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Anticipation, abduction and the economy of research: The normative stance

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ABSTRACT

Anticipation operates under *abductive* modes of reasoning. Anticipatory abduction is normative and appeals to principles of the *economy of research*. As a defeasible mode of reasoning, abduction copes with fundamental uncertainty of the future in rational, logical and anticipatory manners. Abduction arises from the mind's ability to perceive logical and counterfactual relationships. This perceptual experience (i) happens on an interval, (ii) is linked to the past and (iii) is proactively and continually future-oriented. Since anticipation refers not only to reasoning about future but also to exploiting future in our present action, abduction alone would only partially explain anticipation. For this reason, we integrate it with normative facets that derive from the theory of *the economy of research* and the *pragmatistic* interpretation of abduction, as a relation between a *hope* that hypotheses materialize in a certain way and our decisions to act upon those hypotheses. This proposed unification of abduction, economy of research and pragmatism provides a complete Peircean methodology that can recover anticipation from its logical and pragmatistic roots.

1. Introduction

This paper proposes to ground the concept of *anticipation* on a logical method that implies reorientation of the conceptual employment of anticipation in futures research. We argue that anticipation operates under *abductive* modes of reasoning, taken in a wide sense that combines reasoning with the normative facets of the *economy of research*. Originally proposed by Charles Peirce, abduction is a defeasible mode of reasoning that can tackle fundamental uncertainty of futures in rational, logical and anticipatory manners. This means also a pragmatistic interpretation, as abduction arises from the mind's ability to perceive logical and counterfactual relationships. Importantly, perceptual experience (i) happens on an interval, (ii) is linked to the past and (iii) is proactively and continually future-oriented. Building on these observations we propose that abduction can be adopted to enrich theories of anticipation in the light of such economic and normative considerations.[1]

A few conceptual and promissory notes need to be issued first. When thinking about futures, two concepts are unavoidable – risk

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[1] See also Magnani (2009), who has also stressed the link between abduction and anticipation, defining anticipation within the phenomenological tradition as an intentional expectation that needs not be connected to the future events.

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and uncertainty. Risk is different from uncertainty. It refers to situations in which we know something is unknown. We can assign a probabilistic value to a phenomenon, we know the relevant probability distributions, and we take it to be possible to calculate the chance of such anticipated events coming or not coming to pass. Among the many definitions, a classical one takes risk to be the probability "that a particular adverse event occurs during a stated period of time, or results from a particular challenge" (Royal Society, 1983: 2). The Royal Society talks about risk "as a probability in the sense of statistical theory", which obeys "all the formal laws of combining probabilities." In a technical sense, risk is thus strictly probabilistic. Under circumstances in which conditional probabilities are well definable, risk does indeed play a key role.

Yet in many situations, fundamental uncertainty prevents assigning *ex ante* probabilistic values to events that have never been met or even conceived of before. Since there is a constant, unanticipated and often an unintended influence of our actions on the future, probabilistic measures of risk lose much of their importance. This is so even if we, in principle, could assign *ex ante* probabilities to novelties. Speculation and derivatives trading exemplify such contingent cases (Ayache, 2015).

Epistemology behind the concept of risk fails to capture this deep Knightian uncertainty (Knight, 1921), which resists assigning probabilistically meaningful values to future events (Hansson, 2009). Applying risk assessment in the context of fundamental uncertainty is a means committing to the tuxedo fallacy: a frustrated appeal to methods that disappoint us as soon as they are applied to decision problems that lack crucial structural features. Brimming with *unknown unknowns*, the kinds of futures that we aim at reasoning about and that are essential to conscious anticipation, tend to lack such features. Fundamental uncertainty is not like rolling the dice in a casino (a situation of *known unknowns*) but rather a jungle where every step unpredictably influences the next and reveals the obstacles as one stumbles along (Hansson, 2009).

Since it is hard to deal with fundamental uncertainty with exact methods, people are more likely to ignore it (Alles, 2009). This type of bias is common in science and society, where few disruptive and hazardous situations can be identified and fully evaluated. Nevertheless, ignoring unknown unknowns can be at best irresponsible and at worst existentially disastrous. We need to allow for both novelty and extinction in the future, and to be prepared to deal with events that lie beyond prevailing intellectual powers. In the futures studies, this role is occupied by anticipation (Miller, Poli, & Rossel, 2013). Setting it aside from notions such as foresight, prognostication or prophesying (Poli, 2017), anticipation is to conceive of future as having some being (though not necessarily existing) in the present (Miller, 2018). In scientific research, abductive reasoning, interspersed with important methodological and normative factors, is supposed to fit the same role.

