THE “MULTIREALIZATION” OF MULTIPLE REALIZABILITY

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Abstract
Multiple Realizability (MR) must still be regarded as one of the principal arguments against type reductionist accounts of higher-order properties and their special laws. Against this I argue that there is no unique MR but rather a multitude of MR categories. In a slogan: MR is itself “multi-realized”. If this is true then we cannot expect one unique reductionist strategy against MR as an anti-reductionist argument. The main task is rather to develop a taxonomy of the wide variety of MR cases and to sketch possible reductionist answers for each class of cases. The paper outlines some first steps in this direction.

1 SHORT INTRODUCTION

Multiple Realizability (MR) must still be regarded as one of the principal arguments against reductionist accounts of higher-order properties and their special laws. The MR argument, following Putnam (1967) and Fodor (1974), is widely known: higher-level properties M possess multiple lower-level realizers or instantiations. Since the realizers are “drastically heterogeneous”, no bi-conditionals between higher-level M-types and lower-level P-types can be established. But this means that the higher-order laws of the special sciences cannot be reduced to lower-level laws, since, following the classic account of theory reduction by Nagel (1961), the failure of M/P-biconditionals is equivalent to the non-existence of unique bridge laws between M and P. The upshot is that in the reducing science the unifying power of the higher-level law gets lost and that at best a generalization over an unsystematic disjunction of lower-level properties can be retained. Hence, type-reductionism fails.

The MR argument is indeed a remarkable argument. What really makes it remarkable is the curious fact that, given its simplicity and generality, the argument came surprisingly late and entirely unexpectedly. In retrospect it seems almost unbelievable how it could have been overlooked for so long. Perhaps the argument was overlooked because, in a very elementary sense, the argument is bogus. This might also be the implicit reason why working scientists are usually not alarmed by this argument. Hence, the primary task of this paper is to uncover the bogus nature of the MR argument by showing that MR is not a unique phenomenon, but rather spans a variety of classes of MR cases. In a slogan: MR is itself "multi-realized". The paper aims to develop a taxonomy of the multiplicity of MR cases and to sketch corresponding possible reductionist strategies.

2 SHARED INTRINSIC PROPERTIES

MR cases are omnipresent. As a starter, let us consider an easy and apparently innocuous example: the case of water. Water is usually identified with H_2O. From a more fine-grained perspective, however, water molecules come in different varieties: hydrogen oxide ^1H_2O, deuterium oxide D_2O and tritium oxide T_2O, or, accordingly, regular water, heavy water and tritiated water. This three-fold distinction between the three types of water can of course be traced back to the distinction between the three isotopes of the hydrogen atom: protium ^1H, deuterium D and tritium T, where in the case of deuterium one and in the case of tritium two further neutrons are added to the proton of the regular hydrogen nucleus (hence, $D = {}^2H$ and $T = {}^3H$).

This setting already includes several MR scenarios: First, water is multiply realized as regular, heavy and tritiated water; second, water molecules are multiply realized as ^1H_2O, D_2O and T_2O; third, hydrogen is multiply realized by means of the isotopes protium, deuterium and tritium; and fourth, the hydrogen nucleus is multirealizable as one proton, the compound of a proton and a neutron, and the compound of a proton and two neutrons. While all this is well known, it seems pretty clear that no working scientist ever believed that because of these various MR cases there is a pressing problem with the reduction of molecular chemistry to atomic physics or the like. This is not to say that there might not very well exist problems in reducing chemistry to physics, but those problems do not, in any obvious manner, stem from the MR scenarios just mentioned.

For the sake of our argument, we may assume a bundle ontology point of view. We may describe the entities involved in MR scenarios as bundles of properties. The case of water is a particularly handsome case in this respect since we may simply identify the "nucleonic content" of the various isotopes with their basic properties, which we shall call the p-property and the n-property. To simplify things, let us neglect the oxygen nucleus and just concentrate on the hydrogen atoms. Hence, the n-property of ^1H_2O is 0, while for D_2O it is 2 and for T_2O it is 4. In contrast to this, the p-property of all isotopes is the same, namely 2. Now, most of the laws which govern the behaviour of water can be traced back to the p-property of the three water isotopes. Since the p-property of ^1H_2O, D_2O and T_2O is the same, the electromagnetic properties and, hence, most of the chemical properties are the same. Only in case where the n-property counts (e.g., when the mass of the atoms comes into play) do differences between the three realizations of water occur. In these cases, however, we are no longer facing an MR scenario, since we are not dealing with three instantiations of one kind**,** but rather with three different kinds. In contrast, in the true MR case, where we may consider water as one kind with laws quantifying over this water kind, the behavior of this kind and hence the water laws can be reduced to the p-property of the isotopes, which are the same for the different instantiations ^1H_2O, D_2O and T_2O.

