (Arabatzis & Schickore 2012; Giere 1990; Giere 2011 etc.) Recently, philosophy in general, and in some fields in particular, has taken a naturalistic turn with an orientation towards empirical methodology that manifested in the steep rise of experimental philosophy (x-phi) studies (Knobe & Nichols 2008). New methods were adopted from neuroscience, psychology, cognitive sciences, and sociology, and applied to the inquiry into philosophical concepts, or intuitions, moral dilemmas and other similar topics.

In the experimental[3] philosophy of science (also referred to as "x-phi of science"), the adoption of new methodologies seems to be slower (Wilkenfeld & Samuels 2019) but there is a handful of studies that have gone in this direction: for instance, the landmark analysis of the gene concept (Stotz, Griffiths, Knight 2004), the innateness concept (Machery et al 2019), a study of philosophical views across scientific disciplines (Robinson, Gonnerman, O'Rourke 2019), or of scientific virtues (Schindler forthcoming 2021).

Experimental philosophy of science focuses primarily on scientists' intuitions and concepts, or on the comparisons of lay and scientific concepts. This has hardly been a novelty in the philosophy or history of science. But this recent turn has been motivated by the fact that while historians and philosophers have traditionally relied on empirical sources which were often created or procured only haphazardly with a different intended purpose, or not in a research context, experimental philosophy does this in a systematic and controlled manner in which hypotheses are tested according to a previously designed plan.

Conventionally, these non-methodically obtained primary sources, such as historical records or cases, scientific accounts, laboratory logs etc., are often analyzed to extract scientists' intuitions, views, and concepts to support various theoretical claims. Or philosophers and historians suggest their own concepts or classifications based on secondary sources, i.e. other philosophers' or historians' works. This conventional methodology, however, creates some serious issues. For example, the process of how these concepts, intuitions or beliefs emerge is not always recorded or reflected, and their existence is sometimes implicitly considered unproblematic and universally valid. This matter was already raised by one of the recently recognized fathers of experimental philosophy, Ness (1938), who made a case against the handling of the truth-concept by Tarski and the Vienna Circle. A few decades later, Laudan cites "intuitions of scientific rationality" (1977) as *a priori* assumptions of

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[3] The term *experimental philosophy* usually denotes both *empirical* (also called *observational*) and *experimental* studies in philosophy.

scientists in support of his theory of science, and similarly, Lakatos's meta-theory (1971) is highly dependent on the same implicit premise of the rationality of scientists. Such approaches can be also considered problematic from the philosophical point of view (Machery & O'Neill 2014). The other problem is that the concepts, taxonomies, interpretations suggested by philosophers can lack grounding in actual scientific work, and can be highly selective in their choice of sources and thus become divorced from the everyday practices, not to mention the fact that these philosophical outputs are seldom validated or critically assessed by scientists themselves.

Thus, while conventional methods are a legitimate and fruitful branch of historians' or philosophers' work, especially when better sources are simply not available, experimental philosophy provides a viable alternative, with more overview and control over the whole process of data creation and collection, which can help to avoid or minimize *some* of the pitfalls which inadvertently accompany the traditional methods[4].

In our project *Objectivity: An Experimental Approach to the Traditional Philosophical Question*[5] – in addition to classical philosophical and historical analysis – we explore the potential of empirical methodology to investigate the concept of objectivity among natural scientists. Our research lies at the intersection of three approaches: historical, philosophical and experimental (empirical), and can be thus classified as integrated history and (experimental) philosophy of science – IH(E)PS.

Natural scientists' view of objectivity

The primary focus of the project was the examination of the current understanding of objectivity among natural scientists, with the following main research questions:

• *Do natural scientists work with the concept of objectivity explicitly, or is it present rather only implicitly in their work?*
• *How do natural scientists understand and define objectivity?*
• *How is their understanding of objectivity related to their disciplines and main activities (styles of reasoning)?*

Our project employed integrated methodology (Creswell 2003): in addition to theoretical analysis it combined qualitative (interviews) and quantitative methods (questionnaires), with the quantitative phase drawing on the findings from the qualitative phase. To explore the ways in which objectivity is conceptualized by the scientific community and to discover the context in which it appears, we took full advantage of the interdisciplinarity of our research team, in which scientists constituted a substantive part[6], so that we could remain as close as possible to current scientific practice. From the onset, the scientists in our team provided important insights which helped to shape the research hypotheses and ensure the feasibility of the project.

Our goal was to impose as little as possible of our own structurations and preconceptions on the objectivity problem, so we tried to access the scientists' intuitions and views directly,

[4] Experimental philosophy necessarily creates its own issues which stem from the chosen methods, sampling, artificiality of the research situations and other factors, which have effect on the results.
[5] Funded by The Czech Science Foundation (Grant 18-08239S): Objectivity: An Experimental Approach to the Traditional Philosophical Questions).

