How Scientists reach Agreement about new Observations

David Gooding

Science Studies Centre
University of Bath

Epistemology has been socialised. Cognitive and social interactions between observers are now as important as their interventions into the course of nature. This contrasts with traditional views of how we get natural facts into our discourse about nature. These assumed the efficacy of individual observers' causal interactions with the natural world, making their interactions with other observers irrelevant. Kant's conclusion that empirical access depends also upon our concepts did not challenge the individualistic character of the epistemology of science. Observers' agreement about their observations showed that each individual can have independent perceptual access to one and the same world.

Historical and sociological studies of science show that social and procedural aspects of observation in the laboratory make an essential contribution to consensus about observations (see Knorr-Cetina and Mulkay (1983) and Gooding (1985a). The sociological turn suggests that to explain observers' consensus about their observations we must examine their interactions with each other. However, like the traditional, individualistic theories, recent studies fail to address the question of how new perceptual information passes from personal experience to public discourse. How do individual observers communicate novel information so as to incorporate it into their talk and thought about the world?

Here I am concerned mainly with the role of representational practices in leading observational consensus, but I also hope to show why, although many versions of the world are compatible with the world, not just any version will do (see Goodman 1978, p. 91 ff.). Empirical beliefs are constrained by experience, even if they cannot be made to stand in direct opposition to it. This is because there is a strong connection between the success of practices and representations. This interdependence reflects the complementarity of thought and action and, more generally, of nature and culture.

1. Representation and Observational Consensus

How is a new phenomenon recognized and accepted as anomalous? Quine

PSA 1986, Volume 1, pp. 236-244

https://doi.org/10.1086/psaprocbienmeetp.1986.1.193124 Published online by Cambridge University Press

postulated similarity of stimulation as the basis for observational assent (Quine 1973, pp. 37 ff.). His explanation presupposes the communicability of the stimulus effects. It therefore presupposes prior agreement amongst observers about how to represent the "impingements" of an environment (p. 41). Quine offered no account of how such agreement can arise for novel stimuli. He was more concerned with translation between existing conceptual schemes. The problem for the observer of a new phenomenon is not that others hold different theories, but that with respect to novelty, everyone is a novice, a lay-observer. What is observed is not, apparently or self-evidently an instance of existing classes of objects or percepts. Observers typically invent descriptions which they can easily communicate in order to direct the attention of others to just that aspect of a phenomenon they intend. The adequacy of these new representations has to be argued and demonstrated.

"Adequacy" presupposes agreement about what is represented. What is such agreement about? My answer draws upon three salient features of observation. First, the information constructed during experimentation is rudimentary and its significance is not always self-evident, even to its originators. This information does not emanate, ready-made, from the natural world. At first it has no existence in mental or linguistic representations independent of the practices which produce and communicate such representations. Second, in order to discover new phenomena experimentalists invent new ways of making the world impinge on consciousness in shareable ways. They make new information evident. Consensus about observational novelty is rooted, not in causal stimuli emanating from nature, but rather in human activity (as von Wright (1971), Hacking (1983) and others have argued). Third, in order to make shareable what would otherwise remain a private experience, observers must leave a private world of phenomena to enter a public world of talk about percepts and objects.

The need to make the semantic ascent obliges them to construct preliminary representations. Their semantic ascent is not as Quine envisaged it (1960, pp. 270-276). A single "ascent" does not obviate the need to descend again to the phenomenal world of objects and (non-linguistic) behaviour. This is because that world cannot by itself determine that all observers will make the same ascent. The world cannot constrain every observer to attach the same bit of linguistic behaviour to the same "stimulus". The ascent of any individual must therefore be tried against those of other observers as well as against the world. Because the one-to-one mapping of percept and concept postulated in traditional epistemologies does not accommodate these features of observation, we need a more dynamic and interactive conception in which every observer's construals of the world are tried against other observers as well as the world.

2. Construals

Studies of the initial, exploratory stages of experimental processes show that scientists' primary concern is to represent and communicate possible interpretations of novel phenomenal input, i.e., to produce shareable new experimental possibilities. I shall call these new possibilities construals. Experimenters construct representations to communicate information relevant to their projects. They articulate interpretive possibilities (construals) against regularities which they are learning to identify or produce. Construals enter discourse as practical, operational bases for the communication and interpretation of new phenomena. Thus, they may articulate a concept implicit in exploratory practices or enable a phenomenon to be made accessible to many observers (see Heilbron 1981 and Gooding 1985b). As the bases for the formation of consensus about possible interpretations, construals are quasi-linguistic. They are neither percepts nor concepts.

Construals highlight the importance of all aspects of perception to the construction of experience. Observers are not disembodied, passive receptors of visual information. Visual perception is usually inseparable from other types, e.g., sensorimotor information. Of course visual information is often obtained independently of other kinds, but this information owes its significance to a prior process of construal, interpretation or abstraction.

