Chapter Five

EXPLORATORY STRATEGIES: EXPERIMENTS AND SIMULATIONS

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Introduction

The use of computer simulations in different scientific activities has increased considerably in the last few years. However, philosophical reflection on computer simulations is rather scarce, partly due to the relative novelty of this type of activity, and partly due to complexity of the subject. What aspects should be taken into account, and what perspectives must be adopted for the investigation are among the most important questions to ask when analyzing computer simulations from a philosophical point of view.

In the present work, we suggest that an analysis based on exploratory strategies can be used to illuminate and characterize epistemic and methodological aspects of computer simulations. Putting the focus on the exploratory strategies implies adopting a perspective that, albeit it is relevant to the experiments and simulation analysis, is not limited to any of these areas. Exploratory strategies can be found in very diverse scientific practices. Notwithstanding, they can be used to underline relevant philosophical aspects of experimental practices and computer simulation practices alike. In this way, our proposal explicitly surpasses the comparison between experiments and simulations, albeit we are convinced that analyzing exploratory strategies in experiments and simulations helps substantially in the elucidation of their methodological and epistemological roles.

The elucidation of the role of the exploratory strategies in computer simulations and experiments would contribute to the philosophy of both activities. Because the relation between computer simulation and experimentation has been understood in a very different way by the philosophical literature, a brief revision of some of the central issues will be needed. In addition, philosophical literature on exploratory experiments presupposes, although it rarely makes it explicit, an exploration notion that we will briefly address in this article. It is important to note that in their original contexts, both discussions have the pretension of drawing limits between simulations and experiments or between exploratory experiments and other experiments. On the contrary, as we repeatedly say in this paper, instead of stipulating limits for each type of practice, we propose to establish a ‘topology’ of the ways science tests, searches, and explores.

We organize our work in the following way. First, we will schematically describe the way in which computer simulations are compared with experiments to establish the differences with the perspective defended in this paper. Second, we will address the distinction between exploratory experiments and other types of experiments. We will analyze exploratory strategies in experiments and simulations with the sole purpose of making our argument clearer; it is also important to keep a certain similarity to the way this matter has been questioned in philosophy. However, in most scientific practices, boundaries are not so clear. More than being a difficulty for the chosen cases, this seems to be the way in which contemporary scientific activity is organized. We think this could be an additional advantage of adopting the perspective of exploratory strategies, because it is neither centered on the distinction between experiment and simulation nor restricted only to experimental practices.

Philosophy of Computer Simulations: Experiments and Simulations

Experiments have been compared to simulations taking into account ontological and inferential aspects on one hand, and representative or interventional aspects on the other. So, although there are many ways of implementing a simulation on a computer, they can be characterized as a sequence of time ordered states that represent another sequence of time ordered states (Cfr. (Guala 2002), (Hartmann, 1996), (Parker, 2009)). Representation and imitation seem to be the main concepts. On the other hand, an experiment is usually characterized as an interventional activity.

A main concern in reflections on these subjects is usually the question of the validity of the simulations or, in more general terms, their epistemic credentials. At the same time, the discussion of ontological and epistemic problems usually assumes a basic scheme: simulations are seen as systems characterized principally by some model that typically refers to another system (usually called target system). In this way, the question about the validity is set forth in terms of the relation between a given system and the target system, as well as the possibility of generalizing these results or connecting them to other systems. Accordingly, Francesco Guala (2002) has proposed that the differences between an experiment and a simulation can be understood by appealing to the type of justification of the inferences that relate the different systems. The inferential link that can relate the experimental result of a system A with the result of another system B can be very strongly justified, according to Guala, if both systems are operating under the same causes. Here one must suppose that there is only an abstract and formal correspondence between a computer simulation and a simulated system, while between an experiment and a target system there usually is a correspondence at a deep level. In this second case, the same causes should be operating in the experiment as well as in the target system.[1] A main concern in reflections on these subjects is usually the question of the validity of the simulations or, in more general terms, their epistemic credentials. At the same time, the discussion of ontological and epistemic problems usually assumes a basic scheme: simulations are seen as systems characterized mainly by some model that typically refers to another system (usually called target system). In this way, the question about the validity is set forth in terms of the relation between a given system and the target system, as well as the possibility of generalizing these results or connecting them to other systems. Accordingly, Francesco Guala (2002) has proposed that the differences between an experiment and a simulation can be understood by appealing to the type of justification of the inferences that relate the different systems. The inferential link that can relate the experimental result of a system A with the result of another system B can be very strongly justified, according to Guala, if both systems are operating under the same causes. Here, one must assume that there is only an abstract and formal correspondence between a computer simulation and a simulated system, whereas between an experiment and a target system there is a correspondence at a deep level. In this second case, the same causes