It can of course easily be seen why the MR case of water isn't a problematic case at all. For in general, water laws quantify over p-properties. And hence, although water isotopes differ in n-properties, this difference doesn't count for the typical water properties, which are, as p-properties, one and the same for the three isotopes. Thus, from the p-property perspective, the MR scenario collapses. The more general upshot is that higher-level laws in many cases do not quantify over all the properties – the whole property bundle – of the higher-level entities but only over a suitable subset – a partial property bundle, perhaps only one property – thereof. This motivates to the following more general conclusion: *Higher-level laws quantify over causally relevant higher order properties of the supposed higher order entities only*. In many merely superficial MR cases it is therefore sufficient for a full-blown type-reduction (in a Nagelian schema of reduction or perhaps in a some more refined way) to reduce the reduction-relevant properties to causally relevant lower-level properties which the multiple realizers share. In the case of water such causally or reduction-relevant properties are the p-properties of the isotopes. Whether the realizers differ in other properties doesn't affect a successful type-reduction at all.

We've highlighted an important and at the same time innocuous category of MR cases: the class of shared intrinsic properties of the realizers. But of course there's more to come. Let us consider another kind of example. "Games" seem to provide an interesting case of MR as well – just think of soccer games, card games, Olympic games, children's games, gladiator's games etc. The examples also seem to instantiate "drastically heterogeneous" cases, a crucial ingredient not fulfilled in the case of shared intrinsic properties. However, as Wittgenstein has forcefully argued, "game" is a family concept: the members of a family show "*… a complicated network of similarities overlapping and criss-crossing*" (Wittgenstein 1953, §66), but there is no single property shared by all the members (cluster concepts are similar cases). Let's assume Wittgenstein is right on this. Insofar as the case of games provides a genuine MR case, it does obviously not belong into the MR-class of shared intrinsic properties. But we get a quick explanation at hand: while there is no single property shared by all the family members, there are nevertheless certain properties shared within certain member sub-classes. We must therefore simply restrict our shared-intrinsic-properties approach to such sub-classes to demystify family concept cases as MR cases.

This is actually the general strategy of David Lewis (1969) in his early reaction on Putnam. Lewis promotes a "restricted" type-type-identity theory allowing for domain-specific reductions. Take the case of "pain" as an infamous example of MR. Under Lewis' account the reductionist should rather restrict herself to certain subclasses or subtypes. From the same logic Lewis denies viewing pain as a natural kind. There may be pain-in-men, pain-in-dogs, pain-in-Martians, pain-in-robots, or what have you, but there is no such general kind as pain. So Lewis and Wittgenstein in a sense meet: the idea of domain-specific reductions harmonizes with the case of family types, since suitable sub-types may exactly be those which share certain lower-level properties. And, of course, such domain-specific cases then come out, again, as innocuous shared-lower-level-properties-cases.

The "Wittgenstein-Lewis-view" aligns with the empirical fact that apparently nobody is able to present non-trivial and interesting generalizations over the class of *all* pain or game realizers. There simply are no overall pain or game laws, but just laws about suitable subclasses. This echoes Wittgenstein's anti-essentialist attitude: lacking a shared – let alone essential – property, no law-like generalizations "all *F*'s are *G*'s" over "family types” *F* and *G* exist. Under Wittgenstein’s idea of family resemblance it becomes plausible why we have pain and game *concepts* (and therefore perhaps mistakenly assume the existence of unanimous pain or game generalizations), but why we should at the same time not expect the existence of general pain or game *laws* – after all, over which property should they quantify?