[6] The team consisted of philosophers of science, sociologists, and working scientists (physicist and biologists).

which was reflected in the fact that most of the themes for the quantitative phase (questionnaire survey) were gleaned from the qualitative phase (individual or group interviews), mainly those which appeared crucial for contemporary science[7]. Subsequently, the quantitative survey also served as a tool for confirmation and validation of the hypotheses suggested during the qualitative phase.

Methodology of the qualitative phase

In the first, qualitative part, we wanted to reveal what the contemporary discourse on scientific objectivity looks like by sourcing views from working scientist themselves. As mentioned previously, The rationale behind this was to access scientists' views and operational concepts of objectivity, including the contexts in which they are used, without an intermediary. To that end, we tried to reduce the priming before the interviews and we provided the participants only with minimum cues as to the character of our project and our expectations, in order to elicit their spontaneous answers[8]. This was achieved by starting the interviews with questions such as: *"How do you understand objectivity?", "What do you most associate with the term scientific objectivity?",* which aimed to eliminate unnecessary influence on the part of the interviewers.

In the qualitative phase, which lasted from April to June 2018, we conducted individual and group semi-structured interviews (focus groups) with a total of 41 scientists from various disciplines[9], recruited with the snowball method.

Findings from the qualitative phase

As mentioned earlier, this phase focused mainly on unraveling the most common ways in which scientists think about objectivity and how it appears in the context of their disciplines. For that purpose, the recordings were analyzed and searched for the presence of concepts most commonly associated with the notion of objectivity. From the multiple responses we chose the following eleven disparate categories: Mathematical consistency, Quantification, Intersubjectivity[10], External view, Accuracy, Closeness to the truth, Testability, Correspondence to reality, Reproducibility, Critical thinking, and Impartiality, which in our view captured the breadth of the scientists' reasoning about the concept.

It is immediately apparent that some of these categories match the conceptions which are found in extant philosophical or historical literature. On the other hand, the interviews also revealed that the current philosophical literature probably treats the topic of objectivity quite disproportionally. For example, issues such as reproducibility (particularly in less scientifically developed cultures[11]), have only recently started coming to the philosophers'

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[7] This is not to say that experimental philosophers enter the research with a blank slate. It goes without saying that they also bring their own presuppositions and inclinations, originating for example in their academic paths, which inevitably have a bearing on the choices made in the research process, or can in other ways bias it.

[8] This is, of course, not entirely possible as the participants were primed by the research situation itself, particularly by the way they were recruited, the stated research goals, team composition, and possibly other factors.

[9] The sample consisted of 2 mathematicians, 12 physicists, 4 chemists, 21 biologists, 2 medical doctors; 24 PhDs, 8 Assistant Professors, 9 Professors; 7 women, 34 men.

[10] For the questionnaire, we added an explanatory sentence ("intersubjectivity, the possibility to share scientific results with others"), as the term "intersubjectivity" alone was not comprehensible for some scientists.

[11] Scientists named mostly Asian countries, with China and India in the lead. See also Cyranoski (2017), Huang (2018).

attention, despite the fact that they comprises the bulk of scientists' actual concerns about objectivity (Baker 2016).

The eleven categories of objectivity can be grouped in several ways. Nevertheless, from the analysis, a basic axis of differentiation arose, which we called "special objectivity" and "general objectivity", and this taxonomy also served as the foundation for the quantitative part of our study.
On this most basic level, scientists' reflections on objectivity follow these two paths:

1. The first pertains to objectivity in particular disciplines (hence *special objectivity)*, because in each one of them there are specific issues stemming from the nature of the objects studied, the state of theoretical knowledge, and the methods used. *Special objectivity* can be related to the objective existence of the entities studied, e.g. particles, species, genes, corresponding experimental or observational methods, and subsequent theoretical questions. For example, in most biological disciplines the introduction of "DNA barcoding", i.e. identification of biological species with DNA sequences (Hebert & Gregory 2005) in the past 10 to 15 years, raised several fundamental questions about this novel technique, which concern its place next to conventional taxonomical methods, standardization (choice of the genetical markers), or re-definitions of the key biological concepts (species) – sometimes leading to ongoing debates among the disciplines' practitioners (Staley 2006).

