A general theory of objectivity: Contributions from the Reformational philosophy tradition

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Abstract
Objectivity in the sciences is a much-touted yet problematic concept. It is sometimes held up as characterising scientific knowledge, yet operational definitions are diverse and call for such paradoxical genius as the ability to see without a perspective, to predict repeatability, to elicit nature's own self-revelation, or to discern the structure of reality with inerrancy. Here we propose a positive and general definition of objectivity based on work in the Reformational philosophy tradition. We recognise a suite of relation-frames – ways in which things function and relate to each other, which can be analytically distinguished in the process of conceptual abstraction. These relation-frames also ground the diverse aspects of scientific analysis within which relationships and properties may be abstracted from entities and systems. We argue that objectivity can be understood as characteristic of representations that attempt to portray a subject in an earlier relation-frame than that in which it characteristically functions. In short, objectivity is projection. This proposal is exemplified from mathematics and the natural sciences and some possible objections to it are considered, as well as its extension to the social sciences.

Keywords
Objective · Subjective · Kant · Bias · Relation-frames · Replication · Representation

1. Introduction: the challenge of objectivity

Objectivity is commonly understood in the natural sciences as a desirable feature of knowledge or of processes by which knowledge is obtained, broadly denoting the reliability of knowledge and its detachment from the knower. Thus, objective scientific knowledge means knowledge that is independent of the perspective of any particular scientist: the view from nowhere, as Thomas Nagel famously construed it (Nagel, 1986). Accordingly, objectivity "expresses the idea that the claims, methods and results of science are not, or should not be, influenced by particular perspectives, value commitments, community bias or personal interests", among other factors (Reiss & Sprenger, 2017, p. 1). There is also a corresponding virtue of objectivity: objective scientists are adept at respecting the norm of removing their perspectives from the knowledge that they help produce. This is not sufficient to ensure the truth of such knowledge, but is generally taken within scientific communities and wider society as a necessary requirement for its reliability.

However, the idea of novel discoveries being made by a scientist whose personal perspective is irrelevant is paradoxical, and more than a little problematic in the context of the historical development of the sciences. We can legitimately ask what elements of a scientist's unique training and experience are to be laid aside when she perceives how the world 'objectively' is, and why some people become notable scientists at all. Objectivity-as-unbiasedness tells us what objectivity precludes (e.g., bias, idiosyncrasy, perspective, and values), but not, more positively, in what it consists. What kind of perception is left when all bias is removed? And operationally, how can the unbiasedness of a scientist be confirmed? Is there any general way to assess scientific methods or results for unbiasedness, or must individual scientists be vetted somehow in pursuit of this ideal? The modern suggestion that the objective scientist should at least be one with no religious commitment is controversial and discredited on both historical (Harrison, 2015) and sociological (Ecklund, 2010) grounds, at least if objectivity is in any way associated with scientific success. While it may be easy enough to accuse particular scientists or scientific outputs of bias in particular instances where allegedly improper influences are identified, we are a long way from having a set of tests of unbiasedness that can be applied as the preventive treatment to secure objectivity as scientific work progresses. The want of an objective test for unbiasedness is paradoxical: can objectivity be attributed objectively?

In its own spirit, objectivity arguably needs a more operational working definition. Having introduced the core idea of objectivity as unbiasedness, this paper examines the more empirical option of objectivity as repeatability, and its crisis (Section 2), before broadening the scope to consider the roots of objectivity as faithful representation of phenomena (Section 3). Section 4 then introduces an ontology of relation-frames, which supports our novel proposal of objectivity as projection (Section 5). Section 6 provides a systematic series of examples before Section 7 addresses some objections and extensions. Section 8 concludes by assessing the significance of our general theory of objectivity.

2. Objectivity as repeatability

An operational account of objectivity must fill the lacunae left by the largely negative view of objectivity-as-unbiasedness. One promising alternative may be called objectivity-as-repeatability. Objectivity, on this view, is the quality of scientific methods or results that makes them repeatable – or, by extension, the virtue of a scientist who is skilled in accurate replication of methods or results. For example, five of the eight operational definitions of objectivity outlined by Douglas (2004) concern repeatability, whether by an individual researcher, within a research community or among independent methods (the remaining definitions being negative, about avoiding undue influence of values). As this diversity suggests, the concept of scientific repetition is not altogether straightforward. At one extreme, it might allude to a scientist's motor skills enabling him to go through the *same motions* repeatedly while conducting an experiment; at the other extreme lies *similarity of conclusions* drawn from multiple experiments that differ in their design and execution. The former may be insufficient for a definition of objectivity, but the span from there to corroboration of findings using multiple methods takes in a number of important options. These options have received special attention thanks to the Replication Crisis, at which we must briefly look.