To understand anticipation, it is useful to perform a brief methodological reflection on what one might come to know in science. Such exercise exposes the status of future scientific hypotheses and the development of intellectual ideas in science as such future scenarios. Abduction plays a major role in the methodological toolkits of scientists when forming their theoretical conduct under the conditions of fundamental uncertainty. Abduction is the mode of reasoning that concludes the presence of novel values and modalities in the conclusion. Its conclusion is a recommendation to remain hopeful in the expectation that nature would come out in the way this mode of reasoning has professed it to be.

Abduction is also the only type of reasoning that creates hypotheses to account for the surprising facts by *guessing*. Indeed, it has sometimes been described as what distinguishes a scientific guess from other more mundane guesses (Pietarinen, 2015; Peirce, 1907). Unlike probabilistic risk assessment methods, abduction assesses the plausibility of hypotheses, among other values such as fruitfulness and an expectation to be 'on the right track' with one's informed guesses and intellectual surmises. It produces conclusions that may well be correct, but in a stronger sense than what asserting mere possibilities could accomplish. The process of abduction does not end with the creation of hypotheses: it is also a call for action. In science, actions are typically manifested in decisions to submit hypotheses produced by abduction to experimental test. Despite being the least secure of the reasoning modes that are in the scientists' toolkit, abduction is considered to be the only mode of reasoning that can eventually give rise to genuinely new insights (Pietarinen & Bellucci, 2014; EP 2:216).

Such characteristics can be compared with anticipation, which likewise is associated with action and which, like abduction, does not guarantee epistemic success. This said, anticipation fills a larger role than abduction as it refers to more than a specific *mode* of reasoning. It is also concerned with recommendations of how to act upon abductive conclusions. To anticipate is to be able to interpret how futures may talk back to us through various anticipatory exercises (Miller et al., 2013). As argued in the present paper, conceptually speaking, abduction alone would explain anticipation only partially. For this reason, we propose to integrate it with normative facets found in the theory of *the economy of research* and in the *pragmatistic* interpretation of abduction. These normative facets aid in articulating the important relation between one's *hope* (or expectation) that hypotheses are fulfilled in a certain way in certain kinds of circumstances, and our *resolutions to act* upon them. The epistemology is thus decidedly non-Cartesian; it is an 'action-first' epistemology. This unification of abduction, economy of research and pragmatism is then taken to provide a complete and properly Peircean methodology by which we can recover the gist of anticipation from its logical and pragmatistic roots.

2. Anticipation

Current literature accepts the commonsensical view that the future does not exist in the present (see e.g. Nadin, 2010; Miller et al., 2013; Poli, 2017; Miller, 2018) as a prerequisite for understanding anticipation and the role it plays in our lives. For if it would, it would not be the future anymore but the present – "we would already be there", in a manner of speaking. The only form in which the future can partake in the present activities is in the form of anticipation (Miller, 2018). This means that the only way to take the future into account in our actions, and the only way to incorporate the future in the present moment of experience, is through anticipation. The future is viewed as the potential of existence that may actualize sometime later than what is experienced as 'now' (Miller, 2018). That moment of 'later than now' can only be anticipated.

In this paper, we challenge this commonsensical view and provide an alternative explanation of how the future can be accommodated and persist in the present. This can happen through abduction. If successful, it does not explain away the concept of anticipation from the theories and practices that concern our engagement with the future. On the contrary, the proposal is to support anticipation with somewhat stronger philosophical and logical arguments than what has been done before.

This support is derived from Peirce's theory of pragmati(ci)sm, especially due to the centrality of perception in it. Peirce saw in perception the emergence of some crucial elements of the logic of abduction (EP 2: 208). Perceptions have a generality in that their content is drawn partly from the past connections and partly from the expectations (including hopes and fears) of how the future may turn out to be. The content is a hypothesis – one might say it is the predictive brain's best guess about the way some aspects of the world may turn out to be. Much of such processing happens at unconscious levels of cerebration. Since these guesses, surmises and presumptions have an important social selection and survival value, a recommendation to investigate that hypothesis is thus also formed in abduction. What is formed in perception must therefore come from the processes linked to abductive reasoning. If they come from abduction, it is already in perception that such reasoning is performed and where ideas occur to the conscious agent.[2]

In an intriguingly similar vein, anticipation can be described as our basic attitude towards the future – wired into the very way we think and operate. At the same time, definite and undisputed definitions of anticipation seem to be lacking. Some standard definitions include "(a) a prior action that takes into account or forestalls a later action (b) the act of looking forward or (c) visualization of a future event or state" (Merriam-Webster, 2018). Anticipation has been used in all of these different and even rival meanings. All of them may involve perception is some ways. Although anticipation has been acknowledged in many fields, theories and uses of the terminology have been quite field-specific and it is fair to state that no general theory on anticipation exists yet (Miller et al., 2013; Poli, 2010).

