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ÍNDICE/TABLE OF CONTENTS

ARTÍCULOS/ARTICLES

NOTA CRÍTICA/CRITICAL NOTICE

REVISTA DE LIBROS/BOOK REVIEWS

OBITUARIO/OBITUARY

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Multiple Realization, Levels and Mechanisms

Sergio Daniel Barberis

RESUMEN

Este artículo se centra en el marco para las relaciones composicionales entre propiedades, o relaciones de "realización", propuesto por Ken Aizawa y Carl Gillett (A&G) y, en particular, en el análisis de la "realización múltiple" que estos autores defienden en ese marco. Sostengo que el análisis de la realización múltiple de A&G demanda una elucidación de la noción de nivel y que el marco propuesto por estos autores no resulta exitoso bajo ninguna de las interpretaciones disponibles de los niveles en ciencia. Por lo tanto, existe una preocupación fundamentada acerca de la viabilidad de la propuesta de A&G.

PALABRAS CLAVE: *realización dimensionada, explicación mecanicista, niveles de organización, niveles de mecanismos, escala.*

ABSTRACT

This paper focuses on the framework for the compositional relations of properties in the sciences, or "realization" relations, offered by Ken Aizawa and Carl Gillett (A&G) in a series of papers, and in particular on the analysis of "multiple realization" they build upon it. I argue that A&G's analysis of multiple realization requires an account of levels and I try to show, then, that the A&G framework is not successful under any of the extant accounts of levels. There is consequently a real concern that the A&G framework for realization may not be viable.

KEYWORDS: *Dimensioned Realization, Mechanistic Explanation, Levels of Organization, Levels of Mechanisms, Scale.*

I. INTRODUCTION

Since the early sixties, the concepts of "realization" and "multiple realization" have been central in the metaphysics of mind and the philosophy of science [cf. Putnam (1960); Block and Fodor (1972); Fodor (1974)]. In the metaphysics of mind, the idea that a mental property *M* is not type-identical to any physical property P_1 because *M* may be realized by multiple physical properties P_1, P_2, …, P_n eventually debunked identity theory and promoted non-reductive physicalism as the default naturalist stance about the mind. In the philosophy of science, the multiple realization of higher-level (e.g. psychological) properties in lower-level (e.g. neurobiological) properties undermined Oppenheim & Putnam's working hypothesis that higher-level properties are step-by-step reducible to microphysical properties [cf. Oppenheim and Putnam (1958)].

However, it was not until the turn of the century that the concepts of realization and multiple realization became the focus of rigorous philosophical analysis. In 2000, Shapiro noticed that "philosophical discussion of [the multiple realizability thesis] is dominated by examples that appeal to the intuitive force of the thesis" and that "no philosopher has ever tried to complete the sentence, '*N* and *M* are distinct realizations of *T* when and only when ____'" [(2000), p. 636]. There has been a growing interest in developing a metaphysical framework for realization since Shapiro's challenge. Aizawa's and Gillett's (hereafter: A&G) "dimensioned" framework for realization relations (and the analysis of multiple realization they build upon it) can be interpreted as an attempt to take up Shapiro's challenge [Aizawa and Gillett (2009a); Aizawa and Gillett (2009b); see also Gillett (2002, 2007, 2010)].

In this paper, I argue that in order to satisfy some desiderata that any view of realization must satisfy (Section II), the A&G analysis of multiple realization requires an account of levels, and I try to show that the A&G framework is not successful under any of the extant accounts of levels (Section III). First, if A&G understand "levels" as non-local, monolithic levels of organization, then the dimensioned framework will not be an illuminating metaphysics for the compositional relations involved in mechanistic explanations in the sciences (Section IV). Second, if A&G understand levels as local, compositional levels of mechanism, then the dimensioned framework will exclude paradigmatic examples of multiple realization (Section V). The dimensioned framework also excludes paradigmatic examples of multiple realization if the levels metaphor in the A&G analysis is interpreted in terms of size scale (Section VI). I conclude that there is a real concern that the A&G framework for realization may not be viable.