1. The second path is related to the functioning of science itself and is largely universal to all disciplines (hence *general objectivity*). It originates in the fact that science is after all a human endeavor and a social activity, carried out in institutions in a certain context and by individuals and groups with their own interests, which has many implications for objectivity, i.e. the existence and influence of stereotypes, biases, distortions and inequalities among the scientists. In this group, we can count all the factors impacting scientific work, such as broader social, political, ideological, educational, or economic factors (policy, funding, reporting, assessment, academic and organizational practices etc.) but also psychological and cognitive factors (personality characteristics, values, orientations, abilities, preferences).

From the theoretical point of view, *special objectivity* can be discussed within the framework created by Alistair C. Crombie and Ian Hacking (see further), whose *styles of scientific thinking* and *styles of reasoning* provide an adequate descriptive and analytical tool to describe the richness and variability of objectivity issues across a broad range of scientific disciplines. Analogically, Solomon's conception of *decision vectors* (2001) provides an ample framework to accommodate the issues concerning *general objectivity*.[12]

Crombie's, Hacking's, and Solomon's frameworks allowed us to at least partially organize and grasp the quite disjunctive views of objectivity which surfaced during our research. In the following section, we will deal in detail with *special objectivity* and Crombie's and Hacking's accounts of the "styles of thinking" and "styles of reasoning" respectively.

[12] This line is not further analyzed in our text.

Crombie's and Hacking's styles and objectivity

Historian Crombie (1994) laid out a history of Western science spanning more than two thousand years and proposed his *styles of scientific thinking* as a unit of analysis, through which this exposition can be organized. In his account, styles evolved as divergent ways of approaching natural or social worlds and made them accessible to scientific study. From the ancient to the modern periods, Crombie recognized six distinctive styles, which contributed to the development of scientific methodology:

1. *Postulation style*, whose method of argument was to explain natural phenomena using rational principles (including mathematical principles)
2. *Experimental argument*, which was used to discover the principles of intentional, planned and reproducible experiments
3. *Hypothetical modeling* that has emerged as a method of transferring and examining man-made properties of objects to natural phenomena
4. *Taxonomy* aimed at classifying objects into systems by comparing their differences
5. *Probabilistic and statistical analysis*, which developed to study the regularities of natural and social phenomena
6. *Historical derivation*, which classifies objects based on the comparison of their characteristics into genetic structures and seeks the causes of their diversification.

Later, Hacking (1992, 1994, 2002) took up the notion of style and, with slight modifications, transposed it into the philosophy of science, as a tool for the analysis of scientific disciplines. Hacking, however, stressed their public nature and called his styles "styles of reasoning".

Both Crombie and Hacking emphasized the link between styles and objectivity. Hacking's philosophical use of styles asserts that despite their historical contingency, styles gradually became established as "timeless canons of objectivity" and standards of scientifically acceptable ways of how to approach natural or social phenomena. For the emergence of a style and its acceptance by the scientific community, first the existence of a scientific object has to be defended and legitimate methods of its study invented, as in the case of mathematical proofs, laboratory experiments, statistical methods etc. during the development of European science (Hacking 2002, 188). Hacking further explains how styles become autonomous and how they are maintained in the process of interactions and negotiations among scientists. For him, scientific objects have no independent existence outside a given style, which also implies that prior to its establishment no scientifically meaningful statements about the investigated phenomena can be produced. Therefore, in addition to new objects, the particular style also introduces novel classifications, ways of explications or verifications, and laws, which are necessary for its recognition, consolidation and maturation (Hacking 2002, 189–194). Thus, style does not serve to reveal objective truth, but in itself defines standards of objectivity within which particular phenomena are explored and within which statements about them acquire meaning and truth value (Hacking 2002, 198).
In contemporary science, the Crombie-Hacking conception can not only provide a foundation for a basic classification and systematization of the vast plurality of scientific disciplines, but also for explanations of their connections to objectivity.

The interview phase of our research revealed that the Crombie-Hacking styles are still actively present in contemporary scientific practice and that they still pose challenges of various sorts. For example, in the form of conflicts about the role of mathematical postulation and experimental argument in fundamental physics, or the heavily debated use and abuse of the statistical style (significance criterium) in biology, medicine, and other sciences. Challenges usually also arise whenever different styles meet and create “trading zones” (Galison 1997), which usually happens after new research methods are introduced into a discipline, for example the tensions ensuing after the influx of laboratory methods into biology (“white” laboratory versus “green” field biology). Importantly, the representation and distribution of styles in contemporary science is not static but constantly changing over the time (e.g. the gradual ascent and current omnipresence of statistical style in practically all disciplines), and the styles are also responsible not only for the variability among the disciplines but also within them creating subdisciplines with uneven combinations of styles.