4 The empirical nature of MR, causal powers and functional reduction

It might seem, however, that we have turned the logic of the MR argument on its head: we’ve argued for the impossibility of general pain or game laws under the presupposition that no shared intrinsic pain or game properties exists. But the MR argument is meant as an argument for the possibility of just the opposite: the possibility of law-like generalizations over drastically heterogeneous realizers. And one way to spell out drastic heterogeneity is to reject shared intrinsic properties. The systematic question behind all this is of course whether the MR argument should be considered an empirical or an a priori argument. Lawrence Shapiro (2000, 2004) has given a number of reasons in favour of the view that MR is a matter of nomological rather than logical possibility, but perhaps no deep metaphysical consideration is necessary here. Not only should it be obvious that we cannot infer about the MR status of the world from mere a priori considerations – the empirical nature of the MR thesis has also been made explicit in the statements of MR proponents themselves: “*These are not supposed to be knock-down reasons; they couldn't be, given that the question of whether reductionism is too strong is finally an* empirical *question. The world could turn out to be such that every kind corresponds to a physical kind … It’s just that, as things stand, it seems very unlikely …*” (Fodor 1974, pp.102–103).

As so often in philosophy discourse the question is on which side of the debate the main burden of proof lies. But even if MR proponents accept the main burden, this wouldn’t settle the issue because, as they see it, the empirical evidence is already on their side (cf. Fodor: “*as things stand*”). It seems therefore more promising to tackle the issue from another angle and to ask how to individuate the various allegedly existing kinds in an *empirical* science. Jaegwon Kim (1998, 2006) has argued that in order to be empirically dignified kinds the higher order kinds must be individuated by means of their causal roles. This is the key idea of Kim's account of functional reduction. His model involves two steps: firstly, to identify the causal role of the higher order *M*'s and, secondly, to identify the lower-level realizers exactly by means of their causal role.

Note that under a more abstract description of this model to individuate something causally means to reconstrue it on purely relational grounds. Hence, a property defined by its causal role, and by its causal role alone, is a relational property only. We follow up on this point in the next section. But there are two important consequences from Kim's account of functional reduction. One is his well-known causal exclusion argument. The argument in brief is that there is no causal work left for the higher order entities, if we accept the otherwise convincing assumptions of the supervenience of *M* over *P* and the causal closure of *P* – and unless one is not willing to accept a systematic causal overdetermination. More precisely, under the assumption that higher-level tokens supervene on lower-level tokens and that any fundamental physical token has a sufficient fundamental physical cause, if it has a cause at all, the supposed extra-causal efficacy of higher-level tokens must be excluded. Functional reduction implies that, as Kim would have it, causation "drains down" from the allegedly causal power of the higher-level to the lower-level.

Another consequence concerns the widespread talk of "cross-classification". As many non-reductionists put it: higher order properties cross-classify the lower-level ones. But as Kim (1998, p.69) has pointed out, this can only reasonably be maintained if one is willing to give up supervenience. For in order for two taxonomies to cross-classify, the possibility is admitted that the higher-level taxonomic class makes causally effective distinctions not made by the lower-level class. And this is a clear failure of supervenience. Cross-classifying taxonomies define, as it were, conflicting causal profiles. Since, however, only non-reductionists of an explicit non-physicalist inclination are willing to give up supervenience in this sense, the talk of cross-classification turns out as rather loose talk not suited to spell out the consequences of MR. MR itself does not imply cross-classification. Intended as an anti-reductionist argument, the MR argument emphasizes the drastically heterogeneous nature of the realizers, but it does not imply any mysteriously conflicting causal profiles.

To sum up this interim section: MR must be understood as an empirical phenomenon. Both MR-proponents and opponents accuse each other not to have the empirical evidence on their side, but it is far less controversial to demand from those, who claim a higher-level autonomy, to individuate their thus claimed entities and properties by means of a scientifically dignified procedure, hence, to individuate entities and properties by means of their causal roles. From this it can clearly be seen that MR does not imply cross-classification but that properties may be individuated purely relationally. This point should be considered now.