II. Desiderata on a Theory of Realization

In order to assess the fruitfulness of A&G's framework, we need a better understanding of several of the desiderata that any view of realization must satisfy [Wilson and Craver (2007)]. First [D1], the realization relation is supposed to be weaker than metaphysical identity, "suitable for developing a brand of physicalism that made room for the autonomy of psychology" and the special sciences [Wilson and Craver (2007), p. 85]. In the same vein, Gillett [(2002), p. 316; my italics] remarks that "there [is] a robust, if loose, understanding of realization as a non-causal determination relation holding between properties that, *although not identical*, [are] in some sense the same." Second [D2], any view of realization should capture the dependence of the higher-level properties on the lower-level properties. If an instance of property *P* is a realizer of an instance of property *M*, then *P* somehow determines *M* or, in other words, *P* is metaphysically sufficient for *M*. Third [D3], realization should be an asymmetrical relation: if an instance of a property *P* realizes *M*, then it is not possible for an instance of *M* to realize *P*. Fourth [D4], realization, unlike identity, should be non-reflexive: no property (or property instance) should be realized by itself. Fifth [D5], realization ought to be a transitive relation. Transitivity implies that if a property *Q* realizes *P* and, in turn, *P* realizes *M*, then *Q* realizes *M* as well. This desideratum is supposed to articulate the intuition that realization is a kind of determinative relation. Thus, if an instance *Q* is metaphysically sufficient for an instance of *P*, and *P* is metaphysically sufficient for *M*, then it is to be expected that *Q* will be a sufficient condition for *M* [Aizawa and Gillett (2009b)].

Sixth [D6], the "vertical" determination of the realizer over the realized must be clearly distinguished from the "horizontal" determination of causal relations. At least since Hume, causation is supposed to be an asymmetrical relation that is temporally extended and relates wholly distinct entities [see Craver and Bechtel (2007); Aizawa and Gillett (2009a, 2009b)]. Realization, by contrast, is a synchronous relation that links entities that are not wholly distinct from each other [Craver and Bechtel (2007); Craver (2007)].

Seventh [D7], any acceptable framework for realization has to enable us to clarify at least what multiple realization involves [Wilson and Craver (2007)]. As a first approximation, we can say that a property *M* is multiply realized by instances of properties $P_1, \ldots, P_n$ if, and only if, every P_i realizes an instance of *M* and they are different in kind from one another. Any acceptable account of multiple realization must set additional constraints on this "bare bones" analysis in order to avoid trivial cases of multiple realization and subsume paradigmatic examples of multiple realization in the sciences.

Finally [D8], any framework for realization relations must illuminate the "making-up" relations posited between properties in compositional explanations in the higher sciences [Gillett (2010)].[1] Almost all of the theorists of realization agree that the context of their investigations is the metaphysics of science, i.e. "the careful, abstract investigation of ontological issues as they arise within the sciences and their explanations, findings, models, and so on" [Gillett (2007), p. 78]; [cf. also Polger (2010)]. In this context, theories of realization are not evaluated a priori but by their fruitfulness. Some theorists of realization, like Shapiro (2004), focus exclusively on one type of explanation found in the sciences, namely Cummins-style functional analysis. A&G correctly note that there are many componential explanations in the sciences which are not functional analyses in Cummins's sense [Aizawa and Gillett (2009b)]. Consequently, Gillett [(2007), p. 96n] uses "mechanistic" explanation to cover a large class of related explanations, including abstract functional analyses and more concrete mechanistic explanations. The idea that explanations in the higher sciences describe mechanisms is often articulated through a model-to-mechanism mapping (3M) constraint on explanatory models [Kaplan (2011)]. According to the 3M constraint, a scientific model contributes to the explanation of some target phenomenon to the extent that elements in the model represent some of the constitutively relevant parts, causally relevant activities, and organizational features of the mechanism for that phenomenon.[2]

Of course, the list of desiderata I have presented is not exhaustive. There may be other desiderata on theories of realization [cf. Craver and Wilson (2007)]. However, I believe that the list I offer will suffice to assess the fruitfulness of the dimensioned view.

