THE LOGIC OF PROGRESS IN NOMOLOGICAL, DESIGN, AND EXPLICATIVE RESEARCH

Theo A.F. Kuipers, Faculty of Philosophy, Aweg 30, 9718 CW Groningen, Netherlands.
Theo@Philos.Rug.Nl

Abstract. Nomological, design and explicative research seem rather different at first sight. However, there is a strong partial analogy between the three types of research since they can formally be represented in terms of either a target set of desired possibilities or a target set of desired features. This implies that their respective definitions of formal progress essentially coincide. The differences between the three types of research are due to the fact that determining actual progress requires specific definitions: empirical progress for nomological research and conceptual progress for explicative research. Only in the case of design research actual progress coincides with formal progress, as long as the target sets of desired and undesired features are determined beforehand.

Introduction

Although philosophers of science use to almost identify scientific research with description and explanation, this is not only a vague distinction, there are also important other types of research, notably design research and concept explication. Description and explanation may concern the actual or historical world, research which will further be neglected in this paper, or it may concern the nomic world, that is, the world of what is physically (chemically, biologically, etc) possible, to be called nomological research. Besides with nomological research this paper will deal with design and explicative research. Design research includes all kinds of constructive research aiming at the making or improving of certain products or processes. Finally, explicative research aims at the construction of a simple, precise and useful concept that resembles an intuitive concept as much as possible.

   The claim of this paper is that there is an illuminating partial analogy between nomological, design and explicative research, with complete correspondence between what I will call formal progress in these three areas. In all three cases there is a target set, and a particular theory, prototype or provisional explication may approach that target set better than another. Although the favourite kinds of terminology are prima facie different, hence hiding the analogy, they can be translated into each other, making the analogy explicit.

   However, to conclude that formal progress has been made, one has to know the relevant target set explicitly. This is only the case in design research. Nomological and explicative research each have their own, though partly similar, way of determining prima facie formal progress, called empirical progress and conceptual progress, respectively.

We will start with characterizing formal progress in nomological research in terms of desired and undesired possibilities which are included or excluded by a theory. This may be translated in terms of desired and undesired features which the theory may or may not have, and also in terms of necessary and sufficient conditions for being a desired possibility, which may or may not be necessary or sufficient conditions for being included by the theory. Of course, several combinations are possible. Next we will deal with empirical progress in nomological research and its relation to formal progress. Design research as well as (formal and actual) progress in it are primarily described in terms of desired and undesired features a prototype may or may not have. Finally, explicative research is usually characterized in terms of necessary conditions, so-called conditions of adequacy, a provisional explication may or may not satisfy and in terms of evident examples and non-examples of the intuitive concept which the provisional explication may or may not respect. These criteria enable a plausible definition of conceptual progress. However, assuming that there is a unique solution to the explication task, it can formally also easily be characterized, including formal progress in it, with the same means as nomological research: desired and undesired conceptual possibilities which belong or do not belong to the extension of a provisional explication.

In the sections about design and explicative research, these types of research will briefly be contrasted to nomological research and to each other, in order to indicate the aspects in which the analogies between these three types of research are not complete.

The crux of the story is formed by an equivalence theorem of a rather elementary nature, in particular as long as a structuralist rather than a logical (language oriented) formulation is given. For (dynamic) logicians it might be interesting to explore the linguistic sophistication and, for example, the articulation of the evident relation to Leibniz's theory of identities.

Formal progress in nomological research

Point of departure of characterizing nomological research is a domain and a vocabulary enabling the formulation of a set CP of conceptual possibilities (i.e. structures of a certain similarity type). Moreover, it is assumed here that the representation of the domain in terms of that vocabulary amounts to a unique, (in some way or other) characterizable subset T of CP consisting of the physical possibilities. This, by definition, not yet known target set may be identified with the (nomic) truth for reasons that will become clear soon. The aim of theory formation and revision is the actual characterization of T, where the elements of T are called the desired possibilities and the elements of its complement CP-T=cT undesired possibilities. A theory X consists of a subset X of CP with the strong claim "X=T". If X includes T X does not exclude any desired possibility. In that case, the weaker claim "T⊆X" is true. If T⊆Y⊂X Y excludes more undesired possibilities than X and hence the corresponding weak claim "T⊆Y" is stronger and nevertheless true. In this sense theory T is the strongest true theory, and this is the plausible explication of 'the (nomic) truth' in the present context.

The elements of X will be called (the) admitted possibilities (by X) and those of cX (the) excluded possibilities (by X).