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[1] Parker argues that Guala's proposal is too restrictive in his experimental notion, even though she accepts that Guala doesn't mean to say all material causes are relevant in this case, but only the ones that are 'closer.' Well then, scientists that are trying new drugs on mice are experimenting, even though the results on humans later turn out to be different. Also, Guala's proposal is very restrictive when it refers to simulations, because it is too strong to say that there are 'never' common material causes. (Parker, 2009)

should be operating in the experiment as well as in the target system.[2] Gilbert Troitzsch (1999) also seems to implicitly presuppose the relation between an experimental or computer system, on the one hand, and a target system on the other. Such relation underlines the differences between a simulation and an experiment, although it focuses on purely interventional aspects. These authors point out that in the case of an experiment one is handling a real object, while in a simulation if anything is to be handled it is a model:

> While in an experiment one is controlling the actual object of interest (for example, in a chemistry experiment, the chemicals under investigation), in a simulation one is experimenting with a model rather than the phenomenon itself (Gilbert & Troitzsch, 1999, 14)

It is probable that the same type of intuition that is sustaining the notion of materiality, or the correspondence on a deep level, is operating behind the notion of the real object. Parker (2009) suggests that the notion that must be considered is the one of relevant similarity, instead of the one of materiality. As we have already said above, if a simulation is understood as a representative system, an experiment is characterized as "an investigative activity that involves intervening on a system in order to see how properties of interest of the system change, if at all, in light of that intervention" (Parker, 2009, 487). When a simulation is arranged on a digital device we have a "computer simulation." Although a computer simulation is characterized in terms of representation, a "computer simulation study" can be seen as an interventional activity inasmuch as one requires "setting the state of the digital computer from which a simulation will evolve, and triggering that evolution by starting the computer program that generates the simulation" (Parker, 2009, 488). Parker believes that this way of characterizing a "computer simulation study" allows us to talk of an interventional activity and therefore of an experiment, because the focus is not on the model but on a programmed digital computer. Although Parker's proposal seems interesting because it tries to account for the difference between mere modeling and computer

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simulation, it does not appear that the sole act of pointing out an interventional aspect is enough to qualify a “computer simulation study” as an experiment in a relevant sense.

There are other philosophers, such as Winsberg (2009), that suggest that instead of considering ontological aspects to distinguish experiments from simulations, one must pay attention to the type of inference made and the role taken by the background knowledge. In the case of simulations, this background knowledge allows us to build models that can later be taken as the object of investigation. Consequently:

> When an investigation fundamentally requires, by way of relevant background knowledge, possession of principles deemed reliable for building models of the target systems, and the purported reliability of those principles, such as it is, is used to justify using the object to stand in for the target, when a belief in the adequacy of those principles is used to sanction the external validity of the study, then the activity in question is a simulation. Otherwise, it is an experiment. (Winsberg, 2009, 586)

In an analogous way of thinking, Morgan (2005; 2003) argues not only about the material but also the inferential aspects of simulations. Experiments and simulations should have different “epistemic power”: the inferences on experimental systems can be better justified when the experiment and the target system that the experiment refers to are made of the same “stuff.” Morgan supposes that traditional experiments have greater epistemic power than simulations because as long as the latter depend completely on a model they cannot confuse or surprise scientists. Here the notion of confusion is not taken in a psychological sense but in an epistemic one: the phenomenon in question is somewhat “surprising” as it cannot be accounted for with the available theoretical resources. Morgan (2003) also points to the material aspect as discriminatory criteria, but now between two types of experiments (material and non-material). Simulations would be among the latter (non-material experiments). In fact, one of the most interesting suggestions from these accounts is that the usual situations in science are “hybrid” scenarios, where a clear distinction between experiments and simulations are not easy to draw.