III. Dimensioned Realization and Trivial Multiple Realization

The A&G dimensioned framework for realization is intended to be a comprehensive alternative to the "flat" or subset view of realization that is usually attributed to Kim (1998) and Shoemaker (2001, 2007). According to the flat view, realization is a dependence relation between a functional role and the physical particular that occupies that role on that occasion. In other words, an instance of a property *P* realizes a functional property *M* only if the instance of *P* exhibits the (causal) features that are distinctive of *M*, i.e. it occupies the functional role that *M* specifies. The flat view comprises two interconnected metaphysical claims [Gillett (2002)]: (i) that an instance of a property *P* realizes *M* only if *P* and *M* are instantiated in the same individual [cf. Kim (1998), Shoemaker (2001)]; and (ii) that an instance of *P* realizes *M* only if the set of causal powers that are individuative of an instance of *M* is a subset of the set of causal powers contributed by the instance of *P* [cf. Kim (1998), Shoemaker (2007)]. A&G consider that these claims of the flat view damage the capacity of that framework to satisfy [D8]. In real scientific cases of realization, i.e. in cases of "mechanistic realization," the realized property and its realizer may be instantiated in distinct particulars at different levels of entities. Furthermore, and in contrast with claim (ii) of the flat view, the realized property and its realizer may not have any causal power in common.

The paradigmatic scientific example of realization A&G consider is a cut diamond s^*, which has the higher-level property of being extremely hard, *H* [cf. Gillett (2002, 2007); Aizawa and Gillett (2009a, 2009b)]. The diamond s^* can be seen as a structure constituted by the carbon atoms s_1-s_n and the properties of each carbon atom as being bonded B_1, B_2, B_3, etc. and aligned A_1, A_2, A_3, etc. with other atoms in particular ways. Many different philosophical theories of properties could (and do) agree that properties contribute causal powers to their bearers [cf. Shoemaker (2001)]. Let us suppose, then, that amongst the causal powers that hardness contributes to the diamond is that of causing scratches on glass. Also, the causal powers of the bonds and relations of alignment of any carbon atom include the capacity of each atom to preserve its relative position in the structure even under stressful conditions. According to Gillett (2002), the instantiation of properties B_1, B_2, B_3, etc. and of relations A_1, A_2, A_3, etc. in the component parts s_1-s_n of s^* together realize the property *H* of s^*, even though these component properties and relations are instantiated in individuals distinct from s^* and contribute causal powers to s_1- s_n that are distinct from those contributed to s^* by *H*. Extrapolating from this exemplar, A&G propose the following schema for dimensioned realization:

DIMENSIONED REALIZATION

Property/relation instance(s) of P_1-P_n realize an instance of a property *M* in an individual s under conditions *\$* if and only if under *\$*, *s* has the powers that are individuative of an instance of *M* in virtue of the powers together contributed by the instances of P_1-P_n to *s* or *s*'s constituent(s), but not vice versa.

According to this schema, realization is an asymmetrical, non-causal, determinative relation between an instance of a property in an individual and a collection of instances of other properties in other individuals, thereby satisfying desiderata [D1]-[D6]. Thus, in most scientific examples, dimensioned realization[3] is an "inter-level" relation.

Dimensioned realization is a transitive relation. In fact, A&G claim that this feature of dimensioned realization represents a victory of their framework over the flat view. To take Gillett's example, if the properties and relations $P_1, \ldots, P_n$ of some microphysical particles together realize the bonding properties and alignment relations $Q_1, ..., Q_m$ of some carbon atoms and other instances of $Q_1, ..., Q_m$ together realize the property of being extremely hard, H, of a cut diamond, then the instances of the microphysical properties $P_1, \ldots, P_m$ realize the property H of the diamond.[4] The transitivity of dimensioned realization explains "how working scientists may move so easily between theories at one or more lower, or higher, levels" [Aizawa and Gillett (2009a), p.195].

The A&G framework for realization faces a problem concerning the satisfaction of [D7]. Consider the action potential mechanism. Imagine that an instance of a property A (e.g. the property of being selectively permeable to calcium ions) in the individual m (e.g. the neuronal membrane) is non-multiply realized by the properties $B_1, ..., B_n$ of other individuals $p_1, \ldots, p_r$ (e.g. the electrochemical properties of the ion channels across the membrane). And imagine that properties $B_1, ..., B_n$ of the ion channels are non-multiply realized, in turn, by the relations $C_1, ..., C_s$ of the amino acids that make up the channels. Given this scenario, one may argue that property A is multiply realized since distinct instances of A will be realized by distinct sets of properties ($B_1, ..., B_n$ and $C_1, ..., C_s$) on different occasions, satisfying the bare bones analysis of multiple realization. However, intuitively, the qualitative distinctness of $B_1, ..., B_n$ and $C_1, ..., C_s$ is not sufficient to ground a genuine case of multiple realization. Indeed, this example constitutes a case of trivial multiple realization.[5]