5 SHARED RELATIONAL PROPERTIES

Let's take another MR example: the case of the harmonic oscillator. This is actually a clear case of MR, harmonic oscillators are multi-realizable by a plethora of physical systems: pendula, springs, atoms, electromagnetic oscillatory circuits and many more. Do all these realizers have certain properties in common? At least this isn't obvious. Generally speaking, a harmonic oscillator is a system where the restoring force is proportional to the displacement from the equilibrium position. This can be captured by means of an differential equation, the oscillator equation $d2/dt2\ x(t) + k\ x(t) = 0$. The oscillator equation represents a higher-level law which unifies and systematizes the harmonic behaviour of the lower-level realizers in a clean, nice way. And we get interesting generalizations from it: whenever something obeys the oscillator equation, it works under a force proportional to the displacement. Moreover, the realizers seem to be drastically heterogeneous. This is formally reflected by the fact that the equation leaves the nature of the proportionality constant *k* open. In fact, the equation gives no intrinsic but rather a purely relational or structural characterization of the harmonic oscillator: all instantiations of a harmonic oscillator share the same set of relational properties defined by the oscillator equation.

We have therefore discovered another class of MR cases, the class of shared-relational-properties-cases, where the harmonic oscillator is a prime example. Unlike the class of shared intrinsic properties this class seems to provide more genuine cases of MR in the sense that structural laws allow for interesting generalizations and that the realizers may differ drastically in any intrinsic, albeit not relational properties. Because of their structural commonalities, however, there is again nothing mysterious about such MR cases.

Mention should be made at this point about the remarkable fact that Structural Realism, a considerable movement in philosophy of physics claiming to provide the most appropriate metaphysics of modern physics, acknowledges primarily relational properties only on the most fundamental level (French and Ladyman 2003, Lyre 2009). Physical laws it seems, even fundamental ones, prove themselves to a large extend as purely structural laws. It has often been a background assumption in the MR debate that the fundamental physical laws quantify over fundamental intrinsic properties. From the perspective of Structural Realism, however, physics includes basically relational properties and collections thereof. On such an account, higher-level properties, if reducible, will eventually be reducible to collections of lower-level relational properties only. This by itself already undermines the MR argument and is grist on the mills of the shared-relational-properties view. Unfortunately, it is beyond the scope of this paper to pursue this line of thought.

Let us rather consider a further example. Genes are sometimes said to be reducible to DNA segments. While this is certainly a gross oversimplification, we may nevertheless use it as an illustration in the sense that genes are multirealizable by means of DNA segments. On the one hand, this has to do with the degeneracy (redundancy) of the genetic code: almost all amino acids are encoded by more than one triplet of nucleotides (DNA codons). On the other hand it is possible to think of other biological substrates on which the genetic code acts. (In fact, when Watson and Crick discovered the genetic code they soon emphasized the fact that it is not the particular bio-substrate that counts but rather, being an information-processing code, the purely structural relations between the coding units.) By characterizing certain laws of molecular genetics as structural laws, we abstract from the intrinsic properties of the realizers (here: DNA segments) and emphasize the causally relevant relations in which they stand. Obviously, the pure structural web of relations can be multiply realized, while, *a fortiori*, the various realizations share just the proper set of relational properties which suffice to set up the intended structure. This can be generalized: the laws of the higher-level sciences, in many cases, do not pick out special heterogeneous kinds that cannot be traced back to more fundamental ones, as Fodor would have it, but typically highlight shared relational properties of lower-level realizers suited to set up a certain structure.

This conclusion also highlights the promising fact that functional properties can quite generally be reconstructed as relational properties by strictly individuating them by their causal roles – as pointed out in the preceding section and in accordance with Kim's account of functional reduction. Generally, for two entities to stand in a causal relation requires that whenever entity *A* occurs, *B* follows as its effect. That is to say, *A* and

B stand in an (asymmetric) relation *R*, where *R* is likewise to be considered a relational property of entities *A* and *B* (*R* is part of the property bundles of both *A* and *B*). Therefore, the different MR realizers will necessarily fulfil the same causal roles and, hence, *must possess at least one* relational property in common: the relational property connected with their common causal role.

6 FURTHER COMPLICATIONS AND DISCUSSIONS

6.1 Kinds by stipulation

Let's start over again with another example. Paying one's dues can be realized in various ways: by means of a bank transfer, by either cash or credit card payment, by sending a cheque, etc. A clear MR case. In the light of the above, the reductionist might use the following counter-strategy: payments are functionally defined. Their realizations may look as heterogeneous as they like, they nevertheless fulfill the same causal role in the web of economic relationships between different parties on a market. The causal effect of party *A* on party *B* – as far as *A*'s dues and their repayment to *B* are concerned – is, *in economic terms,* the same for every particular realization of the payment. Economic laws do merely quantify over causal-relational properties like, for instance, the payment-relation between *A* and *B* and do not care about the particular instantiation of the payment.