Methodology of the quantitative phase

For the purpose of the quantitative study, we reworked Crombie-Hacking styles so that they would conform to the character of typical activities of the scientists. These adjustments reflect what we learned from the qualitative part and from the discussions in our team. In addition, the reasoning behind this step was that science itself has changed substantively and with it both scientific thinking and practical work. For the questionnaire, we also had to make the questions comprehensible and updated for the current scientists, who are not typically not accustomed to the historical or philosophical terminology (e.g. terms like “postulation”). Taking this into the account, we made the following changes and substitutions:

- Hacking’s laboratory style, which he later renounced (2012), was merged with the original *Experimental argument*, as they are today indistinguishable, and has become *Design and execution of experiments*.
- *Hypothetical modeling* became *Modeling and simulation of natural phenomena*
- *Taxonomic style* and *Historical derivation: the genetic method* became *Description and categorization of natural phenomena*, as they are genuinely related and often performed together in current science.
- *Postulation and the search for principles and methods* became *Development of theories and deeper understanding of natural phenomena,* as this, in our opinion, apprehends in contemporary language the essence of what was originally meant by Crombie and Hacking.
- We separated *Working with mathematical structures* from the *Postulation style*, which in Crombie-Hacking typology included postulation of mathematical principles. The reason is that mathematics has become a unique and distinct field almost completely divorced from the other disciplines with which it historically developed.
- We omitted *Probabilistic and statistical analysis altogether*, as this style became so ubiquitous (statistical analysis is used practically in every scientific field nowadays) that it would not bring any additional and useful information.
- On the other hand, based on our discussions with the scientists, we added a new style *Development of methods, technologies and devices*, as it appears quite often as a full-fledged activity of some scientists.

From these options, the respondents could choose their most common activity (and list other activities in 2nd and 3rd place).

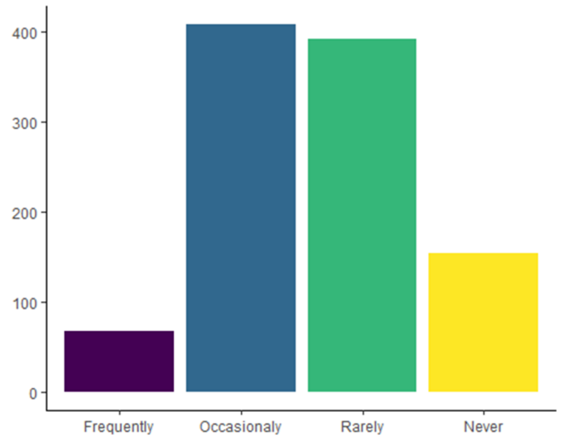
The quantitative phase was carried out as a questionnaire survey, which allowed us to validate and exactly measure the findings from the previous research. E-mails with a link to the online platform hosting the questionnaire (52 items, in Czech language) were administered to natural scientists at Czech research institutions (Czech Academy of Sciences and 3 major universities) with recommendations from the heads of the research institutes or organizations. The data collection was anonymous and ran from April 2019 to June 2020. We received a total of 1021 completed questionnaires (N=1021). The data was checked for completion times, consistency, and occurrence of random answers.

Findings from the quantitative phase

In the following section, we present the most important results which summarize both the findings about the overall understanding and categorization of objectivity among the scientists, and the thorough investigation of the Crombie-Hacking styles and their relations to objectivity.

Explicit objectivity

First, we wanted to know how the term objectivity appears in scientists' mutual communication. In the interviews, we learned that scientists think about objectivity and it is always inherently present in their work, but they don't always do so within a specific objectivity discourse. Rather it is ingrained in their practice, as concrete theoretical or methodological issues. In our survey, we posed the following question: "*Do I ever talk explicitly to other scientists about 'objectivity'?*", to find out the scope of this phenomenon.