A&G are aware of this problem. The diagnosis they offer is that in the trivial case of multiple realization just introduced, the instances of realizer properties $B_1, ..., B_n$ and $C_1, ..., C_s$ do not constitute alternative realizations of property A because the instances of $B_1, ..., B_n$ and $C_1, ..., C_s$ "are not at the same level and are implicitly excluded as even candidates to ground a case of multiple realization" [Aizawa and Gillett (2009a), p. 189]. Consequently, they introduce a level constraint on multiple realization. The schema for multiple dimensioned realization becomes the following:

MULTIPLE DIMENSIONED REALIZATION

A property *G* is multiply realized if and only if:

(i) under conditions *$*, an individual *s* has an instance of property *G* in virtue of the powers contributed by instances of properties/relations F_1, ..., F_n to *s*, or *s*'s constituents, but not vice versa;

(ii) under conditions *$**, an individual *s** has an instance of property *G* in virtue of the powers contributed by instances of properties/relations F^*_1, ..., F^*_m to *s**, or *s**'s constituents, but not vice versa;

(iii) F_1-$F_n \neq F^*_1$-F^*_m, and

(iv) under conditions *$* and *$**, F_1-F_n and F^*_1-F^*_m are at the same scientific level of properties [Aizawa and Gillett (2009a), p. 188].

The fruitfulness of the A&G analysis of multiple realization crucially depends on how one interprets the idea of "scientific levels of properties" in condition (iv). Many philosophers warn that the level metaphor is "multiply ambiguous" [Craver (2007), p. 163] and that levels "are taken to mean an astounding variety of things" [Wimsatt (2007), p. 201]. By linking their account of multiple realization to the notion of level, A&G may have pulled a Trojan horse into their framework.[6]

IV. LEVELS OF ORGANIZATION AND MECHANISTIC EXPLANATION

It is important to note that A&G explicitly state that they have no theoretical account of levels but rather point to a concept of levels they claim is used in the sciences. They assert that

> there is a reasonably clear scientific notion of a level of entities, under some condition, as entities that do or can participate in the same causal mechanisms under those conditions (or which participate in processes that together implement other processes) [Aizawa and Gillett (2009a), p. 189n].

One might ask whether these "levels of entities" are, for example, compositional levels. On the one hand, if entities at the same level *do* participate in the same causal mechanisms, then they necessarily belong to the same compositional hierarchy. On the other hand, if the only requisite for being at the same level is that entities *can* participate in the same kind of causal mechanisms, then two entities may be at the same level without being compositionally related to the same higher-level causal mechanism, i.e. without actually belonging to the same compositional hierarchy. However, it is unfair to read much into the little they say about levels. Therefore, I will follow the strategy of looking at existing accounts of levels in the sciences and analyzing whether the A&G framework is successful under any account.

One candidate to ground the idea of levels of properties in condition (iv) of multiple dimensioned realization is Wimsatt's prototype account of levels of organization [Wimsatt (1994, 2007)]. His account is a prototype view because the levels metaphor is characterized in terms of a core set of features, not all of which are necessary in order for the metaphor to apply [Craver (2015)]. In Wimsatt's view [(2007), p. 200], the "primary working matter of the world" is causal relationships, which together make up patterns of causal networks. In certain conditions, these networks are organized into larger patterns that comprise levels of organization. Sometimes, levels of organization are taken to be hierarchical divisions of entities organized by part-whole relations (Wimsatt 2007, p. 201). In other passages, however, levels of organization are not compositional but

> constituted by families of entities usually of comparable size and dynamical properties, which characteristically interact primarily with one another, and which, taken together, give an apparent rough closure over a range of phenomena and regularities [Wimsatt (2007), p. 204].

In this last sense, levels of organization are thought of as peaks of regularity and predictability at different size scales [Wimsatt (2007); cf. Craver (2007), p. 181]. Note that this characterization does not require entities at different levels of organization to be compositionally related. For example, Wimsatt [(2007), p. 223] classifies "unicellular organisms" and "larger metazoan creatures" into distinct levels of organization, although in most circumstances these items are not compositionally related.