Objectivity-as-repeatability might have faced fewer challenges before empirical evidence called into question the repeatability of findings in many areas of the health and social sciences (Ioannidis, 2005a; Krauss, 2018). While the perceived crisis in scientific replication is at least partly attributed to problems in scaling up common statistical testing procedures (Ioannidis, 2005b), the resulting literature has raised important questions about terminology, about what kind of repeatability is expected of good science and about what constitutes successful replication. To 'reproduce' a result has been defined as to obtain it using the same methods and data as a previous study, and to 'replicate' as to obtain the same result using new data and/or methods (Barba, 2018). We come back to the possibility of reproducing *data* in the next section. Replicability, meanwhile, is also broken down into direct and indirect (conceptual) replicability, this latter option being the use of different methods to confirm a given hypothesis (Schmidt, 2009). Most importantly for the present discussion, it is by no means straightforward to adjudicate the success of one or more attempts to reproduce or replicate a previous result. Indeed, the range of possible statistical techniques for confirming successful replication (Hedges, 2019) may on its own be enough to send well-meaning practitioners back into the arms of straightforward Popperian hypothetico-deductivism. If we take seriously the objectivity-as-repeatability view, it is disconcerting to find a paucity of consensus, standard procedures or textbook treatments on replication, either in particular sciences or the philosophy of science, instead of which we had, at least until the last decade, "[few] papers dealing with the topic, even fewer chapters in books or monographs", "no clear-cut nomenclature", and, worst of all, "a discrepancy between what is described as a replication from a theoretical point of view and what is actually done in everyday science" (Schmidt, 2009, p. 90). While the Replication Crisis continues to be investigated across diverse fields, it already shows objectivity-as-repeatability to be underdeveloped as a foundation for science.

Advocates of objectivity-as-repeatability may not, of course, be deterred by the scholarly underdevelopment of this option, nor perhaps even by its apparent empirical deficit in some areas of the sciences. However, it is significant that the discussion of this option focuses on objectivity as an attribute of knowledge and barely addresses objectivity as a virtue. In contrast to objectivity-as-unbiasedness, objectivity-as-repeatability seems to offer no guidance to aspiring scientists beyond basic honesty and such abilities as fine motor skills, good memory, aptitude in clear description of one's methods and an ability to follow other people's instructions accurately. Indeed, it is difficult, on this view, to see how any particular qualities of a scientist could fully justify the accolade 'objective' as it is used in both scientific and peri-scientific discourse. Objectivity seems to be a virtue, and as such it ought to yield a prescription for how to produce objective science. 'Try to make your results repeatable' can only be a vague start. And in the current research climate at least, any disposition towards seeking funding and spending time attempting to replicate previous published results is likely to be a factor of professional morbidity (Schmidt, 2009).

3. The scope of objectivity

Can we preserve the concept of objectivity as both a virtue and an attribute of knowledge? Douglas (2004) does so by arguing that the concept is irreducibly complex. Indeed, while her eight approaches to objectivity can largely be divided between objectivity-as-unbiasedness and objectivity-as-repeatability, one of them construes it as an attribute of entities or concepts. Evoking Ian Hacking's (1983, p. 22) aphorism with reference to the reality of electrons, "If you can spray them, they are real" (or "reliable", to make space for anti-realist interpretations), Douglas proposes *manipulability* as a criterion for objectivity. This may be tied to a (working) knowledge of things or concepts, but the focus on entities points to another distinction that is important to us and, as it happens, an older sense of objectivity.

Objectivity may be attributed not only to theoretical knowledge and conclusions, but also to knowledge of particular experiences, concerning data – and this is apparently its original meaning. Daston and Galison (2007, pp. 27–35) trace the origins of 'objectivity' to Kant's epistemology and subsequent neo-Kantian approaches to the natural sciences, describing a 19th-century paradigm of 'mechanical objectivity' in which researchers attempted to let nature depict itself, supremely using techniques of photography. With hindsight, given all that we know about not just the editing of photographs but also the importance of the photographer in the selection of subjects, the choice of viewpoint and the framing of the work, the idea that photography could enable nature to reveal itself 'as it is' may be naïve – perhaps arising from the over-enthusiastic embrace of a new technology. But it seems that 'objectivity' was initially a property of specific scientific data and artefacts – iconically, atlases – arising from techniques that seek to capture the particulars of reality. The paradigm of mechanical objectivity, according to Daston and Galison, largely replaced the older scientific goal of 'truth to nature', which depended on the naturalist discerning the ideal type behind diverse individuals in search of general truth (what we might call theoretical structures, patterns or processes). And even if mechanical objectivity has been to some extent superseded by 'trained judgement', in which a limited interpretive role for the scientist returns (Daston & Galison, 2007, pp. 309–361), we can see objectivity here as faithfulness to reality, and only secondarily as unbiasedness or repeatability. Nevertheless, it is closely connected to both.