While this is a first step to dissolve the case of payment as an MR example, there is perhaps more to it. The question is in fact why this example should be an alarming anti-reductionist example at all. Let's compare it to the case of pain. Admittedly, we have already argued that the case of pain is no genuine example because pain is most likely a family concept. But assume it is not, assume it were a genuine MR case. The crucial difference to the payment case is that pain is indeed a natural phenomenon. Hence, to assume pain as a higher-order classification is to assume a natural kind. Payments, however, are certainly no natural phenomena. Surely, economists treat payments as kinds in the sense that they use them in generalizations. But nevertheless payments do not occur in nature. Whether something figures as a currency or payment method is a matter of cultural stipulation and, hence, a convention. We must therefore carefully distinguish between genuine natural kinds and kinds by means of stipulation. Since we are free to declare any token whatsoever as a particular currency, we should not expect some intrinsic nature of the token to bring about its causal economic effects. Such effects are simply brought about by fiat. Not only are they functional, they are functional by convention.

6.2 Approximation cases, idealization cases and intertheory reduction

Temperature, at least in the case of gases, can be reduced to mean kinetic energy of the gas molecules. Consider the case of 1 mole of a particular gas. The number of molecules in such an amount of stuff is Avogadro's constant, which is of the order of 10^{23}, a truly gigantic number. Now, a certain macrostate of an ideal gas characterized by a particular value of the mean kinetic energy of its molecules may very well be instantiated by an equally gigantic number of microstates (we do not dispute about a few orders of magnitude more or less here), all of which in general include different individual molecule velocities which nevertheless lead to the same mean value of the molecules' kinetic energy. Hence, temperature, a property of the macrostate of a gas, is multirealizable by a vast number of microstates. While this is in a sense a truly dramatic MR case, this does not at all mean that the reduction of temperature to individual molecule velocities or kinetic energies is blocked. The different microstates belonging to one macrostate may differ in various properties (e.g. the individual molecule velocities), but as far as the relevant property is concerned – the mean kinetic energy of the molecules – these states are of one kind. Temperature laws may very well be reduced to laws about mean molecular kinetic energy despite the fact that the different microscopic realizations differ in various regards, since temperature laws do not quantify over the differing properties of the microscopic realizers, but only about the property in common. Hence, the temperature case belongs, just like the case of water, to our first innocuous MR class of shared intrinsic properties.

But there's a further complication involved. While in the case of water identifying water with H_2O (and its various isotopes) is quite straightforward, in the case of temperature identifying temperature with mean molecular kinetic energy draws essentially on an approximation. Literally speaking, there exists no such property as the mean kinetic energy. In fact, in any particular microstate the mean kinetic energy will in general be instantiated only by a tiny fraction (if at all!) of the gas molecules. We have a case here where the Nagelian bridge principles cannot be recovered as strict identities – neither for types nor for tokens!

So let's have a quick look at the issue of intertheory reduction. Ernest Nagel's (1961) classic account is based on the idea that reduction is a variant of deduction. In a nutshell: to reduce means to deduce laws. On such an account a higher-level theory T_{high} reduces to T_{low} if and only if the laws of T_{high} may be deduced from the laws of T_{low}. With laws as generalizations over property predicates, this leads to the necessity of establishing meaning relations between higher and lower-level predicates. Nagel therefore introduced bridge or correspondence principles stating that the laws of T_{low} in conjunction with the bridge principles logically comprise the laws of T_{high}.