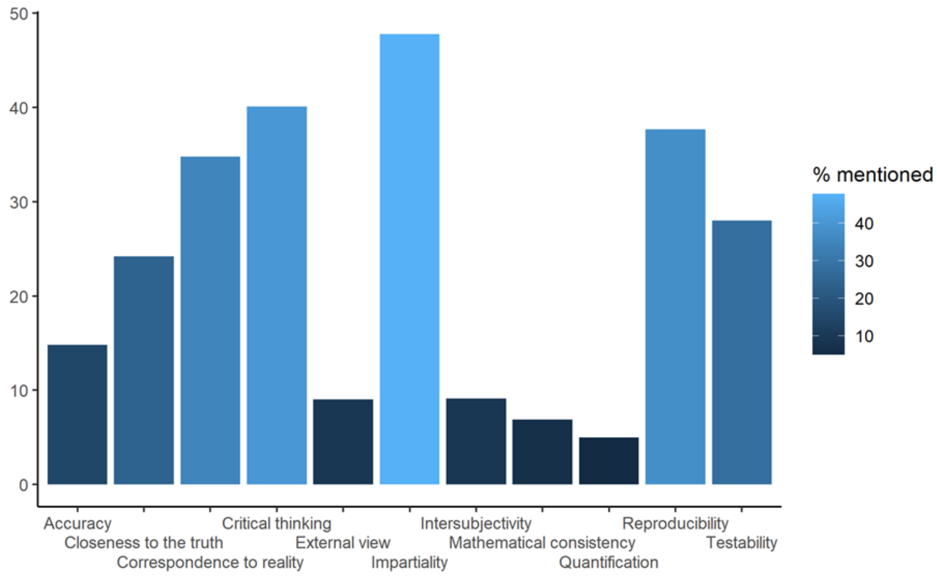


The results show that objectivity is explicitly discussed mostly "occasionally" (40.0%) or "rarely" (38.4%), by scientists but this result may be skewed by the sample selection as the survey participants are probably more likely to be interested in the topic. Objectivity "never" appears in the talk of 15.1% scientists.

Categories of objectivity

Next was a question on the categories of objectivity that were identified in the qualitative part: "*How do I understand objectivity? What does the concept of scientific objectivity most associate to me?*"[13]

[13] Respondents could choose 3 out of 11 options.



Almost half of the scientists relate objectivity to Impartiality (47.8%). This, in our view, suggests a strong identification with the "social" definition of objectivity, and the ideal of science as a neutral, value-free, and unbiased undertaking resistant to all kinds of pressures and influences. This may be surprising because we asked only the natural scientists; however, apparently, they still to a great extent adhere to this social definition.

The second strongest category was Critical thinking (40.1%), which indicates that the participants recognized critical thinking as a natural and inherent feature of science. Critical thinking connotes a critical investigation of ideas to disprove any extant or novel theory, as is advised by critical rationalism (Popper 1934/2014) and generally also inspired by the Anglo-American intellectual milieu (Dewey 1933).

The categories Reproducibility (37.7%) and related Testability (28.0%) came third and fifth, but they can be treated as equivalents of a sort. Together they would make the most frequent response as they refer to the same important characteristic in current discussions on objectivity. Reproducibility is commonplace nowadays in the scientific press and various replication and reproducibility issues are debated by scientists and philosophers of science alike (Baker 2016). Both testability and reproducibility are bedrocks for scientific verification, and as such canonical for science.

Correspondence to reality (34.8%) and Closeness to the truth (24.2%) echo distinct, yet parallel historical and philosophical strains in science (i.e. the empirical and rationalistic). The empirical is committed to the material and concrete experiential world as the ultimate reference point, whereas the rationalistic strives to achieve an abstract ideal such as truth or (mathematical) consistency.

Accuracy (14.8%), and Quantification (5.0%) allow for sensorial experiential data to become accessible to scientific investigations, although not many scientists identify them as key components of objectivity. It can be surmised that these categories are already automatically considered to be necessary preconditions of science, for example in the sense of mechanical objectivity (Daston and Galison 2007) and today they do not pose a serious problem as they have been (to a large degree) solved by availability of precise measurement apparatuses.

Intersubjectivity (9.1%) is a lesser known category to scientists, as it belongs more to philosophical discourse, hence its lower knowledge and popularity in the survey. Likewise, External view (9.0%) is presumably more of a philosophical category (Nagel 1989) than a living scientific concept. Mathematical consistency (6.9%) is a specific category tied to a particular formal discipline, so its frequency basically depends on the number of mathematicians in our sample (as we shall see).

Category relations

As objectivity categories define distinct, yet sometimes kindred virtues and qualities, the logical question is if and how they are interrelated?

For the statistical analysis, we used χ^2 *tests* and *pairwise correlations* which reveal the relationships among the categories and their strength. χ^2 tests compare observed frequencies in a cross tabulation (table based on two categorical variables) with expected frequencies (based on assumption of independence of the two variables). χ^2 tests tells us whether the table as a whole violates the assumption of normality. In this analysis, some of the abovementioned relations were confirmed.