In keeping with the repeatability definition, objectivity as faithful representation may be construed as the reproducibility of actual data. But like the unbiasedness definition, it is operationalised in a negative way: the ability to eliminate biases and perhaps any interpretive role for the scientist at all. Daston and Galison call it the will to will-lessness (Daston & Galison, 2007, p. 203). Cynicism at this point might even lead us to discern sexist overtones, if this will-less faithfulness echoes Francis Bacon's use of 'penetrating' to describe how the scientist enters "those holes and corners when the inquisition of truth is his whole object" (Soble, 1995, p. 197). In any case, objectivity as faithful representation seems too limited to account for the general usage of 'objectivity'. If the objective production of scientific data has grown in importance with the historic rise of the biological and human sciences, where variability among individual specimens is typically more pronounced than in the physical sciences, nevertheless the generation and dissemination of theory via diverse activities of abstraction, generalisation and model-building still remains central to scientific progress. The focus on faithfully capturing evidence and representing it as data does not exhaust the concept of objectivity so much as shift its locus from the theoretical construct (in the older 'truth to nature' approach) to the very sources of theory construction (in the 'mechanical objectivity' and 'trained judgment' views). The proposal that we describe below articulates a sense in which objectivity pertains to theory as much as to data, is as old as scientific thought itself, and is by no means passé.

An adequate view of objectivity, we suggest, ought to provide a positive operational definition that can account for objectivity as both knowledge attribute and virtue, supporting both descriptive and prescriptive usage. In addition, it ought not to demand any such paradoxical genius as the ability to see without a perspective, to predict repeatability, to elicit nature's own self-revelation, or to discern the structure of reality with inerrancy. Ideally, there would even be an objective way to attribute objectivity.

4. Analysis using relation-frames

The ideal of mechanical objectivity, in Daston and Galison's account, was a means of addressing Kant's fundamental distinction in *The Critique of Pure Reason* between phenomena (objects or events as we perceive them) and noumena (objects or events as they exist independently of our perception) (Daston & Galison, 2007, p. 30). One striking historical facet of this account is that the meanings of 'objective' and 'subjective', while always opposed to each other, have virtually switched (Daston & Galison, 2007, p. 30). In pre-Kantian usage, 'subjective' refers to the functioning of things themselves, while 'objective' refers to the appearance of things when perceived (as objects) by subjects (typically humans) (Dooyeweerd, 1953b, pp. 367–368). This usage, which matches the grammatical distinction between 'subject' and 'object', has been replaced (apparently as part of Kant's Copernican Revolution) by today's familiar epistemological usage in which 'subjective' always relates to human thinkers, while 'objective' relates to things in themselves – or at least (*pace* Kant), to things as they can be publicly known, independently of observers or particular methods of observation. The proposal outlined below bridges between the older and the modern usage.

The principal insight of our proposal comes from the tradition of Reformational philosophy, which focuses on entities and their relations and functioning rather than the more traditional concepts of substances and their properties. Originating in the Netherlands in the 1930s (Ive, 2011, 2015), this tradition seeks to avoid a perceived tendency toward ontological reductionisms in Western thought, especially materialism and mathematical Platonism. The core of this approach is the recognition of an ordered suite of *relation-frames*: ways in which things can function and relate to each other, which can also be analytically separated from each other by thinking persons in the process of conceptual abstraction (Stafleu, 1980, 2019, sec. 1.5). Thus, these relation-frames also ground the diverse aspects of scientific analysis within which relationships, functions and laws may be abstracted from entities and systems. A list of fifteen such relation-frames, originally termed 'modal aspects', has been proposed by Herman Dooyeweerd and Dirk Vollenhoven (Dooyeweerd, 1953a; Vollenhoven, 2005) in empirical attempts to discern structure behind the varied phenomena treated by the diverse array of fields of human scholarship. Such diverse aspects are evident from the coexistence and mutual coherence of sciences ranging from mathematics and physics to linguistics and sociology, as well as aesthetics, ethics and religious studies. The list remains open to revision, but the early[1] relation-frames – those most relevant to the natural sciences – have proven resistant to critique by scholars working in the Reformational tradition.