Taking a different perspective to the one we have quoted up to now, Morrison (2009) emphasizes the functional dimension of simulations and experiments. Somehow, she also tries to clarify the conception of experiment by describing some experimental activities such as measurements. This change in perspective allows her to argue about some ways of creating a model with similar functions to a measuring instrument.

In this sense, and for some cases, we could speak of simulations as experimental measuring instruments.

Typically, by comparing experiments and simulations one tries to build a philosophy of computer simulations based on ontological, inferential, representational, interventional, or functional aspects. They could serve to establish limits between experimental and simulative activities. However, to some extent, ontological aspects could play an important role in the comprehension of simulations. Beyond the intrinsic virtues of this way of approaching simulations, our proposal can be taken as a move from ontological to methodological and epistemological problems through the consideration of exploratory strategies. In this sense, most of the ideas quoted in this section allow us to underline differences with our exploratory strategies proposal.

Considering that the notion of exploration has been mainly used in the philosophy literature on experiments, in the following section we will begin with this discussion to continue later with the notion of exploratory strategy.

From Exploratory Experiments to Exploratory Strategies

The notion of exploration in science has not received a great deal of attention in the philosophical literature. Nevertheless, among the diverse proposals to classify scientific experiments it is possible to find reflections about the role of exploration in science. The category of "exploratory experiment" is quite common among the various experiment classifications. In this way, the attempt to elucidate exploratory experiments presupposes characterizations about exploration (for example, cf. (Burian, 2007); (Elliott, 2007); (Franklin, 2005); (O'Malley, 2007); (Peschard, 2009); (Steinle, 1997, 2002); (Waters, 2007)). Although we will show that the diverse characterizations of exploratory experiments do not achieve adequate discrimination of these experiments, the analysis of the different proposals will allow us to show some of the characteristics of exploration. However, these exploration characteristics would not be useful to do an adequate taxonomy of the experiments; they will be the basis of our characterization of "exploratory strategies." In this sense, it is important to remember that exploratory strategies are not specific to the exploratory experiments, but they do constitute a relevant aspect of the best part of scientific activity, including experimentation and scientific simulation.

It has been suggested that exploratory experiments can be understood based on the contrast with experiments where the relevance of theory is substantive. In most of the classifications, this is a distinctive feature.

Franklin (2005), for instance, holds that exploratory experiments are the ones scientists do without considering a particular theory. This concerns the effects of their intervention on the values they are measuring. In a similar way, Steinle suggests there are experimental designs that are guided by theory (i.e. theory driven) and others which are not, the latter being the exploratory experiments. Thus, exploratory experiments could be characterized by their relative independence to strong theoretical restrictions (Cf. (Franklin, 2005, 888); (Steinle, 1997, S69; 2002, 418)).

In the same sense, Steinle (1997) maintains that the standard perspective on experimentation typically considers those cases that are theory driven as the only type of experimentation. Accordingly, experimental activity is understood in terms of: “a theory that led to expecting a certain effect; the expectation led to designing and conducting an experiment; and the success of experiment counted as support for the theory” (Steinle, 2002, 418). However, from this author’s perspective, exploratory experimentation “typically takes place in those periods of scientific development in which – for whatever reasons – no well-formed theory or even no conceptual framework is available or regarded as reliable” (Steinle, 1997, S71). Even those authors that do not explicitly uphold this idea seem to keep this way of understanding exploratory experiments in mind, inasmuch as they choose examples from the initial stages of scientific disciplines.