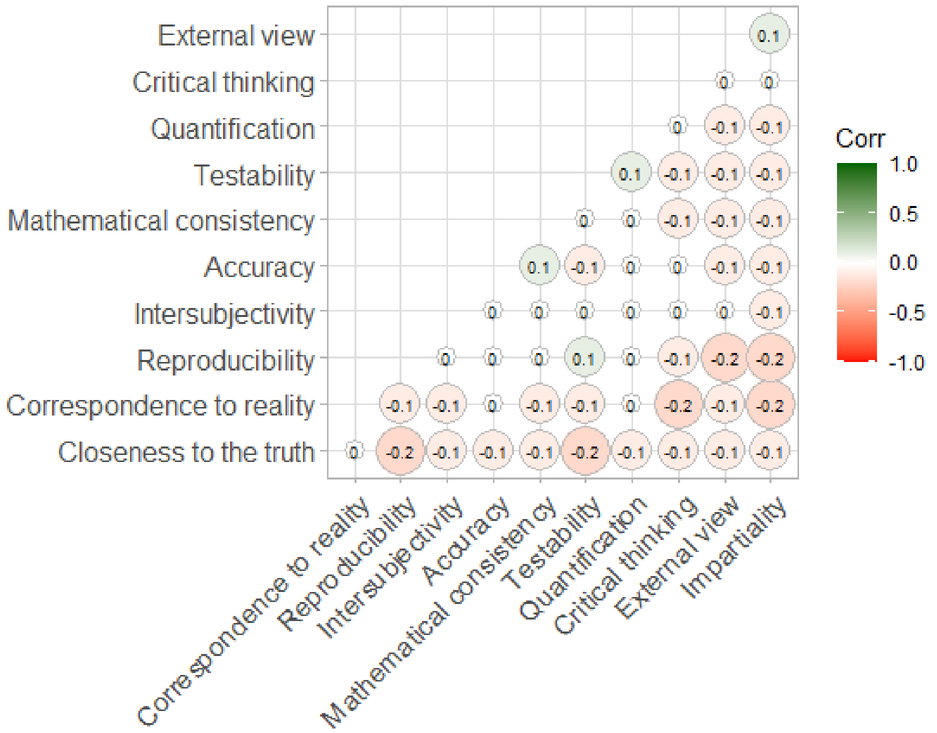
Already from the qualitative break-up of the objectivity concept, we can distinguish that objectivity can be defined by the scientists either positively, or negatively – in terms of affinity, or distancing. The positive quality connotes a close adherence (or affirmation) to something, whether it is the truth, or reality, or accuracy, or mathematical consistency. Whereas the negative quality implies a distance or separation from something – be it impartiality, or intersubjectivity, or external view.

In the qualitative analysis, we confirmed that negatively defined categories tend to group together: one example is Impartiality and External view, which are strongly related ($p<0.001$). This category group also tends to “repulse” other categories: for example, External view is almost never associated with Testability ($p<0.001$), or Reproducibility ($p<0.001$); and Impartiality is almost never associated with Reproducibility ($p<0.001$), or Testability ($p<0.001$) – and also category group: Quantification ($p=0.024$), Correspondence to reality ($p<0.001$) and Accuracy ($p<0.001$).

From the positively defined objectivity categories – Correspondence to reality, Closeness to the truth, Mathematical consistency, Accuracy – only Mathematical consistency shows very weak relation with Accuracy ($p=0.073$). Otherwise, they remain distinguishable standalone categories, which do not display affinity to any other category (they “repulse” them, and they also do not show any affinity to each other). As it turns out, Critical thinking and Intersubjectivity belong to the isolated standalone categories, not linked to any other.

Another possible view is the processual definition of objectivity, which points to the experimental aspects of science, such as reproducibility, testability or quantification. And our data confirm that they “hold together” in a group – as Testability and Reproducibility ($p=0.005$) or Testability and quantification ($p=0.047$) are commonly associated.

These relations can be observed in the following correlation matrix.



The matrix of pairwise correlations visualizes their relations between each two of 11 objectivity categories (all 11 categories are binary variables). For the analysis, we used Pearson correlation coefficients, since this method is best suited for correlations of binary variables.[14]

There are only 4 pairs correlating positively around +0.1, but there are 6 pairs correlating negatively around -0.2, and 25 around -0.1. The dominance of negative correlations has two reasons: First, respondents could choose a maximum of only 3 options out of 11, which means that there were naturally more negative associations than positive. Second, it turns out that our 11 categories are to a great degree exclusive (with the exceptions that were mentioned above), which means that they capture the whole spectrum of disparate dimensions of objectivity.

This finding is also congruent with the other statistical test that we performed – factor analysis. We used *Principal Component Analysis* (PCA), which is suitable for binary data. Factor analysis further pointed to the exclusivity of the objectivity categories because it checks if there are any (latent) unobserved variables that would explain the correlations: In our analysis, the first factor accounts only for 14% of the total variance, and 9 factors (out of 11 possible) were needed for a cumulative variance close to 90%, the tenth factor (out of 11) still accounted for 7.6% of the variability, and only the very last factor made up for less than 5% of the total variability (2.7%). This means that the objectivity categories cannot be further reduced and there are no latent underlying factors.