I do not want to discuss in detail the coherence of Wimsatt's prototype view or its relevance for the philosophy of science, but I do agree with Craver (2007; 2015) in thinking that Wimsatt's idea of levels of organization is ill-suited for illuminating the hierarchical structure of compositional explanations in the sciences, as demanded by [D8]. Levels of organization are more global and "monolithic" than the compositional levels posited in mechanistic explanations. Consider the following statement [Craver (2007), p. 191]:

(L) Pyramidal cells are at a lower level of mechanisms than hippocampi.

Sentence (L) is ambiguous. On the one hand, it might mean:

(L_1) The pyramidal cells that compose hippocampi are at lower levels than hippocampi.

Or it might mean:

(L_2) All pyramidal cells are at a lower level than hippocampi.

While (L_1) is a cogent generalization from the fact that these particular pyramidal cells are components of this particular hippocampal mechanism, (L_2) has exceptions because many populations of pyramidal cells are found in regions of the brain other than the hippocampus. The pyramidal cells which do not take part in the hippocampal mechanism are not at a lower compositional level than hippocampi because they are not compositionally related to hippocampi whatsoever. Craver [(2007), p. 192] says that, from the mechanistic point of view, "it makes no sense to ask if pyramidal cells are at a lower level than hippocampi *generally*. Some pyramidal cells are at a lower mechanistic level than hippocampi, and some are not." (L_2) is the natural interpretation of (L) under Wimsatt's approach, however, mainly because Wimsatt's levels of organization are obtained by abstracting from inter-level compositional relations among particular entities to inter-level relations among types of entities. If the idea of levels of properties in condition (iv) of multiple dimensioned realization were interpreted as referring to levels of organization, it would call into question the capacity of the A&G framework to illuminate the making-up relations posited in mechanistic explanations.

V. Levels of Mechanisms and Multiple Realization

For many philosophers of science, the idea of levels of mechanisms constitutes the basis of a promissory analysis of levels in the sciences that fits core explanatory patterns [Craver and Bechtel (2007); Craver (2007)]. Eronen [(2015), p. 40], who is not sympathetic to the idea of levels of mechanisms, admits that it is "arguably the most coherent and scientifically plausible account of levels of organization to date". Crave [(2007), p. 192] states the following sufficient condition for two objects to be at the same level of mechanisms:

> LEVELS OF MECHANISMS.
>
> *X* and *S* are at the same level of mechanisms if (i) *X* and *S* are components in the same mechanism, (ii) *X*'s φ-ing is not a component of *S*'s ψ-ing, and (iii) *S*'s ψ-ing is not a component in *X*'s φ-ing.

One of the crucial features of levels of mechanisms is that they are not monolithic strata in nature; they only have local significance. Levels of mechanisms are locally individuated within the boundaries of a hierarchically organized mechanism and they are not identifiable independently of that particular organization. One noticeable consequence of this analysis is that there is not a unique answer to the question of when two entities are at the same level. In a nutshell:

> How many levels there are, and which levels are included, are questions to be answered on a case-by-case basis by discovering which components at which size scales are explanatorily relevant for a given phenomenon. They cannot be read off a menu of levels in advance [Craver (2007), p. 191].

I contend that if the idea of levels of properties in multiple dimensioned realization is interpreted in terms of levels of mechanisms, then the approach generates a problem concerning the satisfaction of [D7]. Consider a toy example of multiple dimensioned realization in the neurosciences. Imagine a psychological capacity *D* of some organism, e.g. the capacity of that individual to consolidate perceptual experiences in long-term memory. A capacity of this kind is what mechanist philosophers designate as an "*explanandum* phenomenon." In this story, a group of cognitive scientists discovers that in many conditions, there is some specific neurobiological mechanism B_1 underlying *D*. Like many neurobiological mechanisms, B_1 is constituted by a tightly intertwined collection of diverse neuronal populations, metabolic pathways, macromolecules, ionic channels, specific ion concentrations, genes, etc. organized in such a way as to perform some relevant activities. But there is another research team (the story continues) that discovers that in many other conditions, there is a neurobiological mechanism B_2 that is capable of realizing the capacity *D*. B_2 is also constituted by a collection of neuronal populations, genes, metabolic pathways, etc. Of course, B_1 is distinct from B_2 from the perspective of its component parts, activities, and organizational features. How could we decide whether this is a genuine case of multiple realization (relative to *D*)?