Cases like our "temperature equals mean energy"-approximation obviously pose a problem for this approach, since generally and in fact in many cases T_{high}, from the more fundamental perspective of the lower theory T_{low}, turns out to be only merely approximately true though literally false. Hence, the very idea of reduction seems to be undermined and the threat of eliminativism is lurking. In order to cope with these problems, Schaffner (1967) and Hooker (1981) developed more elaborate accounts of reduction. Their basic idea is that to reduce means to formulate an analogous image I_{low} of T_{high} in the vocabulary of T_{low}. The trick is that by using the vocabulary of T_{low} only, reduction is accomplished without appeal to bridge principles or to worrisome token or type identities. On such an account the higher-level theory isn't entirely eliminated. There is instead a substitute provided by an analogous theory image. (Obviously, this account stands or falls with a proper account of what counts as "analogous").

So sometimes, indeed, higher-level entities or properties are introduced by means of idealization or approximation procedures. While Nagel's original account cannot cope with such cases, other reduction frameworks, most prominently the Schaffner/Hooker account, can. It is indeed a sad fact that in a majority of philosophy of mind discussions the Nagelian approach is often still the only one mentioned, while philosophers of science have discussed so many other options (starting already in the 50's with Kemeny, Oppenheim, Feyerabend, Schaffner, Sneed, Scheibe, Ludwig, to mention just a few). The upshot of approximation cases regarding the MR argument is that one must be very careful whether the allegedly multirealisable higher-level entities can be obtained from direct compositions of lower-level constituents or by means of approximations only. It is neither astonishing nor is it a deep problem that in such cases a naïve Nagelian approach of reduction fails, as long as the approximative or idealized nature of the higher level is acknowledged.

6.3 Higher-level realism, eliminativism, and bottom-up ontologies

The topic of the preceding section touches upon an important ontological issue, a full-blown discussion of which is certainly far beyond the scope of this paper. It should nevertheless be addressed here ever so briefly. It's the issue of the pros and cons of higher-level realism. Given the above MR class of approximation cases, it seems that, from a rigorous point of view, we end up with outright eliminativism: taken literally, mean energy, like other statistic concepts such as the mean woman with her mean number of 1.4 children (in the sad case of Germany), is a proper and instrumentally useful theoretical concept but it doesn't refer to any real property or entity. From the identification of a higher-level property such as temperature with a statistical quantity, the conclusion follows that the higher-level property, in our case temperature, also doesn't refer.

Take David Lewis' explanation of supervenience as another example: "*A dot-matrix picture has global properties – it is symmetrical, it is cluttered, and whatnot – and yet all there is to the picture is dots and non-dots at each point of the matrix. The global properties are nothing but patterns in the dots. They supervene: no two pictures could differ in their global properties without differing, somewhere, in whether there is or there isn't a dot*" (Lewis 1986, p.14). Do global patterns exist? Obviously, they are idealizations from dot distributions. In that sense they supervene on the lower-level dot distributions and are, the same time, multi-realizable by many distributions. The intriguing "realistic" nature of global patterns can best be seen from John Conway's infamous "Game of Life", a well-known example of a cellular automaton. From a set of perplexingly few and simple rules one gets a gorgeous complexity of patterns, a whole universe of "life forms". And it is more than compelling to describe the regular pixel distributions in the Game of Life as stable patterns, which themselves sometimes (again very perplexingly) obey higher-level regularities. Not only is it compelling, the pattern description seems to be the only appropriate description. Daniel Dennett (1991) has therefore pled for a moderate realism about higher-level patterns. For in order to cope with the otherwise overwhelming complexity we have no other choice than to describe the higher-level goings-on from the, as Dennett would have it, "design stance".

The philosophical consideration of such examples may trigger an endless debate about ontology. But whether one sticks with realism (moderate or full-blown), instrumentalism or outright eliminativism regarding higher-level patterns, isn't our primary concern. Our concern should be whether the evidence for patterns as lower-level approximations or idealizations is in accordance with reductionism or not. So here's a claim: *If for some higher-order entity or property there exists a bottom-up account that explains the entity or property if not literally but to any desired accuracy (for the purposes of higher-level observation and measurement), then that bottom-up account is sufficient for epistemic (let alone ontic) reduction.* It is, moreover, obvious that in such cases we have any reason to assume that the causal efficacy of the higher-order entities "drains down" to the lower level, to use Kim's terminology. It's not the mean woman that "does" anything in the world nor is it gas temperature as mean kinetic energy, it is the particular women and particular gas molecules in a microstate that act.