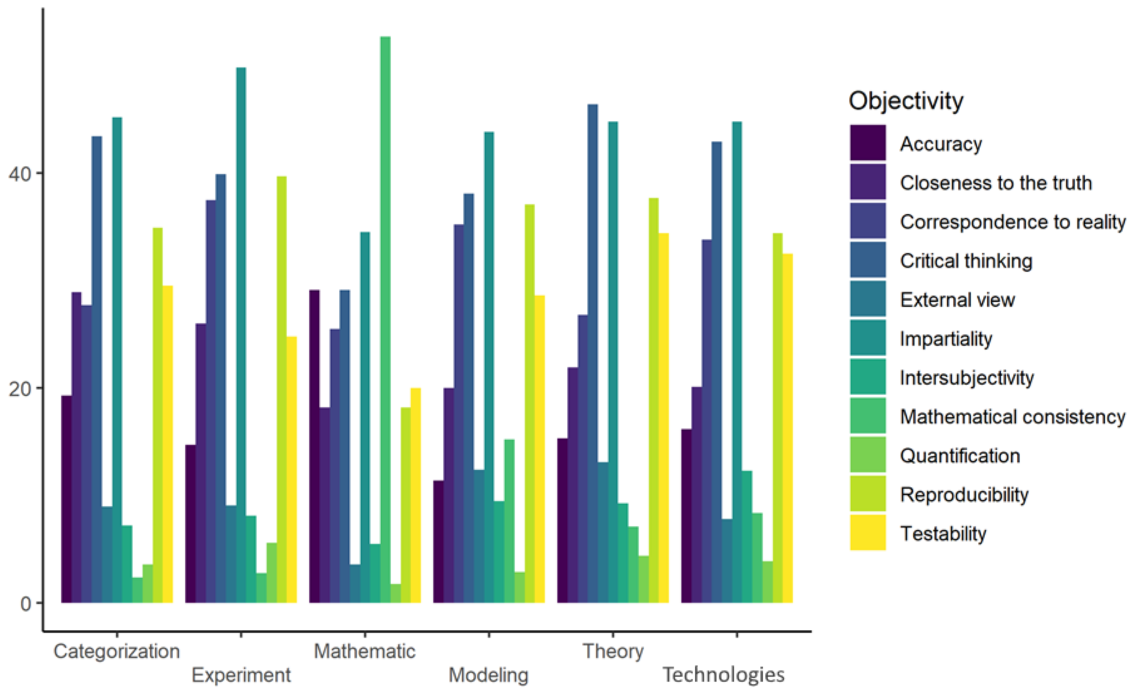
[14] Positive correlations are marked as green, negative ones as red, darker color denotes stronger relationship. Also, for readers' comfort we added correlation coefficient rounded to one digit.

Crombie-Hacking styles

Our next question to answer was how is scientists' understanding of objectivity related to their styles of thinking.

In our sample, the strongest category of the Crombie-Hacking styles[15] was the Design and execution of experiments (48.6%), followed by Development of theories and deeper understanding of natural phenomena (17.9%), Description and categorization of natural phenomena (16,3 %), Development of methods, technologies and devices (15.1%), Modeling and simulation of natural phenomena (10.3%), and Working with mathematical structures (5.4%).

The first chart shows the relations among particular styles (activities) and objectivity categories. The overall message is that understanding of objectivity as expressed in the given categories is not very dependent on the style of scientist, rather it is the same across all styles – with only a few exceptions.



The detailed analysis of the influence of Crombie-Hacking styles doesn't divulge many unexpected findings, and the answers were rather homogenous. Only the scientists working with mathematical structures were significantly different, as they demonstrate disproportionally high preference for Mathematical consistency ($p<0.001$), and Accuracy ($p<0.010$) and low preference for Reproducibility or Impartiality ($p<0.010$, $p<0.050$ respectively). Mathematical consistency was also important for those who employ modeling and simulation style in their work ($p<0.001$). This is hardly surprising, as these distinct styles depend on mathematical consistency and precision.

[15] The respondents could choose up to 3 options from the styles.

Objectivity categories and Crombie-Hacking styles – size of the (sub)samples (%)