The basic definition of formal progress in nomological research, also called (more) truthlikeness, or more precisely, of the claim that Y is at least as close to T as X, now amounts to the combined claim:

(DP) all desired possibilities admitted by X are admitted by Y: $X \cap T \subseteq Y \cap T$

(UP) all undesired possibilities admitted by Y are admitted by X: $Y-T \subseteq X-T$

Figure 1 represents this situation.
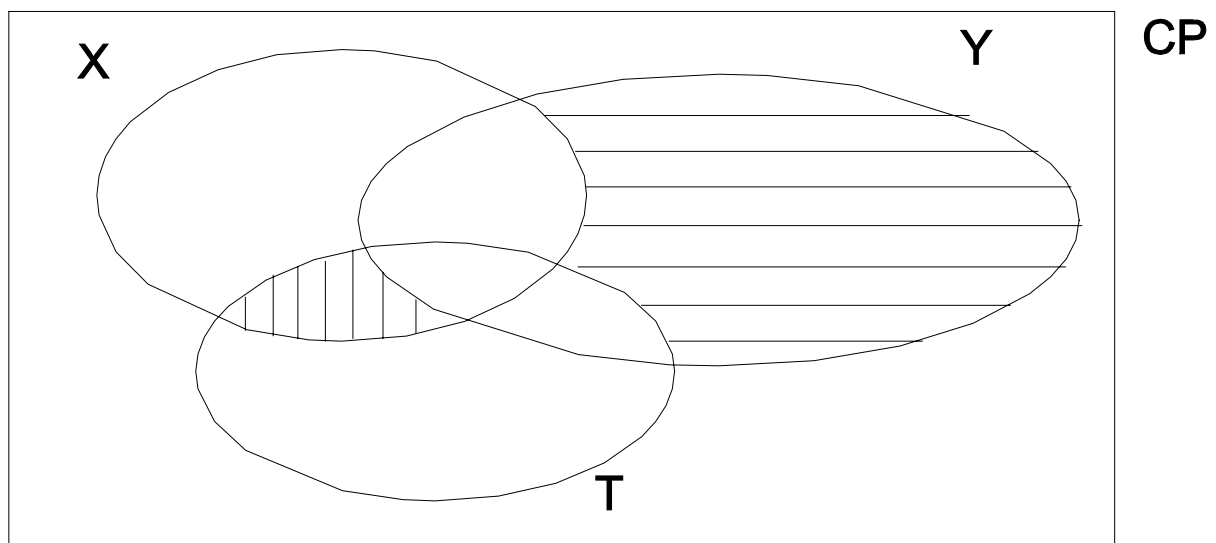
(DP): |||-area empty
(UP): -area empty

Figure 1: Y is at least as close to T as X

Let us now turn to the translation of this definition in terms of desired and undesired features of theories. Point of departure are properties of possibilities. A feature of a theory is conceived of as a property of all possibilities admitted by it. For example, a theory is called symmetric when all its possibilities have a certain symmetric character. A feature of a theory can be represented as the set of conceptual possibilities having the defining feature. It is important to note that this allows us to say that a feature of a theory (precisely) excludes the possibilities lacking the property.

The following definition of desired, undesired and other features is now plausible: desired features are features which include all desired possibilities (i.e. hence only exclude undesired possibilities), undesired features are features which include all undesired possibilities (i.e. only exclude desired

possibilities). All other features exclude desired as well as undesired possibilities and will not play a further role.

  The main equivalence theorem which is now easy to prove is that Y is at least as close to T as X if and only if:

      (DF)   all desired features of X are features of Y (equivalent to UP)
      (UF)   all undesired features of Y are features of X (equivalent to DP)

Note the pairwise similarity of the clauses and the crosswise character of the equivalences. The settheoretical formalization of the new clauses can easily be given in terms of the 'co-powerset' $Q(X)$ of X, defined as the set of supersets of X (within CP).

      (DF) $Q(X) \cap Q(T) \subseteq Q(Y) \cap Q(T)$
      (UF) $Q(Y) \cap Q(cT) \subseteq Q(X) \cap Q(cT)$