To define the role of construals I shall describe four sorts of activity characteristic of empirical enquiry (i.e., enquiry that involves interaction with a phenomenal world that is not wholly constructed by observers). These activities are: construing, interpreting, testing and demonstrating. All four activities involve observation, though in different ways. My examples are taken from immediate responses to Oersted's discovery of the magnetic effects of a current, between October 1820 and the end of 1821. They feature objects that observers devised to fix and communicate their preliminary interpretations of electromagnetic phenomena.

3. Davy's disc and Faraday's cork

In his 1821 review of experiments occasioned by Oersted's discovery of electromagnetism, Faraday depicted objects and images which conveyed likely relationships between electricity, magnetism, wires and magnetized needles. One was a glass box on which a line and an arrow have been drawn. This was a mnemonic device, intended to help the observer remember one of the (by then) favoured ways of interpreting the interaction of currents and magnetized sensors. Even experienced observers like Faraday needed mnemonics to structure perception in new experimental setups and to show lay-observers what to look for. An earlier version of Faraday's device consisted of a wooden dowel on which he drew an arrow to represent the "circumferential" or "circuital" aspect of one form of electromagnetic interaction. Faraday is said to have carried an ordinary bottle cork about with him. He represented the direction of magnetic action of the current by sticking a pin into the cork (Faraday 1821-1822).

These were artefacts. How did they lead to consensus about new phenomena They helped observers identify salient aspects of an effect in a concrete, visual and operational way. Where such devices successfully conveyed just that aspect of a phenomenon intended by an observer, its success would reinforce its use by observers, bootstrapping it into a more interpretive role (see Barnes 1983). Observers would settle upon that intepretation because all could grasp it and put it to use in further exploration. In short, use of such devices helped solve the problem of communicating sameness in the replication of observations. This problem is most acute where both the aspects to be observed and the experimental methods are new.

https://doi.org/10.1086/psaprocbienmeetp.1986.1.193124 Published online by Cambridge University Press

We can recover the pre-articulate construal that led to one of the two main interpretations of electromagnetism, by looking at the process during which these devices were constructed. One construal, according to which magnetic action circulates around the current in planes perpendicular to it, emerged from Davy's exploration of the region of the current. He wanted to reproduce Oersted's effect, but he also had to devise intelligible descriptions of his results.

While repeating some experiments of Ampère, Davy observed that a magnetized needle set in definite positions around the wire. To make the disconnected results of individual interventions intelligible, Davy ordered the outcomes so that successive positions of the needle displayed "an arrangement". It is difficult to obtain any "arrangement" of the sort described in his published report (1821, p. 14). He could have realized this ordering in two ways: operationally and in real time (by moving the needle around the circumference of an imaginary disc) or pictorally (by recording the observed set in each case, so that the order in which observations were recorded was unimportant). Either method would produce the device described by Faraday in 1821, a cardboard disc mounted on an axle, showing the direction of the magnetic effect.

The disc embodied other exploratory behaviour. Following up Ampère and Arago's observation that a wire attracts iron filings, Davy made an important modification. He sprinkled iron filings on a card through which a vertical wire was passed. The resulting pattern suggested a structure of concentric circles in a plane perpendicular to the current. The image of concentric rings of filings was the construal that structured Davy's investigation with the magnetized needle. The image embodied in the disc device provided an interpretation of these two quite different sorts of evidence. By arranging operations and their outcomes in these ways, Davy removed perceptual and procedural uncertainties inherent in Oersted's verbal description of his discovery, which had shown only that <u>something</u> magnetical happens in the region of a current.

Besides enabling observers to agree about the existence of a novel phenomenon, representations sometimes preserve the anomalous character of a phenomenon, <u>i.e.</u>, its potential to change theory. Thus it is important to notice that, in constructing perceptual order out of perceptual confusion, Davy's contemporaries were not blind to aspects of the phenomena that were anomalous with regard to theory. Until 1820 all known forces were push-pull forces whose action could be represented by straight lines. A force that appeared to act circumferentially around the usual line of action was quite extraordinary. A second anomaly was that the action of the wire changed from push to a pull, depending on the position of the magnetized sensor. No known force displayed such a relationship between position and quality of action. Some, such as Ampère and Biot, adopted a "monster barring" strategy, accepting the instrumental fact and using the circuital construal experimentally, while denying the reality of skew forces.

This example illustrates my distinction between a construal and an interpretation. A construal is a provisional interpretation of effects which cannot be understood independently of the exploratory behaviour that produces them. Interpretations may be as tentative as construals but they make phenomena intelligible in a manner less dependent upon operational or behavioural demonstration. Construals enable the ascent from an immediate and concrete world of the laboratory bench to a world of representations (words, images, symbols). Davy's disc and Faraday's cork were used first as construals in the local, laboratory context and then to convey an interpretation of the whole domain of interventions and outcomes through the images of discs and circles.