	Whole sample	Mathematical structures	Modeling, simulation	Theories	Experiments	Description, categorization	Methods and Technologies
External view	9.0	3.6	12.4	*13.1**	9.1	9.0	7.8
Accuracy	14.8	*29.1***	11.4	15.3	14.7	*19.3*$^{+}$	16.2
Mathematical consistency	6.9	*52.7****	*15.2****	7.1	*2.8****	*2.4**	8.4
Testability	28.0	20.0	28.6	*34.4**	*24.8**	29.5	32.5
Impartiality	47.8	*34.5*$^{+}$	43.8	44.8	49.8	45.2	44.8
Closeness to the truth	24.2	18.2	20.0	21.9	26.0	28.9	20.1
Correspondence to reality	34.8	25.5	35.2	*26.8**	*37.5*$^{+}$	*27.7**	33.8
Quantification	5.0	1.8	2.9	4.4	5.6	3.6	3.9
Intersubjectivity	9.1	5.5	9.5	9.3	8.1	7.2	12.3
Critical thinking	40.1	29.1	38.1	*46.4*$^{+}$	39.9	43.4	42.9
Reproducibility	37.7	*18.2***	37.1	37.7	39.7	34.9	34.4
Size of (sub) sample:	**1021**	**55**	**105**	**183**	**496**	**166**	**154**

Note: Substantive significant differences are in bold, statistically significant differences in italics ($^{+}$ = p<0.100, * = p<0.050, ** = p<0.010, *** = p<0.001).

There were several other noticeable relationships (although significant only at a level of 5% or 10% level – i.e. p<0.050, or p<0.100). Those working with the description and categorization style subscribe to Accuracy (p<0.050, or p<0.100). Those who develop theories conceive of objectivity in terms of Testability and Critical thinking, or External view, whereas Correspondence to reality is less important for them (all p<0.050, or p<0.100). On the other hand, for the experimental style, Correspondence to reality is rather important (p<0.050, or p<0.100), while Mathematical consistency is unimportant (p<0.001). Those developing methods and technologies are agnostic in regard to the objectivity categories and they do not show any significant deviations from the average of the sample.

Conclusion

Among our important findings is that most scientists (almost 80%) discuss objectivity explicitly only occasionally or rarely, but – as some of them indicated in the interviews – the idea is immanently present in science as a core value and precept, and thus doesn't have to be considered on a daily basis. If it does happen, it is very likely due to practical concerns surrounding the scientists' everyday work and their overall conditions. In the categorical breakdown of the objectivity concept, besides Impartiality (with 48% of responses), scientists put strong emphasis on Reproducibility (38%), the related Testability (28%), and Critical thinking (almost 40%), which are all in a way related to the unbiased operation and also skeptical or critical functions of science through which objectivity and robustness of the findings are maintained. The dominance of these categories also signals that scientists think about objectivity rather in terms of concrete implications than in philosophically imbued categories, which again very likely remain in the background because they are considered to be implicit preconditions that make science possible in the first place.

The categorical breakdown itself and the subsequent statistical analysis are among the most important results of our research, because they clarify the use of the objectivity concept among working scientists and also yield a precise description of the category relations. Individual categories can be grouped in several ways, which were suggested in the article: One of them is classification based on the positive affirmation to qualities such as truth, reality, accuracy, or mathematical consistency, in contrast to the qualities evoking distancing such as critical thinking, impartiality, intersubjectivity, or external view. The third group is made up of the categories that express processual characteristics such as reproducibility, testability, or quantification.

As far as Crombie-Hacking styles are concerned, their presence was quite firmly identified in some disciplines in the qualitative phase; however, their traces remained rather fragmentary and rudimentary in the quantitative phase. It is nevertheless possible that a more detailed analysis which would take into account a finer division into subdisciplines would reveal some deeper relationships. At present however, the overall conclusion is that the Crombie-Hacking styles do not impose much influence on (and do not provide explanations of) the way objectivity is understood by scientists – their preferences remain stable across all the styles. We found, however, some discernible patterns, if not very pronounced – the preference among theoreticians to conceive of objectivity in terms of testability or critical thinking, and for experimenters in terms of correspondence to reality, and the very strong preference of those working with mathematical structures (and to a lesser extent also models and simulations) for mathematical consistency. Again, this is not unexpected given their historical genesis. From this we can infer that the scientists also slightly prefer those definitions of objectivity that are familiar and comprehensible to them and typical for their disciplines.

In general, our research proves that an interdisciplinary approach, which we dubbed the integrated history and (experimental) philosophy of science, using tools from empirical sciences to questions stemming from a historical or philosophical context, is possible. Bottom-up approaches and methods can produce a rather exact and transparent picture of how concepts are understood and employed in particular groups including scientists. However, the transfer of these concepts to an empirical setting involves some limits. While it proved to be relatively easy to study the concepts with qualitative methods, which can help to better focus further research and put conceptual theoretical analysis on firmer footing, it proved to be more difficult to make them suitable for quantitative analysis as they had to be updated and simplified (and this attenuated version may stray from the original source). Also, even these adjusted versions may not produce many significant results in the quantitative research.

All in all, experimental philosophy of science, despite being a relative newcomer to the field, can provide a hitherto untapped source of information and knowledge, which can be seen as a complement to conventional methods.

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