The first six relation-frames are identified as: numerical, spatial, kinetic, physical, biotic and sensory, with corresponding disciplines of mathematics (covering the numerical and spatial relation-frames), physics/chemistry (covering kinetic and physical), biology (covering biotic and some sensory issues) and psychology (covering sensory relations and functioning). Each relation-frame is conceptually foundational to, and simpler than, those that follow it, which in turn open it up to the conception of wider possibilities. For example, the numerical relation-frame can only describe quantitative relationships (smaller/equal/larger, ratios, etc.), while the spatial relation-frame opens up the use of numbers to describe dimensionality; conversely, spatial relations may be numerically described in terms of magnitudes. Moreover, a numerical plurality of similar shapes becomes possible once we conceive of the spatial relation-frame, and the concept of equivalence (besides equality) arises. Then, when the kinetic relation-frame is considered, numerical and spatial relations can be conceived of as changing in time, and the concept of relativity arises. Table 1 lists some of the characteristic concepts of the first six relation-frames in their order of increasing complexity[2].

Each relation-frame is characterised by its laws and core concepts. With respect to a given law, something is a subject if it is directly subjected to that law, or an object if it can be indirectly subjected to that law (i.e., via a subject). For instance, numbers of all kinds are directly subjected to numerical laws, and in that context should be considered subjects. They are not subjected to spatial laws directly, but can be indirectly (via spatial subjects like triangles, as we discover through geometry), and can then be considered spatial objects. Since the numerical relation-frame is the first one, there can be no numerical objects, and every countable thing, from concepts to human beings, is directly subject to numerical laws. The laws of the spatial relation-frame, meanwhile, only apply directly to things that have a form, leaving numbers as potential objects in this relation-frame (Table 1). All material entities, including those such as plants that are characterised by the biotic relation-frame, also function physically as subjects, while anything whatsoever may be regarded as an object from the perspective of a law in a suitably late relation-frame. The sciences have been characterised by the discovery, description and application of the natural laws by which things relate to each other, as well as the discovery and classification of natural kinds that characterise each relation-frame.

[1] 'Earlier' and 'later' are the preferred overarching relations, reflecting the undergirding role of time in Reformational thought.

[2] The full conventional list of relation-frames (aspects) can be viewed on *The Dooyeweerd Pages* at https://dooy.info/aspects.html.

Table 1. The first six relation-frames, of particular relevance to the natural sciences, with some of their characteristic concepts.

Relation-frame	**Characteristic sciences**	**Characteristic concepts**	**Characteristic entities, systems and processes**	**Potential objects under laws of the relation-frame**
Numerical	Number theory	Quantity, equality, smaller/larger	Numbers, sets, groups, equations	*None*
Spatial	Geometry	Magnitude, equivalence, dimension, distance	Forms, displacements, symmetry, graphs	Numbers
Kinetic	Relativity theory	Velocity, relativity, wave-packet, space-time	Motions, wave-packets	Numbers; forms
Physical	Thermodynamics, Quantum physics	Interaction, equilibrium, energy, force, entropy	Bodies, interactions, flow, reactions	Numbers; forms; motions
Biotic	Biological sciences	Life, growth, reproduction, evolution	Cells, plants, metabolism	Numbers; forms; motions; non-living material
Sensory	Psychology, Ethology	Sensation, response, intention	Animals, behaviours, perceptions, qualia	Numbers; forms; motions; inanimate material

5. Objectivity-as-projection

Our proposal is that an objective account is one that projects relations in one relation-frame onto relations in an earlier one. That is, objectivity is characteristic of representations that portray a subject in an *earlier* relation-frame than that in which it is qualified (i.e., characteristically functions). In a linguistic metaphor, an objective representation is one that transcribes its subject into a suitably-early relation-frame. In a spatial metaphor, it is the projection of structures or phenomena from their full native reality onto a lower-dimensional space, rather as a three-dimensional bird in flight may cast a two-dimensional shadow on the ground. ‘Dimensions’, in this metaphor, refers to relation-frames in which events and relationships may be characterised, and the projection is from a later relation-frame, such as the biotic or physical, to an earlier one, such as the spatial or numeric.