However, the related literature, which sees the discriminatory criteria in the theoretical guide, also underlines other aspects that are important for characterization, such as the purpose of these experiments, their use or the experimenter’s expectations. For example, the variety of epistemic goals present in the exploratory experiments becomes relevant:

> The contrast of exploratory experimentation to the theory-driven type, as understood as the standard view, is not only visible in the different epistemic goals (search for regularities vs. test of expectations), but also in the character of the guidelines of the experimental activity. (Steinle, 2002, 422)

Likewise, we must remark that the exploratory experiments are not circumscribed to a particular historical or theoretical context:

> (…) exploratory experimentation is not so much bound to certain historical periods, fields of research, or scientific traditions, but first and foremost to specific epistemic situations: those situations namely in which, for reasons whatsoever, the very concepts by which a certain field is treated have been destabilized and become open for revision. Situations in which theories and well-formed expectations are tested, in contrast, require a well-

> elaborated conceptualization, a stable language by which the expectation can be expressed in the first place. Exploratory and theory-driven experimentation are connected to different constellations and situations of our knowledge, to different regimes of stability on a conceptual level. (Steinle, 2002, 425–426)

Finally, some philosophers underline the relation between the experimental activity's purposes and its results:

> Roughly speaking, the aim of exploratory experiments is to generate significant findings about phenomena without appealing to a theory about these phenomena for the purpose of focusing experimental attention on a limited range of possible findings. The findings might be significant with respect to a variety of goals ranging from the practical goal to learn how to manipulate a phenomenon to the theoretical goal to develop a conceptual framework that will help focus future experimental attention. (Waters, 2007, 5)

It is important to note that the previous three quotations correspond to authors that defend the theoretical dependency criteria for the distinction of exploratory experiments. However, in all three one can notice that other characteristics are the ones that stand out in this type of experiments.

When exploration is taken as a distinctive characteristic of some experiments, it does not appear to be adequately characterized by its dependency on the theory. In fact, whoever tries to defend this idea should be able to explain the different levels of theory involved in an experiment, and determine which of these levels is or are relevant to the "theoretical guidance."

To say that an experiment is guided by a theory means that the expectations regarding its results are theoretical, or that the design of the experiment depends on a theory, or that the instruments used are theory dependent, etc. It is possible that a large part of the difficulty of the characterization, in terms of theoretical dependence of the exploratory experiments, is due to the lack of a sophisticated notion of theory and of levels of theory involved in the design, execution, and analysis of experimental results.[3] However, the perspective of the dependency to theory, even when attention has been paid to the previous observation, does not reflect important epistemological and methodological aspects of exploration in science.

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[3] A first approach to the different types and levels of theory involved in an experiment can be found in (Hacking, 1992).

In this sense, Steinle himself states that in exploratory experiments we can distinguish the following activities as typical methodological practices:

- Varying a large number of different experimental parameters,
- Determining which of the different experimental conditions are indispensable, which are only modifying,
- Looking for stable empirical rules,
- Finding appropriate representations by means of which those rules can be formulated,
- Forming experimental arrangements that involve only the indispensable conditions, thus presenting the rule in particular clarity. Those experiments are typically characterized as “simple,” “elementary,” or “pure case” (Steinle, 1997, S70).

One of the activities pointed out as typical in an exploratory experiment is the variation of parameters. This is usually a regular procedure in experiments, not only exploratory but also in general. The variation of parameters can be done with different aims in mind: from the calibration of a measuring instrument to the intention of obtaining some empirical regularity. Now, the purpose of an experiment can turn the variation of parameters into an exploratory experiment even though it is carried out under strong theoretical restrictions. This makes one believe that an exploratory experiment is best characterized by its purpose rather than by its particular relation to theoretical aspects. This relationship with theory can only be understood if no qualification appears as an inadequate characterization.

In addition, emphasizing the aims and the roles of the experiments helps us to distinguish between exploratory strategies that not only form part of exploratory experiments but also of experiments with different purposes, such as hypothesis confirmation. This point seems relevant for different reasons. In the analysis of cases that usually accompanies the characterization of exploratory experiments, there is confusion between what we could call the exploratory experiment typology and the searching and exploring strategies. However, it seems clear that there are exploring strategies belonging to non-exploratory experiments, as they are also part of other non-experimental scientific practices.