Figure 2 represents these conditions.
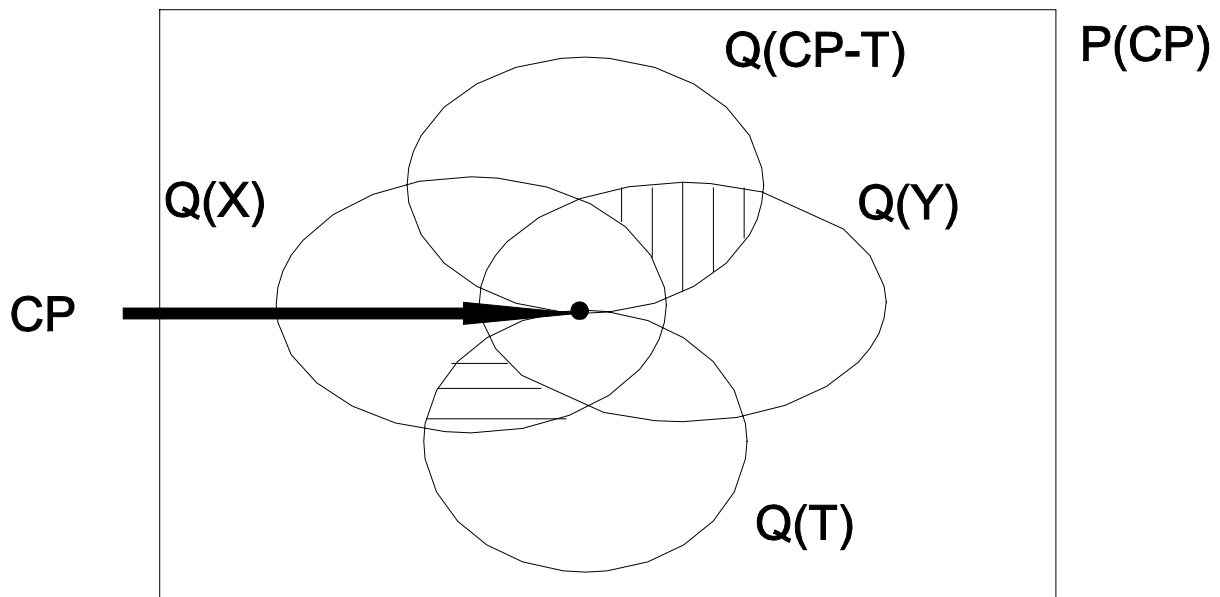
$$(UF)\ [(DP)] : |||\text{-area empty}$$
$$(DF)\ [(UP)] : \text{-area empty}$$

Figure 2: Y is at least as close to T as X in terms of features

From the equivalence theorem it follows that there can be given, besides a possibility version of the definition of formal progress in nomological research, a feature version, with a corresponding reformulation of the aim of theorizing: aiming at a theory fulfilling a target set of desired features, while lacking another set of undesired features. Figure 2 also represents this, where the figure could be restricted to the set of relevant features, i.e., the sets of desired and undesired features, represented by Q(T) and Q(cT), respectively. Note that they have just one feature in common, viz. the tautology, represented by CP itself. Note, moreover, that a dual version is possible in terms of desired possibilities and features, that is, the combination of (DP) and (DF), where the aim of theorizing now amounts to admitting the (target set of) desired possibilities, while fulfilling the (target set of) desired features.

So far for formal progress in nomological research. I will postpone the topic of empirical progress and truth approximation.

Some further interpretations and equivalences

Let us first note that (DF) cannot only be interpreted in terms of desired features, but also in terms of true consequences, for a superset of X (within CP) may well be seen as representing a consequence of X and a superset of T (within CP) as representing a true claim. Hence, (DF) also amounts to the claim that all true consequences of X are (true) consequences of Y. Popper's bad luck with his definition, generally conceived as failing, roughly[1], in terms of more true and fewer false consequences, may now be reinterpreted in terms of a too liberal definition of undesired features, viz. all non-desired features, that is, undesired in our strict sense and otherwise. In terms of consequences, they may well be called false, since they are false for at least one desired possibility. Hence, we need a stronger interpretation of a false consequence, called 'strongly-false', defined by, false such that all its non-tautological consequences are false as well. It is easy to check that (UF) can now be read as claiming that all strongly-false consequences of Y are (strongly-false) consequences of X.[2]

Since (DF) may be interpreted in terms of desired features or true consequences it is plausible that it can also be read in terms of necessary conditions: for all necessary conditions C to be desired (i.e., to be a desired possibility, $T \subseteq C$) which are also necessary to be a member of X ($X \subseteq C$) are also necessary to be a member of Y ($Y \subseteq C$).

This suggests the possibility of interpreting (DP)/(UF) in terms of sufficient conditions. Zwart (1998, p. 8, 52) has observed that these clauses are formally equivalent to a clause in terms of powersets:

---

[1]. In informal formulations with 'more' and 'fewer', these phrases are used in the settheoretic sense. E.g. 'Y has more true consequences than X' means that the set of true consequences of X is a proper subset of the set of true consequences of Y.