The novelty of this view invites several points of clarification. First, the relation-frame in which a structure, process or phenomenon ’characteristically functions’ means the latest relation-frame in which it functions actively or spontaneously: i.e., as *subject* (in the pre-Kantian sense). In the tradition of Reformational philosophy this has been termed the ‘qualifying’ relation-frame: for natural non-living entities it is the physical relation-frame, for plants it is the biotic and for animals with a basic nervous system it is the sensory relation-frame. In a realist view, the physical sciences largely deal with physically qualified structures and processes and the biological sciences with biotically or sensitively qualified ones (see Table 1 for examples). In a non-realist view, perceivable phenomena might be taken to function actively in the sensory relation-frame insofar as phenomena exist subjectively in the minds of observers. This may affect what counts as objective for an anti-realist as compared to a realist.

Second, projection means the use of natural processes to attempt to represent systems in a relatively earlier relation-frame. The processes underlying projection may themselves be physical, biotic, sensory, etc, and are also at least partly cognitive; the key point is that projection is not radically arbitrary. However, the correctness or usefulness of the outcome is not a criterion of its objectivity, nor is the reliability of the process of projection, avoiding a regress to the question of what reality is really like. Objective accounts *might* point to some real coherence among relation-frames, but it is an empirical discovery if they do.

Third, our definition can apply both to data and (at least for realists) to models. That is, objectifying an entity – such as by measuring or photographing it – is characteristic of objectivity in data collection, while objectifying a structure, process or phenomenon in a model of reality – such as by specifying its typical dimensions or creating a diagram or 3-dimensional model of it – characterises objectivity in theory-making. While objectivity in theory-making means to isolate and describe some property of a structure or process in an earlier relation-frame, objectivity in data collection means to project a property of an individual or situation onto an earlier relation-frame using a suitable method. Photography is a good example of the latter. Notwithstanding the range of factors that must be specified and controlled by the photographer, a photograph can produce a spatial projection of any situation that is at least physical (i.e., qualified by the physical or a later relation-frame). Simple quantification of length using a graduated ruler is also such a method, projecting a spatial property onto a numerical one. Indeed, insofar as the world is regular or law-governed, in principle any method that generates outputs in a certain relation-frame in response to phenomena that function actively in a later relation-frame is likely to have some objective validity, at least with sufficient replication and statistical treatment. We return to this consideration in Section 7 below.

Finally, objectivity-as-projection lends itself to a corresponding virtue: aptitude in seeing systems projected onto earlier relation-frames. An objective scientist might be a theorist who is adept at conceiving ways to quantify, diagram or otherwise model obscure systems, or an experimentalist adept at measuring, imaging, filming or even making casts of entities. The innovators of such techniques have often been the founders of disciplines and sub-disciplines, but even the more pedestrian scientist is generally skilled in their application. The objective observer sees in a way that simplifies complex reality.

Why should objectivity be defined as projection to an earlier relation-frame and not to a later one, or to an alternative representation within the same relation-frame? Our claim centres on the idea that objectivity, intuitively, should impose a constraint on the description of data or a model. Not just any description can be objective; an objective description of nature is one that is somehow constrained by nature itself. This is surely a basic way in which objective accounts may merit such accolades as faithfulness to reality, unbiasedness and repeatability. Projection to an earlier relation-frame, then, is a transcriptional and simplifying constraint. The multi-faceted fullness of a real situation or phenomenon may be described in many ways, and subjective interpretations enjoy unlimited freedom of description. Projection to an earlier relation-frame means the challenge of discovering a functional analogy that captures (or transcribes) a part of reality in a simplifying way, without of course claiming to offer a sufficient or exhaustive account (see Section 7 for discussion of reductionism). Meanwhile, representation within a later relation-frame is not objective because it brings in features that are extraneous to the system or situation being described, arising from human subjective functioning. Teleological and anthropomorphic models are examples of this, whether in physical models, such as the principle that 'water seeks its own level', in biotic models, such as homeostasis being the drive towards a set point, or in evolution, such as that adaptations have purposes. Representation within the same aspect is a borderline case, but crucially it does not accept the constraint of using an earlier, foreign relation-frame. (We consider an example in the next section.)

It should be clear from the above discussion that suitable quantification can constitute, or contribute to, an objective representation of any structure, process or phenomenon other than one that is itself really just numeric, such as a discrete mathematical function (we can say that the structure to be objectified must be *at least* spatial, as illustrated in the next section). Similarly, a graphical representation can count as an objective representation of any structure, process or phenomenon that is at least kinetic. Our account gives the importance of measurements and diagrams in the natural sciences as a constituent of their objectivity. Our most basic illustration, however, will come from the field of mathematics.