Yet, it is necessary to point out that search strategies or exploratory restrictions do not seem to be the defining feature of exploratory experiments. However, their consideration allows a more adequate description of certain aspects of scientific and experimental practices in particular.

Exploratory Strategies in Scientific Practices

We organize this section in the following way: first, we will make explicit what we understand as an exploratory strategy; then we will show some examples that will permit us to contextualize our proposal. Finally, we will analyze some cases regarding exploratory experiments presented by the literature to show the advantages of our proposal. In particular, we will show how adopting the point of view of the exploratory strategy leads to a more direct relationship with computer simulations.

In this paper, we will consider any activity or resource that allows us to do an exploration as an "exploratory strategy." These activities or resources can be very different, but as long as they perform the function of allowing us to question, search, probe, or explore, we will call them "exploratory strategies." It is important not to restrict the notion of a strategy by setting rules or any other structure implying a procedure. The relevance of this point will become evident in the following paragraphs as we present the ways in which exploratory strategies can be instantiated.

A first way of characterizing exploratory strategies is in terms of what they are looking for (what they explore), the way in which they do this operation (how they explore) and to what end they are doing it (what they explore for).

A second way of characterizing exploratory strategies would be paying attention to the structure of the search –or, if you prefer, to the restrictions in the "searcher"– and the structure of the media in which one is searching –the restrictions in the search space. We could have searches with few restrictions – for them to be as adequate as possible – or searches with strongly selective criteria. This way of understanding exploratory strategies can be instantiated as searching rules or heuristics. The structure of the searching rule will let us account for part of the restrictive capacity of the exploratory strategy. We can call this way of understanding exploratory strategies as 'type 1.' We can also explore using judicious construction of an exploration space or by limiting the size of this space. This way of understanding exploratory strategies we will call 'type 2' strategies. We are using, although in an indirect way, the metaphor that distinguishes between the search strategy and the space where the strategy takes place. In the same way that we talk of restrictions in the type 1 strategies, we can suppose that the space structure involves, among other things, graduating the restrictions. One could argue that the distinction between type 1 and type 2 strategies is not genuine because type 2 strategies can be rewritten in terms of type 1. Although in principle it seems possible to do this rewriting task and eventually reduce one type to the other, this perspective does not look adequate when we are trying to account for epistemic and methodical aspects associated to the description of scientific practices. In this ‘reduction’ task, the specific ways in which the exploration is being done, within the simulations or the experiments, would not be adequately shown.

Before continuing, let us see some examples that help put our discussion in context. The first case involves the so-called combinatory chemistry and high-throughput screening. Combination chemistry can be described, in very general and schematic terms, by methods associated with combinatory synthesis and high-throughput screening. According to Valerie Gillet, an investigator in this area, combinatory chemistry “refers to the synthesis of large numbers of compounds in parallel where product molecules are formed as combinations of available reagents or buildings blocks” (Andrew R. Leach & Gillet, 2007, 617). High-throughput screening “is an automated process whereby a large number of compounds (104 – 105) are rapidly screened for biological activity” (Andrew R. Leach & Gillet, 2007, 617). This focus on synthesis and screening, more than a new methodology, represents an automation of traditional methods with the help of new instrumental resources. Combinatory synthesis can be seen as a procedure to construct, in different ways and suppositions, a ‘search area.’ The high-throughput screening can be seen, not only by its design but also by its application, as a ‘search strategy.’ Let us have a look at these two types of analysis.

Starting with high-throughput screening one can understand the types of search involved here from their historical evolution. During the 80s it was taken as an advantage for this search to be as little restricted as possible, so as to be able to obtain the largest number of candidates for a new drug (leads), by the sole record of the force of automation. Sometimes, this way of search is described as “serendipity” (Cf. García, 2009). With time it became clear, from the poor results obtained, that a more selective search was required. Therefore, restrictions were added to the type of mechanism that was desirable in a drug precursor. Among the restrictions for selecting drugs candidates, we can quote the Lipinski’s rule of 5 (Lipinski, 1995) –a set of desirable characteristics in drug, such as solubility or permeability. However, there are also other types of restrictions that may take the form of superposition or adjustment between molecular structures. This way of understanding high-throughput screening is sometimes called “rational” or “design” to mark its differences to a search without too many restrictions.