The terms 'interpretation' and 'construal' express a contrast rather than a disjunction. Construals guide exploratory behaviour. They can be concrete or behavioural embodiments of phenomena produced by intervention. Intepretations are more visual, more verbal and more idealized versions of those construals. Both are constructed to solve the problem of communicating about a perceptual world. The phenomena do not become independent of intervention. However, the procedural, non-discursive basis of experience becomes less important to communication as more visual, symbolic or conceptual modes of understanding are introduced. Human intervention eventually falls out of the account altogether, leaving a residue of objectively natural phenomena. Until recently, most accounts of discovery have discussed only this objective residue.

4. Construals and Predictions

A review of the main results obtained during the two months following news of Oersted's discovery included a description of Wollaston's prediction that a wire should rotate upon its own axis. Ampère showed this in 1822; in the meantime Faraday had shown that a wire can be made to move in circles around a magnet (and a magnet around a fixed wire). Faraday was investigating the fact that whether a needle is attracted or repelled seems to depend simply on position. He wanted to interpret this in a manner compatible with another anomaly, the structuring effect represented by Davy's disc and circles of filings. Faraday's laboratory diary shows there was an unresolved tension between two construals: one based on conventional ponderomotive (attractive or repulsive forces), the other on Davy's disc or circles. By the end of the day (3 September 1821), he had resolved the tension (1931, pp. 49-50). The crucial development occurs as a verbal restatement of a pictorial summary compressing all of his results into a single pair of diagrammes: "These (effects) indicate motions in circles round each pole..." There is a diagramme of the motions, which he had not yet produced. But Faraday now had an interpretation which he could state both pictorially and verbally: "Hence the wire moves in opposite circles round each pole and/or the poles move in opposite circles round the wire." This statement was in fact a prediction. Faraday recorded how he constructed the first of several proto-types of the now famous rotation apparatus.

Even a clear interpretation, used predictively, does not specify all the material conditions necessary to realise an effect. Faraday's first proto-type did not produce continuous motion of the wire, nor did it make it revolve. He learned the unspecified conditions by modifying his apparatus. Faraday's notes are an important resource for our understanding of how ideas interact with instruments in the process of making an effect observable. Each entry (with its accompanying drawing) interprets the previous trial (or entry) in the light of what

Faraday had just done. The notes do not describe tests of a single, unchanging hypothesis. Rather, the construal changes and develops as each successive trial adds new information.

By the end of the day, Faraday had succeeded in producing continuous rotation of the wire. At this stage, the fact of rotation was not private in the epistemological sense, but it was still personal to him. His concluding entry for the day shows that he had already turned his attention from obtaining circular motions to demonstrating them (1931, p. 50).

This is the structure I attributed earlier to Davy's exploration of space with the needle. In these examples, different aspects of an effect (or different types of perceptual information) were resolved into one by the emergence of an interpretation. Discovery sequences such as this illustrate four uses of perceptual information: in construals, interpretation, testing and demonstration. They also show a transition from a construal (in which the immediate outcomes of exploratory behaviour were all-important), through a tentative interpretation confirmed by a successful trial (the magnetic rotations) and embodied in the new instruments that demonstrated them (the first dynamo and electric motor).

5. Four Uses of Observation in Discovery

A necessary condition of the communication and acceptance of representations is that they enable further interaction with the world, by other people and in other ways. Further interaction requires successful strategies to communicate observational practices and to interpret their outcomes. Predictive strategies develop out of these. Interpretation and prediction are often viewed as logically-distinct types of inference and so regarded as quite distinct activities. In conclusion, I will argue that they are interdependent and that this interdependence is important to the success of exploratory work engendered by novel observations.

A construal is the first of four stages of the interpretation (cognitive processing) of a phenomenon:

(1) Construal: until the significance of novel information has been sketched out, construals of it retain the provisional and flexible character of possibility. The corresponding observational "entity" is a rudimentary or instrumental fact, a fact which is recognised and accepted primarily for instrumental rather than theoretical reasons.
(2) Interpretation: as the relevance of construed information to existing theory is worked out, a construal of that information may be adopted as an interpretation which has theoretical plausibility. Its relevance can be agreed without prejudging its precise evidential or semantic relations to existing theory. An interpretation is not static: it interacts with phenomena, with established concepts and with precepts which observers invoke to defend (or choose between) them. It also becomes more susceptible to deliberate trial, as we saw in the case of Faraday's rotations.
(3) Definitive interpretation: when an interpretation also has explanatory potential, this may influence further construal and

https://doi.org/10.1086/psaprocbienmeetp.1986.1.193124 Published online by Cambridge University Press

exploration of a phenomenal domain. A definitive interpretation brings about observational closure, because that interpretation of a phenomenon becomes uniquely self-evident to members of the core-set of observers. They transmit it to a larger community of lay-observers by means of exemplary practices. A definitive interpretation also generates predictions.
(4) Exemplar: finally, as its use becomes widespread, the interpretation acquires the status of an exemplar or paradigm.