6. Objectivity illustrated

The basic validity of objectivity-as-projection may be demonstrated by a curious feature of the history of mathematics. Euclid's *Elements*, for centuries the textbook of mathematics in the Western world, treats geometry without numerical quantification (Grattan-Guinness, 1996). The demonstration of theorems of geometry in the *Elements* does not invoke numerical lengths, areas or volumes; rather, it depends on demonstrating the non-numerical equivalence of constructed lines and shapes to each other. Euclid's version of Pythagoras' Theorem, for example, states that the square on the hypotenuse is "equal to the squares" on the other two sides (Fitzpatrick, 2007, p. 46): lines are not quantified nor lengths multiplied, and neither are areas quantified or added up. Later mathematicians, allegedly influenced by the rise of algebra, saw that quantifying spatial relations provided a powerful set of tools for the application of geometry in architecture and other forms of engineering (Stillwell, 2019). For our purposes, the important observation is that forms of objectivity we now take for granted were not always so assumed: even geometry can be, and long was, practised without objectification of spatial relations to numerical ones. Indeed, Shapiro (2001, p. 231) suggests that this feature of the Euclidean approach has its successor in the 'Science without Numbers' of Hartry Field (Field, 2016). If Field's proposal raises the curious prospect of the de-objectification of physics, it is different again from the Aristotelian tradition of physics which for the most part lacked any quantification of kinetic, let alone physical, relations (Stafleu, 1987, p. 22, 2016, sec. 1.4). The objectification of the kinetic and physical sciences may have taken place some centuries after the objectification of geometry, but it too is now built into successful scientific practice to such an extent as to be taken for granted.

The centrality of quantification to the natural sciences needs no special illustration. However, while metric scales are foundational to the physical sciences, it should be noted that counting is a basic form of quantification, and one that might be argued to contribute to the objectivity of many areas of the biological and social sciences. Spatial representation too is ubiquitous in the sciences, from molecular models via the dispersal kernel to social distance (in a pre-Covid sense), and from the graph via the atlas to the electron micrograph. The case of kinetic representation is less familiar in some areas. Moving images are a relatively recent innovation in the history of the sciences, and only in the last few decades has their creation come within easy reach of scientists at large. Video footage is certainly an important data source in some areas of biology and the human sciences. It also seems that animated models may be growing in prominence as part of theory development in molecular biology; certainly, animations are widely used in education.[3]

Looking further along the sequence of relation-frames we come to physical representations, especially those serving as models in the biological sciences. For example, the concept of the ion pump in molecular biology represents biotic reality in the pre-biotic terms of fluid propulsion. This is of course a metaphor, but one that carries more than linguistic force: in a biophysical model of cell dynamics, there is theoretical reward from objectifying the proteins in question as pumps of a continuous fluid that represents certain species of ion. Not all analogies or models are objective in the sense of projecting a system onto an earlier relation-frame, however. The fluid-in-pipes model of the flow of charge in an electric circuit, for example, is a physical analogy of a physical system and arguably its benefit is more didactic than conceptual. It does not bring a natural constraint to bear on the theory of circuits, and it would not be used for research purposes.

For a thematic set of examples, we move on to the science of ecology. Gunton and Gilbert (2017) show how a range of diverse paradigms that coexist in contemporary ecology objectify biological systems of study in terms of physical systems (ecosystems ecology and also plant metabolic theory), spatial patterns (macroecology) and numerical quantities (population dynamics and species-richness studies). All of these paradigms make use of quantifications and in this sense all of them objectify ecological systems to the numerical relation-frame, but their spatial and physical models also play important intermediate conceptual roles. Without objectifying its subjects of study, ecology would arguably remain at the level of natural history. And natural history itself depends, like ecology, upon objective data-collection methods: measurements, diagrams and illustrations.