A&G would say that for mechanisms B_1 and B_2 to multiply realize *D*, their respective constituents must be at the same level of properties. Remember that, from the dimensioned point of view, the potential realizers of *D* are not the composite properties of being mechanism B_1 and being mechanism B_2, but the collections of properties instantiated in the particulars that constitute, in this case, mechanisms B_1 and B_2 (see Dimensioned Realization in Section III). The properties instantiated in the component parts of B_1 and B_2 are not instantiated in the same object that instantiates *D* and they are not compositionally related to each other, so it is an open question whether the components of B_1 and B_2 are at the same level of mechanism. Even if B_1 and B_2 were composed of the same kinds of objects, there is nothing intrinsic to them that would allow us to decide if they are at the same level in each mechanism or not. Eronen [(2015), p. 44] makes this point explicit: "[we] cannot, for example, say that a Na^+ ion in the hippocampal LTP mechanism is at the same level as a Na^+ ion in the retinal mechanism of phototransduction, since they are involved in distinct mechanisms." Suppose that mechanisms B_1 and B_2 both incorporate, e.g., potassium channels; it does not follow that those channels are at the same level of mechanism. Levels of mechanisms have only local significance and they are relative to particular mechanistic hierarchies. It makes no sense to ask whether the components of B_1 and B_2 are "at the same level of mechanism" once we have accepted that B_1 and B_2 are distinct from each other.

The notion that the locality of levels of mechanisms raises a problem for the dimensioned view concerning [D7] can be illustrated with a paradigmatic example of multiple realization. Considered from the mechanist point of view, the compound eye of the horseshoe crab and the camera eye of some vertebrates are as different as two kinds of neurobiological mechanisms can be [Weiskopf (2011)]. The lateral eyes of the horseshoe crab are composed of simple structures known as ommatidia. Each of these ommatidia contains photoreceptive cells that can activate a central eccentric cell. This central cell is connected to adjacent ommatidia, constituting the "lateral plexus." These ommatidia are organized in such a way that the activity of one ommatidium can be inhibited by the depolarization of adjacent ones. In contrast to the relatively simple structure of the lateral plexus of the crab eye, the retina of the vertebrate eye is extremely complex. It is organized into several layers, and there is a greater range of cell types with highly specific connectivity patterns. Despite these differences, both mechanisms can produce the phenomenon of lateral inhibition. In this phenomenon, the activity in one kind of photoreceptor inhibits activity in other receptors. This pattern of activation may produce a particular experience known as Mach bands, i.e. the appearance of light or dark stripes after the end of a brightness gradient. The same functional property (lateral inhibition between receptors) that accounts for a phenomenon (the perception of Mach bands) is realized in significantly distinct neurobiological mechanisms across different species. This is a paradigmatic example of multiple realization in the neurosciences. Crucially, these mechanisms differ in the number and complexity of their parts, the nature of their activities, and the dynamical organizational features of their parts and activities. Since they are distinct mechanisms, the whole question of whether the entities that constitute B_1 are at the same level of mechanism that the entities that constitute B_2 seems awkward from the perspective of mechanistic explanation.

VI. Deflationary Accounts of Levels

Recently, Eronen (2015) has raised some doubts as to whether levels of mechanisms reflect the nature of levels in the sciences. Sometimes, Craver seems to suggest that two items are at the same mechanistic level if "they are in the same mechanism, and neither is a component of the other" [Craver (2007), p. 195]. Eronen considers Craver's same-level criterion to be problematic because it implies that there are no levels over and above compositional hierarchies. He finds it odd that the subcomponents of the different components of a mechanism — e.g. Na^+ channels in both rod cells and cone cells of the retina — that are playing similar roles in similar components and that potentially interact with each other may not be at the same level. Conceptually, there has to be something more than composition involved in the idea of levels. Eronen proposes a deflationary account of levels of organization, one in which some considerations of *scale* might be involved.

Eronen's proposal is that the term "level of organization" is ambiguous and contains, at least, two conflicting elements: composition and scale. The combination of composition and scale in the same notion of level leads to conceptual incoherencies. However, those elements are relatively well-defined and surely useful in the philosophical understanding of mechanistic explanation, reduction, and downward causation. For things to be arranged on a scale, one only needs to select a property that can be quantitatively measured in those things (size, time, energy, force, etc.). One could argue, for example, that all the Na^+ channels that are subcomponents of the cells in the mechanism of phototransduction (and all the Na^+ channels beyond that mechanism, as well) are at the same level because they can be arranged in the same segment of a size scale.