These distinctions between construals, interpretations, definitive interpretations, and exemplary or paradigmatic interpretations open up a cognitive space between the practical and pre-theoretical realm of exploratory observation and the more theory-laden activity of experimental testing and observation. What occupies this cognitive space, the interdependence of these different cognitive constructs, and how they interact during experimentation, are major problems for further study.

6. Interdependence and Empirical Success

In the examples, scientists were not working with 'observations' or 'theories' (as these terms are usually understood in the philosophy of science). Their construals of the phenomena enabled each member of the various research groups to do three sorts of thing:
(1) to structure the new phenomenon in terms of one of its aspects and to remember this despite variations in other aspects of the perceptual field (e.g., Oersted's "conflict" was operationalized in terms of the manipulation of magnetized sensors; Faraday's cork realised a relationship between magnetic action and electric current);
(2) to make sense of their own and of each other's experimental manipulations and discourse about these, and to communicate this sense to others outside the laboratory (e.g., mnemonic devices and images published by Faraday and others); and
(3) to suggest further exploration which enlarged both phenomenal and instrumental domains (e.g., the new magnetic motions realised in Faraday's prototype dynamo and electric motor; Wollaston's "rotations" realised by Ampère in 1822).

Can scientists have their practical cake and eat of its truth content? I think that they can, because of the interdependence of practical and cognitive activities such as these, and because of their interdependence as observers. By the end of 1821 two construals had become definitive interpretations of the phenomena: Davy and Faraday's rotation and the Ampère-Biot reduction to conventional, Newtonian forces. These construals displaced others (such as Oersted's "conflict") because they performed social and cognitive functions more effectively than the others. They embodied more successful solutions to the practical problems engendered by phenomenal novelty.

Three sorts of interdependence of thought with behaviour and its outcomes can be identified in the case discussed above:
(i) the interdependence of communicative and instrumental activity during the exploratory phases of inquiry (Davy's routes to the "disc construal"), (ii) the interdependence of instrumental and predictive success during experimentation (Faraday's first rotation apparatus) and (iii) the

https://doi.org/10.1086/psaprocbienmeetp.1986.1.193124 Published online by Cambridge University Press

interdependence of these with preferred representational styles at every stage of the process (contrast the inadmissibility of skew forces for Ampère with Davy and Faraday's acceptance of them).

This broadened view of experimentation acknowledges the importance of construction and invention in empirical enquiry as enablers of the pursuit and proof of truth and falsity. On this view, "observation" and "experimental test" (as they are usually understood) appear as idealized, limiting cases of a larger set of cognitive and epistemological strategies.

https://doi.org/10.1086/psaprocbienmeetp.1986.1.193124 Published online by Cambridge University Press

References

Barnes, B. (1983). "Social life as bootstrapped induction." Sociology 17: 524-545.

Davy, H. (1821). "On the magnetic phenomena produced by Electricity." Philosophical Transactions of the Royal Society 111: 7-19.

Faraday, M. (1821-22). "Historical Sketch of Electromagnetism." Annals of Philosophy 2: 195-200, 274-290; 3: 107-121.

----------. (1931). Faraday's Diary. Volume 1. (ed.) T. Martin. London: Bell.

Gooding, D. (1985a). "Experiment and concept formation in electromagnetic science and technology." History and Technology 2: 151-176.

----------. (1985b). "In nature's school: Faraday as an experimentalist." In Faraday Rediscovered. Edited by D. Gooding and F. James. London and New York: MacMillan/Stockton. Pages 105-135.

Goodman, N. (1978). Ways of Worldmaking. Hassocks: Harvester.

Hacking, I. (1983). Representing and Intervening. Cambridge: Cambridge University Press.

Heilbron, J. (1981). "The electric field before Faraday." In Conceptions of Ether. Edited by G. Cantor and M. Hodges. Cambridge: Cambridge University Press. Pages 187-213.

Knorr-Cetina, K. and Mulkay, M. (eds.). (1983). Science Observed. Beverly Hills and London: Sage.

Quine, W.V.O. (1960). Word and Object. Cambridge, MA: The MIT Press.

------------. (1973). The Roots of Reference. La Salle: Open Court.

von Wright, G.H. (1971). Explanation and Understanding. London: Routledge and Kegan Paul.

https://doi.org/10.1086/psaprocbienmeetp.1986.1.193124 Published online by Cambridge University Press