A final example comes from the sensory relation-frame. Object relations theory (Fairbairn, 1949) serves within psychoanalytic psychology to explain (characterise, represent) how the developing infant

[3] Readers unfamiliar with this genre may discover it by doing an online search for 'cell biology animations'; one of the most impressive is Harvard University's 'The Inner Life of the Cell' at https://www.youtube.com/watch?v=wJyUtbn0O5Y. Most people find quite mesmeric the animation of a kinesin (a motor protein) 'walking' along a microtubule, dragging a vesicle.

begins to make sense of its relations with others. Initially, these others are understood as part objects, so a baby's primary caregiver (normally its mother) is not seen as a relational subject[4] but as a disparate collection of objects – such as the good breast (that provides milk when the baby is hungry) and the bad breast (that does not). As the infant grows, so long as its early relationships have been good enough, it is able to assemble these perceived objects and come to a realisation that the same real entity that, for instance, provides milk, warmth and desired contact (the mother) sometimes also fails to do so as quickly and completely as would be liked. We can therefore see the developing child as a spontaneous scientist, objectifying its experience in early relation-frames even before it appreciates the richness of its external reality.

7. Objections and extensions

Our proposal moves away from the Enlightenment ideal of 'objectivity' as a pillar of foundationalism. Objectivity is not a property of knowledge *per se*, such as reliability or infallibility; nor is it a desirable epistemic attitude or state, such as certainty, incorrigibility, positivity or the like. Instead, objectivity is a mode of representation that is briefly summarised by the metaphor of projection. Colloquially, it is the scientist's attempt to 'pin down' nature: to tame the tangled bank.

It might be suggested that objectivity-as-projection needlessly excludes some forms of modelling or explanation. There are other kinds of abstraction that seem to make important contributions to scientific progress. There is abstraction to types of entity such as the electron, oxygen, *Homo sapiens*, etc, and to ideal types (Galilean idealisations): the frictionless plane, the ideal gas, the population in Hardy-Weinberg equilibrium, and so on (examples from the social sciences could be adduced). These 'concrete' abstractions are unquestionably foundational to much scientific work, but they are the product of abstracting types rather than relations. This fundamental distinction in Reformational philosophy (Stafleu, 1980, p. 11) precludes such types being inherently 'objective' and indeed it concurs with prevailing discourse in which objectivity is mostly used in an epistemological sense, predicated of knowledge and of knowers. What would be objective, nonetheless, is the modelling of a type of entity in an earlier relation-frame, e.g., the electron as a spatial point, with a quantified charge, or indeed *Homo sapiens* as an animal.

Conversely, given a view of the world as law-governed, it might be asked whether our definition allows too much. Surely, it might be argued, even a biased, inconsistent propagandist would become 'objective' under our definition merely by providing superficial sketches or plucking numbers from the air? As a test case, Ernst Haeckel's famous drawings of embryos in support of the theory that ontogeny recapitulates phylogeny are objective *qua* spatial representations of biotic processes, even if their accuracy is rated somewhat less by today's biologists than by initial audiences (Hopwood, 2015). Similarly, asking an untrained volunteer to describe sensory properties of foodstuffs on a numerical scale is objective despite the dominance of subjective human functioning in the process. Clearly in both cases it would be desirable to reduce human bias, to secure replication, and to seek the most faithful representation possible, but these desiderata are enhancements to objectivity rather than essential constituents. Objectivity-as-projection is a form of representational practice, regardless of the perceived success of any example of such practice.

We should also clarify the distinction between objectivity and reductionism (all forms of reduction). Even on a realist interpretation, objectivity-as-projection does not entail any claim about the sufficiency of an early relation-frame to account for phenomena characterised by higher relation-frames. Although our proposal might be taken in support of a programme of metaphysical reduction (albeit an uncommon form in which numerical reality is fundamental), objectivity-as-projection itself merely means finding that simpler (earlier) frames of reference can give insight into a complex reality or phenomenon. Any stronger claim about the metaphysical independence of the simpler frame (Clouser, 2005, Chapter 4) would go beyond the common notion of 'objectivity' as an epistemological concept. An alternative realist interpretation of the success of an objectivity-as-projection view would be that there is a real coherence among relation-frames, such that quantitative laws, for example, naturally apply to processes characterised by higher relation-frames.

[4] The Reformational philosophy tradition posits that humans function as subjects in all relation-frames (Dooyeweerd, 1953a, p. 5).

The predicate ‘objective’ is often used as though it admits of degrees, even though objectivity is held up as an absolute ideal, and indeed both ‘unbiased’ and the original Kantian concept have an absolute character. In the view outlined here the basic criterion of objectivity is binary: either a representation attempts to project a system to an earlier relation-frame or it doesn’t. Degrees of objectivity could be considered in terms of how much earlier the object relation-frame used is than the subject relation-frame: to represent a biotic process using numerical quantities (e.g., life-expectancy) would then be more objective than representing a physical process numerically (e.g., in terms of its internal energy). In fact, quantified in this way, the degree of objectivity would itself be an objectification of the analytical process of projection. As a special case, the question as to whether a representation is objective or not itself becomes an objective question about whether the representation involves projection in the direction of earlier relation-frames. In this way there is a satisfying reflexivity about objectivity-as-projection.