Eronen's deflationary analysis of levels brings scant relief for A&G. If A&G understand levels of properties in condition (iv) of multiple dimensioned realization as mere levels of composition, then they face the problem that levels of composition are too local to ground paradigmatic cases of multiple realization (cf. Section V). Alternatively, A&G may argue that for the components of two mechanisms B_1 and B_2 to be multiple realizations of some property *D*, those components must be close enough on a size scale. This line of reasoning would generate a problem for the A&G framework concerning the satisfaction of [D7]. The components of a mechanism – even the *direct* components of a mechanism, i.e. "those components that are not components of any other component of the mechanism" [Eronen (2015), p. 49] – can be of drastically different sizes. For example, the mechanism of action potential includes direct components as different in size as neuronal membrane regions and potassium ions, and "the direct components of the rod phototransduction mechanism include things as different as outer segments and Na^+ ions" [Eronen (2015), p. 53]. In general, the mechanisms studied by the sciences host direct components that cannot be arranged in the same segment of a size scale. In our paradigmatic example, both the compound eye and the vertebrate eye have direct components of radically different sizes. Thus, if the potential realizers of lateral inhibition were restricted to one segment of the size scale, then the properties of the parts of the camera eye and the properties of the parts of the compound eye would be excluded as candidates to ground a case of multiple realization—a conclusion that fails to satisfy [D7].[7]

VII. Conclusion

To avoid the problem of trivial multiple realization, the A&G analysis of multiple realization requires an account of levels. I have argued that the A&G framework for realization is not successful under any of the extant accounts of levels. There is consequently a real concern that there may not be a good notion of scientific level that fits the bill, and that the A&G framework for realization may not be viable.

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NOTES

[1] Because of their exclusive focus on functional realization, Polger and Shapiro (2008) would not agree that D8 is a desideratum for any account of realization. Again, this doesn't affect my argument because D8 is clearly a desideratum for A&G, at whom I am targeting.

[2] The framing of these desiderata presupposes that the relata of the realization relation are property instances. There is some debate over this, however. For example, Polger and Shapiro (2008) argue that such a view leads to contradiction. This point does not affect my argument against the A&G framework.

[3] For a similar use of the expression "dimensioned realization", see Endicott (2016).

[4] "[W]e should note that our schemata take realization to be a transitive relation – a feature that it shares with other scientific composition relations. Thus, if property instances F_1-F_m realize, G_1-G_n in certain individuals and under specific conditions, and G_1-G_n realize property instance H, then F_1-F_m realize H" [Aizawa and Gillett (2009b), pp. 18-19].

[5] Philosophers like Larry Shapiro and Tom Polger have argued that the dimensioned framework implies that there is "too much realization" and therefore it is trivial [Shapiro (2004); Polger and Shapiro (2008)]. Shapiro and Polger are concerned that the dimensioned view is not clear on how the realized property relates to its realizers and seems to imply that almost any difference in the realizers of a property is a case of multiple realization [cf. Piccinini and Maley

(2014)]. My concern is that the A&G framework seems to imply that the fact that a higher-level property is realized by different properties at different levels is sufficient for that higher-level property to be multiply realized.

[6] One could argue that it is simply false that potential realizers of some higher-level property must be at the same lower level of entities. Koch [(2004), p. 474] argues that "it is sobering to realize that to implement a single operation – multiplication – the nervous system can choose from mechanisms that operate at the individual synapses and spines, to those that require small population of cells. This raises the unsettling, but quite plausible scenario in which any one computation is carried out using a plurality of mechanisms at different spatial and temporal scales." The whole strategy of "leveling multiple realization" might be mistaken. I will not consider this objection to A&G in this paper, because I do not think that the level constraint on multiple realization can be given any plausible interpretation in the first place.

[7] This objection also applies to the interpretation of condition (iv) of multiple dimensioned realization in terms of Wimsatt's levels of organization if one emphasizes the idea that higher-level items are larger than lower-level items. If things in the same size range are at the same level of organization, then the direct components of B_1 and B_2 – in which the potential realizers of *D* are instantiated in our toy example – may be at different levels of organization and, therefore, they would be excluded as candidates to ground a case of multiple realization.

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