The increase of restrictions in the search was not the only resource used to improve the performance of these systems. The use of combinatory chemistry to design libraries of compounds has become more sophisticated since the 90s. This aspect can be seen as an instantiation of the second criteria to classify exploratory strategies. In fact, the construction of libraries of substances seems like a way to restrict or guide the search by means of a rational structuring of the problem's space. This began the discussion about the way one could obtain libraries of substances with a sufficient degree of variation to make the search interesting. This supposes a relevant notion of "variation." Although this notion can be instantiated differently according to the case, the construction of a more general notion has been attempted. A standard way of understanding this notion is to link the concept of "diversity" to that of similarity. In the context of the construction of libraries, what one needs is some codification of the substances in question (molecular descriptors are usually used) to be able to later define a measure that can be taken as a degree of similitude. In this way, one can determine if a sample of substances is more "diverse" than another in terms of some quantifiable criteria (Cf. Bleicher et. al., 2003).

In several of the more interesting stages of work in combinatory chemistry, simulation, experimentation, and exploration strategy practices are involved. This makes it far from simple – and probably inconvenient – to make differences between experiments and simulations when investigation processes are under consideration rather than their constituent parts. For instance, one can take not only the construction but also the search in *virtual libraries* (an approximation sometimes called *in silico*). In this case, libraries of aspects and properties of the substances with relevant descriptions are constructed, and the search is done in these virtual spaces. Thus "in silico" screening "refers to the use of computational techniques to select compounds, either from existing libraries…or from virtual libraries that represent the compounds that could potentially be made via combinatorial synthesis" (Andrew R. Leach & Gillet, 2007, 618). If what interests the researchers involves the known links ("ligands") for a compound with a certain "target," then you can build a "pharmacophore" model to account for the compounds structural aspects. It is important to point out that "a pharmacophore does not represent a real molecule or a real association of functional groups, but a purely abstract concept that accounts for the common molecular interaction capacities of a group of compounds towards their target structure" (IUPAC Recommendation cited by A. R Leach, et. al., 2010, 539). For this reason, this type of model is usually used for virtual searches (virtual screening) and predictive "docking" models in general; that is, rational design models that in some way allow to have expectations on candidate ligand receptors (Andrew R. Leach & Gillet, 2007, 166ff).

One way to systematize the virtual search types is to consider the amount of structural information and biological activity available (Andrew R. Leach & Gillet, 2007, 158ff).

First, if what is known is only a single active molecule, virtual search will generally be based on the possibility of binding. Second, if there are various active molecules, you can build a pharmacophore model and then search using 3D properties. Third, a neural network can be used when there is sufficient information about active and inactive structures. Finally, when the 3D structure of a protein is known, “protein-ligand docking can be employed” in the search (Andrew R. Leach & Gillet, 2007, 160). Thus, the virtual search involved in this type of computer simulation depends on the type and the amount of information available on the chemical compound’s space. Any results that may be of interest can become part of experiments in real libraries.

The virtual library search can hardly be seen as an exploratory experiment; in this case, however, it is clear that exploratory strategies are used. Moreover, it is possible that similar strategies are used in both the virtual and real experimental spaces. Considering the discussion in the previous section, here we would have experiments using exploratory and search strategies in contexts where the goals can be confirmatory. An example of this would be the search process that is triggered when it is estimated an achieved precursor or a more or less reliable candidate for a drug. The process in this scenario is a type of search, although for confirming a promising result. This is a good example of situations that Morrison called “hybrid,” which are so common in current scientific practices.