8. Significance of the Reformational view

We have argued that objectivity can be understood as concerning the applicability of the laws of earlier relation-frames (e.g., the numerical one) to objects and their relations that are qualified as subjects in later frames (e.g., the physical and biotic). It entails a kind of triangulation with respect to the observer or knower. Using a spatial metaphor again: by referring to two different relation-frames, we can reduce the effect of our own (cultural, historical, semantic) perspectives, thus enhancing the objectivity of our empirical findings or conceptual theorisation. Objectivity in this sense is normative insofar as scientists find it desirable to capture, i.e., ‘pin down’, some aspect of complex reality in a simplifying way.

This definition of objectivity helps account for the importance of measurement and quantification in the sciences, and also for the central role of diagrams and illustrations in many scientific disciplines. Indeed, the nature of objectivity seems to be such that when relations among subjects in one relation-frame are projected onto an earlier relation-frame, the laws that pertain to the earlier relation-frame continue to apply to the relations in the later frame. For example, when post-Euclidean geometers quantified lengths numerically, the utility of this lay in the fact that the laws of arithmetic turn out to apply to lengths, areas and volumes. Similarly, arithmetic applies to velocities, by means of a Lorentz transformation to account for relativity, to physical quantities such as energy, using appropriate laws of mass-energy equivalence where appropriate, and to biotic quantities such as lifespan and growth rate, subject to appropriate specifications. Laws of geometry, in turn, apply to motion and gravitation, with appropriate relativistic treatment, and to physical phenomena such as fields (Stafleu, 1980, p. 112). In this way, the proposal of objectivity-as-projection can be taken as a more general account of ‘The unreasonable effectiveness of mathematics in the natural sciences’ (Wigner, 1960). It can also help explain the increasing tendency of the human and social sciences to rely on quantification.

Looking to the social sciences, we note that an understanding of objectivity-as-projection may also help account for the adequacy of written accounts as objective representations of social phenomena. The lingual (or sign) relation-frame is foundational to the social, economic and jural relation-frames, for example, which allows descriptions of socio-economic phenomena to count as objective. In due course, it may be increasingly possible to use earlier relation-frames, although the ongoing arguments within economics about the utility of mathematical modelling should caution us against hasty objectification in the social sciences. Economics itself deserves special treatment on account of the overarching importance of money as an objectification of (subjective) value.

We conclude by reflecting on how the view advanced here relates to prevailing concepts of objectivity. Empirically, objectivity-as-projection seems to correlate with the main concepts of objectivity alluded to earlier. First, objectivity-as-projection ought to yield some degree of repeatability across time and among different researchers and methods. In the case of data, objectification entails the application of a method, typically involving an instrument, in order to produce numerical, graphical or other traces that objectify some more-complex reality in a replicable way. In the case of theory, objectification entails a conceptual move, such as the claim that a numerical or spatial model captures important properties of a real type of entity. Such claims stand or fall not merely on plausibility or utility but also on their ability to be communicated from one expert to others, providing a form of repeatability among different researchers. Second, objectivity-as-projection reduces the space for biases and personal values to alter representations. Discovering a functional projection from one relation-frame to an earlier one introduces a natural constraint and results in a thinner, simpler representation, whether of data or in theory. Returning to our spatial metaphor, there is less scope for disagreement about the shadow of a bird in flight than about the bird itself. Even where objectivity does not involve projection below the lingual relation-frame in some social sciences and humanities research, significant constraints are nonetheless introduced by the use of a common language. Objectivity-as-projection can at least be considered a positive operational tool to reduce the scope for bias.

Ultimately, the plausibility of this Reformational view of objectivity comes down to a question of whether something like the proposed sequence of relation-frames is real or at least reliable. The proposal is a transcendental-empirical one (Strauss, 2009, p. 231), and the consensus (at least among philosophers in the Reformational tradition) about the identity and order of the first six or seven relation-frames is striking. Indeed, it is in the natural sciences, which deal with these early aspects of reality, that the ideal of objectivity seems best realised. In the spirit of empiricism, we envisage our approach as a tool for understanding the successes, challenges and respective progress of diverse scholarly disciplines, and one which should be judged by its fruitfulness.

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