7 Conclusion

The paper's overall theme was that MR is no unique phenomenon, but that it is itself "multi-realized". Needless to say that this is not the same sense of multirealization as in MR itself, but rather a metaphorical use (hence the quotation marks). A variety of different classes of MR cases has been carved out in the paper. Here's again a list of them:

(1) Shared intrinsic properties
(2) Shared relational properties
(3) Functional properties
(4) Domain-specific sub-types
(5) Family concepts
(6) Kinds by stipulation
(7) Approximation cases

This list is probably not exhaustive nor is it meant to be clear-cut. In fact it were a serious misunderstanding to assume that the different MR classes are clear-cut. The point is that in many cases we need to combine different classes and their corresponding possible reductionist recipes! This shall be outlined here, on the fly I will also point out connections and similarities to more recent work in the field.

First we may distinguish "real" from "fake" cases. Real MR cases are either grounded in shared intrinsic (1) or relational (2) properties. Shared-intrinsic-properties-cases are in general innocuous (the case of water), whereas non-trivial cases quite often rely on functional properties

(3), which can, as we have seen, usually be reconstrued as cases of shared relational properties (2). In such cases the higher-level generalizations will be structural laws (the harmonic oscillator). As far as I understand him, the idea of structural laws also provides the background of Battermann's (2000) analysis, if only stated by means of the concept of universality.

The general idea to restrict attention in MR cases to the causally relevant, shared properties can also be found in Shapiro (2000, 2004) and Pauen (2002). Bickle's (2003) ruthless reduction of psychological phenomena to the molecular level can, I think, be understood as an attempt to ground psychological multirealizability in shared intrinsic molecular properties. Shapiro (2000) has moreover set up an interesting dilemma for MR proponents. His concern is about the empirical evidence of the MR thesis and the existence of truly interesting and genuine cases of MR. Shapiro argues that in the genuine cases the different realizers bring about the function in causally different ways. Hence we should not be concerned with property differences of the realizers which do not contribute to the function. In Shapiro's example: whether a corkscrew is made out of aluminium or any other steel doesn't really matter. However, the fact that here exist different mechanisms to realize a corkscrew – a winged mechanical device opposed to a gas injection device – is of interest. Shapiro's dilemma now is that either the realizers differ in the causal way they bring about the function or they do not. In the latter case we have no interesting case of MR at all, if they do, however, then they are really different kinds, because in that case only a few shared laws or generalizations will be left – laws or generalizations he attributes as "*numbingly dull*" (Shapiro 2000, p.649) such as "mouse traps are used to catch mice" or "eyes are used to see". While I basically agree with Shapiro's analysis, the emphasis is a bit different. If all mouse traps bring about the causal effect to catch mice then they share this very property and mouse trap "laws", as generalizations over exactly this property, are possible. Admittedly, such generalizations aren't very instructive, but the crucial point is that even "numbingly dull" generalizations subsist only on the basis of shared properties – if only, in the extreme, by sharing just one relational property. Of course, the fewer commonalities, the less useful the generalizations.

Classes (4) to (7) can in principle be combined both with each other and with classes (1) and (2). We have seen some examples already. Family concepts (5) will generally allow for domain-specific sub-types (4) on the basis of shared properties (1,2). Recently, Lewis' idea of domain-specificity was revived by Esfeld and Sachse (2007) in terms of "functional sub-types", i.e. a combination of (3) and (4) without, however, further analyzing (3) in terms of (1) or (2). Classes (6) and (7) are largely overlooked in the literature, though they most certainly play an eminent role, especially the class of approximations and idealizations (7), where, strictly speaking, MR proponents only mistakenly assume genuine multirealizable kinds.

I should finish with the remark that, admittedly, the paper has an ambitiously wide scope. It touches upon many deep philosophical issues which cannot all be addressed adequately in just one paper. However, since the issues are deeply intertwined, it is my firm belief that when we consider only single pieces of it alone important points will be missing. This is also intended by the term "multirealization" (in quotes): the many faces of the MR problem. And exactly because of the many faces there is no unique antidote against MR's supposedly anti-reductionistic force. But there is perhaps enough hope that all of the various "instantiations" of MR can be dismissed case by case (or class by class, respectively). So the paper should eventually be considered an outline of a prospective framework of how to deal with the MR problem (or "problems") from a strengthened (type) reductionist perspective.

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