[2]. See (Kuipers, 1997) for a detailed analysis. See also (Zwart, 1998) for that purpose, and a creative recycling of a part of Popper's intuitions.

$$P(X)\cap P(T)\subseteq P(Y)\cap P(T)$$

where he calls (the proposition corresponding to) a subset of X an <u>antecedence</u> of X. Unfortunately, whereas members of $Q(X)\cap Q(T)$ are plausibly called true consequences of X, there does not seem to be an intuitively appealing term for members of $P(X)\cap P(T)$ in terms of antecedences, that is, antecedences of X which are also antecedences of T. The term 'correct antecedence' might be introduced, leading to the following paraphrase of the relevant clause: all correct antecedences of X are (correct) antecedences of Y. However, an interpretation of the powerset version of the clause in terms of sufficient conditions is more easy to give: for all sufficient conditions C to be desired (i.e., to be a desired possibility, $C\subseteq T$) which are also sufficient to be a member of X ($C\subseteq X$) are also sufficient to be a member of Y ($C\subseteq Y$).

Finally, the powerset version of (DP)/(UF) suggests that there is also a powerset version of (UP)/(DF), which is indeed the case:

$$P(cX)\cap P(cT)\subseteq P(cY)\cap P(cT)$$

However, we did not find a plausible reading of this clause, let alone an intuitively appealing one.

In summary, we have found that the second clause of the definition of formal progress in nomological research, formulated in terms of undesired possibilities, can be reformulated in terms of desired features or true consequences and necessary conditions, all based on the co-powerset version of the clause. The first clause, phrased in terms of desired possibilities, may be rephrased in terms of undesired features or strongly-false consequences, based on the co-powerset version, and correct antecedences or sufficient conditions, based on the powerset version.

Empirical progress and nomic truth approximation
Lack of space forces us to give only a sketch of empirical progress and its relation to nomic truth approximation, assuming that T is unknown and assuming a (relative) distinction between observational and theoretical terms. However, the basic (dual) definition of <u>potential empirical progress</u> is easy to give. Theory Y is empirically more successful than theory X if and only if 1) all established true observational consequences of X (or simply called general successes) are consequences of Y, 2) all observed (individual) counterexamples of Y (desired observational possibilities excluded by Y) are counterexamples of X, and 3) Y is better in at least one of these respects. Further testing of the comparative hypothesis that Y will remain empirically more successful than X may lead to the conclusion, using an unavoidable inductive jump, that Y is a case of <u>genuine empirical progress</u> relative to X.

It is not difficult to make plausible, on the basis of two theorems, that the instrumentalist rule of success, that is, the rule to choose for a genuinely more successful theory, is not only functional for approaching the observational nomic truth (formal progress on the observational level), but also for the theoretical and referential nomic truth, i.e., formal progress on the theoretical level and the referential 'level', respectively. Hence, instrumentalist criteria serve realist purposes, ironically enough,

whether they are intended or not. For details, see Kuipers (to appear), in which it is also argued that the realist has an advantage over the instrumentalist in that the former can relativize counterexamples in a way the latter cannot.

Not only empirical criteria may play a role in theory choice, but also theoretical criteria, that is, criteria in terms of logical, conceptual or aesthetic features. In a recent paper (Kuipers, to appear) an <u>a priori</u> analysis is given of the relation between beauty, empirical success, and truth. It supports the findings of James McAllister in his inspiring <u>Beauty and revolution in science</u> (1996), by explaining and justifying them. First, scientists are essentially right regarding the usefulness of aesthetic criteria for truth approximation, provided they conceive them as less hard than empirical criteria. Second, the aesthetic criteria of the time, the 'aesthetic canon', may well be based on 'aesthetic induction' regarding features of paradigms of successful theories which scientists have come to appreciate as beautiful. Third, they can play a crucial, dividing role in scientific revolutions. Since aesthetic criteria may well be wrong, they may retard empirical progress and hence truth approximation in the hands of aesthetic dogmatists but not in the hands of aesthetically flexible, 'revolutionary' scientists.

<u>Progress in design research</u>

As was already pointed out in (Kuipers, Vos, and Sie, 1992), design research may be characterized in terms of aiming at a product realizing a set of desired features, and avoiding a set of undesired features. From the previous analysis it is clear that this can, for example, be reconstructed in terms of realizing a desired possibility. Moreover, formal progress in design research now amounts to the claim that one prototype has more desired features and fewer undesired ones than another. However, this is, of course, also the plausible definition of actual progress in design research, assuming that the sets of relevant (i.e., desired and undesired) features are fixed and finite. Finally, assuming a distinction between structural and functional features, the possibility of functional equivalents arises in the same way as the possibility of (on logical grounds) observationally equivalent theories in the context of nomological research. However, this immediately suggests a dissimilarity between the two types of research. In design research every reason to favour one functional equivalent to another can be rephrased in terms of an additional desired or undesired feature. In nomological research, assuming a realist position, it may well be that one observationally equivalent theory is closer to the theoretical-cum-referential truth than another, without disposing of a similar extension possibility in some straightforward way.