Shown in this schematic presentation are some of the advantages of our proposed characterizations. However, it is clear that such characterizations require a more careful elucidation. Returning to the first characterization of exploratory strategies, it could be endorsed that the functional aspects of these strategies are only linked with the third item (what they explore for) of the first characterization. However, to account properly for the functional aspects requires an explanation of the ways in which the exploration is performed and certainly of its goal. In turn, the first aspect of the first characterization of exploratory strategies (what are they looking for?) could be understood as referring to the particular scientific discipline in which they are used – chemical, physical, or otherwise – or the main purpose of the experiment or activity performed. Yet, this does not seem to be its primary meaning. If an experimental design uses a variation of parameters in order to calibrate an instrument, then the alleged exploratory strategy here seems to be aimed at the instrument itself (or at least at some relevant contexts to increase the precision or accuracy of the instrument). From this point of view, we can see that exploration activities are also involved in the different aspects of design and execution of an experiment or other scientific activities. Among the latter, we can point out the situation in which models are explored; that is, we explore the limits of a model, the empirical approximation of a model, the adjustment of a model to other models, etc. This aspect of exploratory strategies can also have a more sophisticated network. For example, when we consider the field of computer simulations, we have, and typically this is the case, exploratory strategies at different levels, in this sense, the question about what these strategies look for, has a different response at each of these levels. The scientists have general goals that characterize the computer simulation’s main objective. However, this central goal does not invalidate the aims of other strategies at lower levels. Thus, we can have a computer simulation whose main objective is to explore a model in a certain way, but which also has different exploratory strategies in its “lower” levels. This complexity is not necessarily a difficulty, since it allows us to explain the relative independence – at least in a certain sense – between each of these exploration strategies. Depending on the type of problem in which we are interested, we can distinguish different strategies at different levels.

Regarding the second aspect of the first characterization of exploratory strategies – how to perform the exploration – here one can consider different types of search, exploration and inquiry. Virtually all we have considered in type 1 and 2 strategies could come into this point, taking into account the restrictions on the search and the structuring of the space where the search is made. Either way, it is possible that this approach can be developed in the future by checking other aspects through which the types of search can be seen, or by specifying the types of restrictions that are taken into account. For example, returning to the case of high-throughput screening, one could take into account the differences between the exploration based on structural aspects (such as “host-based coupling”) and those based on properties. The latter could include the aforementioned rule of Lipinski. A compound can have “drug-likeness” if it has certain properties, such as absorption or permeability (which is unlikely if the compound in question has a molecular weight greater than 500). While what we might call structural searches also have the goal of finding compounds that may be plausible candidates for a new drug, the type of restriction that guides the search is very different. The methods called “molecular docking” would fall into this category. In general, what is intended to be found in the “docking” experiments is the 3D structure resulting from two or more molecules. Computational methods involved here are concentrated on two tasks: exploring the space of possible "protein-ligand geometries" (Andrew R. Leach & Gillet, 2007, p. 161) and the weighted evaluation of these geometries to enable them to "identify the most likely binding model for each compound and to assign a priority order to the molecules." (Andrew R. Leach & Gillet, 2007, p. 161). To a large extent, the difficulty of this task lies in the degrees of freedom in rotation and translation of molecules – in relation to other molecules – which affect their geometrical configuration. For this reason, the biggest effort is often in the design and implementation of algorithms that account for this problem.

The third aspect of the first characterization of exploratory strategies (what is the exploration performed for?) is important because it allows us to highlight another angle of the relationship between exploratory strategies and other scientific activities and experiments. One might suppose that this appearance coincides with the one that allowed us to distinguish between exploratory experiments and confirmatory experiments. However, as we saw above, the goal of an overall activity is not the reason for the exploratory strategies involved. Continuing with the aforementioned example we mentioned above, we might have an experiment whose design or calibration assumed exploratory strategies, but whose ultimate goal is to test or confirm a given hypothesis. At least in principle, given the complexity of current experimental designs and the different levels sometimes involved, there may be exploratory strategies at an execution level, although the aim of the experiment itself is another.