Some other differences are:

1) a design target set is a free and changeable choice[3], whereas the nomological target set is fixed given

---

[3]. Vos (1991) nicely illustrated this possibility for drug research: given a certain interesting substance, the subsequent aim of research may become the search for an appropriate disease to cure with it.

a domain and a vocabulary,

2) a design target set is known, whereas the nomological target set is not,

3) this enables a straightforward (comparative) evaluation of a (new) prototype, in contrast to the indirect evaluation of a (new) theory,

4) to revise a prototype may be expensive for material reasons, to revise a theory is relatively inexpensive,

5) for a fixed domain and vocabulary, nomic truth approximation is, ideally speaking, free from external influences, whereas design research is basically open for such influences.

   However this may be, as has been indicated, there are strong formal analogies, simply due to the fact that design research can be, like nomological research, and usually is, unlike nomological research, characterized in terms of aiming at (realizing) a target set of desired features, while avoiding a set of undesired features.

Progress in concept explication

A brief exposition may also suffice for concept explication. Starting from a vague, intuitive concept, the task is to give a simple, precise and useful definition of a concept that resembles the original. Like nomological research, this may be represented in terms of conceptual possibilities. Let us further assume first that there is a unique solution and hence a unique set of desired possibilities. Let a provisional explication also be conceived as (determining) a unique extension of conceptual possibilities. Then it is plausible to define formal progress in explicative research formally in the same way as in the case of nomological research.

   In actual explicative research, the resemblance of a provisional explication is evaluated, in terms of evident examples, that is, evidently desired possibilities, evident 'non-examples', that is, evidently undesired possibilities, and, finally, so-called conditions of adequacy, that is, conditions to be fulfilled and which correspond to desired features. Hence, the definition of 'conceptual progress' in explicative research is straightforward. Provisional explication Y is better than provisional explication X, roughly speaking, if and only if Y treats more evident examples and non-examples properly and/or fulfils more conditions of adequacy.

   The partial analogy of explicative research with design and nomological research is obvious, including the possibility of functionally equivalent explications. However, at least two differences with nomological research are very interesting. There is no analogue of evident non-examples, for this would require the realization of physical impossibilities. Moreover, while nomological research is more or less bound to a unique solution, explicative research may well lead to the conclusion that two or more interesting explications can be given, which mutually exclude each other. For design research a similar non-uniqueness of the solution holds. However, like in nomological research, there does not seem to be an analogue of evident non-examples in the case of concept explication. Moreover, we have

seen that actual formal progress in design research is relatively easy to recognize, but not so in concept explication. Hence, although there is a strong analogy between design and explicative research, both aim a certain product, the analogy is not perfect.

Conclusion

The overarching analogy between the three types of research may even be characterized in terms of products: all three aim at a certain product, viz. a theory, an artifact, and a concept, all serving certain purposes. We have argued that these types of research, including formal progress in it, can in principle be described in terms of admitting desired and undesired possibilities or, equivalently, in terms of having desired and undesired features. Hence, although scientists may feel strong differences in what they do, due to strong differences in determining prima facie formal progress, they may also feel a strong kinship on a more abstract level of formal progress.

References

Kuipers, T., (1997), "The dual foundation of qualitative truth approximation", Erkenntnis, **47.2**, 145-179.

Kuipers, T., (1999), "Kan schoonheid de weg wijzen naar de waarheid?", Algemeen Nederlands Tijdschrift voor Wijsbegeerte, juli-nummer.

Kuipers, T. (to appear), From instrumentalism to constructive realism, to appear in the Synthese Library (Kluwer AP).

Kuipers, T. & Vos, R. & Sie, H., (1992), "Design research programs and the logic of their development", Erkenntnis, **37.1**, 37-63.

McAllister, J., (1996), Beauty and revolution in science, Cornell University Press, Ithaca.

Vos, R., (1991), Drugs looking for diseases, Kluwer, Dordrecht.

Zwart, S., (1998), Approach to the truth. Verisimilitude and truthlikeness, dissertation RU-Groningen, ILLC Dissertation Series, Amsterdam. (A revised version will appear in the Synthese Library (Kluwer AP).)