From this characterization, taking some cases from the literature on exploratory experiments, exploratory strategies can be analyzed in a new light. As noted in the previous section, the concern about drawing a line between exploratory experiments and other interventional practices has left in the background other interesting aspects of these scientific practices. In order to show the advantages of our proposal we discuss some of these examples. In our analysis, we will focus on what we called type 2 strategies that is in the form in which the exploration space is selected and configured. In a complementary way, we highlight the importance of instruments in these cases. Franklin (2005) noted that the adoption of certain instruments is often accompanied by an increase in experimental "exploratory practices." The impact of the instruments is similarly highlighted by several of the philosophers who analyze exploratory experiments. However, it can be argued that not only are there methodological strategies associated with the mere adoption of an instrument to carry out a task, but also with its configuration and use.

Moreover, the notion of instrument, understood from the methodological resources, can serve to understand the role of computer simulations. O'Malley (2007) presents a case within the scope of what is often called "metagenomics." This case is related to the discovery of proteorhodopsin in marine bacteria gene (in the Monterey Bay). Metagenomics can be characterized by the manner in which the samples to be examined are selected. Under the assumption that genomic diversity is not sufficiently represented by the crop cloning methods used to sequence the genetic information, samples taken from some "natural" environment that is relevant to the investigation are used. In this way of selecting the samples, we can see a first sense of exploration linked to the selection of the space where the investigation is to be performed. This consideration is reinforced when comparing the sample "area" to the cultivated samples space where experimental protocols tend to favor their "isolation." O'Malley also highlights this aspect, as it allows him to describe a form of exploratory experiment. However, beyond this first exploratory direction presented by O'Malley, one might suggest a second direction associated with the sequencing of the samples.[4] For several years, a parallel sequencing technique ("shotgun" Sanger sequencing or massively parallel pyrosequencing) is being used, and is often seen as a suitable complement to the objectives of metagenomics. It seems clear that there is a sense of exploration involved in the parallelism in this type of method (Eisen, 2007).

Franklin quotes another case in the literature on exploratory experiments, which concerns the use of what is called "microarrays" (DNA chips). Franklin underlines the use of this tool in the investigation of the role of certain proteins in the cell cycle. This instrument consists of a "plate" of a material that can serve as a "grid" for samples to be analyzed. These plates must be constructed of a material that allows DNA binding. Due to the parallel nature of this technique, it is often used to investigate "the differential expression of the genes." The level of gene expression is measured by a "probe," which is added to the sample to be investigated and that has been "marked" (with a fluorescent or radioactive tracer). These marks are analyzed in an image that indicates the level of gene expression. The differential aspect of gene expression can be investigated by changing the conditions in cells (with or without a particular alteration). The first exploratory aspect that can be noted in this context has to do with the configuration of the space in which the

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[4] The use of shotgun sequencing is quoted in O'Malley´s work, although its methodological importance isn´t highlighted in terms of exploratory strategies.

sequencing will be done. This point becomes clearer when comparing this technique with that which gave rise to it: Northern and Southern blot. In principle, the only difference between the two techniques is that the latter only allows the study of genes "one at a time." Yet there is another aspect of the exploration that can be pointed out here, related to the design of the configuration of the DNA chip samples. Because of the amount of samples available, the design of these early stages is usually done with the help of specialized software that allows putting into practice strategies that are considered appropriate for the exploration. Thus, one can take any diversity criterion – for example, by homology – and apply it to construct a sample. In this sense, it seems that there is a relationship between sample design and the ways to explore.

Final Words

We have tried to explain how an insight into exploratory strategies allows us to show different methodological and epistemological aspects of computer simulations in science and scientific experimentation. Our intention has been to collaborate in the construction of theoretical tools that help to analyze and highlight the epistemological and methodological richness of certain aspects of these practices that have been overlooked in philosophical research. In this sense, we believe that the activities of exploring and searching have not received sufficient attention in the field of the philosophy of science.

The analysis of exploratory strategies has allowed us, through the presentation of some cases, to show the different levels at which exploration is relevant in scientific practices. However, this is only a first approach to the characterization of a concept that we believe is promising for the task of understanding, from a philosophical point of view, the role of computer simulation and scientific experimentation in scientific practices.

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