In the context of the futures studies, anticipation refers either to a scientific discipline distinct from forecasting and foresight, or to a technical terminology that describes anticipatory systems (Poli, 2017). These two uses are connected. For the purpose of the present paper we are interested in the conceptual meaning of anticipation as a technical term. Anticipation as a technical term is closely connected and defined by an anticipatory system. One of the best-known definitions of an anticipatory system is given by Rosen (1985: 341):

> "An anticipatory system is a system containing a predictive model of itself and/or its environment, which allows it to change state at an instant in accord with the model's predictions pertaining to a later instant."

Anticipation, as the defining property of an anticipatory system, has two distinct sides. First, one must have a forward-looking attitude (Ekdahl, 2000; Rosen, 1985). In pragmaticist terms dating from Peirce (EP 2: 86, 95, 195, 245, 271, 340), the rational meaning is in the future consequences of concepts and propositions, including models, representations, states of affairs and intellectual signs. Meaning is forward-looking. Peirce described it as concepts having their "logical interpretants" "in a relatively future tense" (EP 2: 410). Behind this is the notion of the mind and consciousness which *is*, in the concrete sense that can be made precise by applying Peirce's synechistic continuity[3] to anticipation, partly in the future. What characterises "being" and "mind" is the ability of imagining or perceiving the future as a *form* that corresponds with the options (b) and (c) of the lay term. Second, the mere propositional attitude is not sufficient, as one needs to be engaged in an activity concerning the future, in the present decision-making situations (Ekdahl, 2000; Rosen, 1985). When these two sides are combined, the agent has acquired an ability to anticipate: to have an understanding of possible futures, which can be incorporated in the present action to elicit favourable outcomes. According to this definition of anticipation, it occurs whenever certain conceivable or experimental considerations about the future are taken into account in the decision-making contexts concerning present action (Poli, 2017; Rosen, 1985). As such, this outline of the definition comes closest to the version (a) of the term's vernacular meaning.

Anticipatory system is any system that is able to take into account future states in order to inform and guide its present actions (Nadin, 2010; Poli, 2017; Rosen, 1985). For example (adopted from Rosen, 1985), when a hiker meets a bear in the woods, they might desire to vacate that particular area. The reason according to Rosen is not the simple sight of the bear as such but the anticipation of the future events that might follow from such sighting. A sight of a bear triggers resolutions to action but does not cause the action itself to take place. When seeing a bear, the hiker modifies their actions in accordance with their predictive system – system that foresees multiple potential outcomes of a bear sighting including an attack, injury and death. A similar scientific example is that of drawing a hypothesis, which is to be proven later on. Proposing a hypothesis can be framed as an anticipation that certain results will follow from certain experiments, which thus serves as a motivation for further actions aimed at testing the hypothesis. A scientist is able to anticipate from experience possible outcomes and to choose the proper methodology, protocols and experimental design in order to tease out those futures in which the hypothesis is hoped to be proved.

However, the concept of an anticipatory system, and thus anticipation itself, is limited neither to human decision-making nor to the decision-making under conscious action (Poli, 2014). This parallels with perception as largely unconscious operation of abduction. Anticipation can be used to describe the behaviour of all living beings (Nadin, 2010; Rosen, 1985), and even some non-living

[2] Shanahan (2005) has proposed an application of a related idea of perception as abduction to data processing in sensory machines. Further applications to the burgeoning field of machine vision seem endless. On predictive brains, see e.g. Hohwy (2013). Clark (2013) situates the neural prediction to embodiment in cognitive sciences. The visual and diagrammatic side of abduction is emphasized in Magnani (2015), among others, and Thagard (2007) presents evidence of abduction operating on multimodal representations, including perceptions.

[3] Synechism is a scientific value – rather than a metaphysical principle – which insists on the concept of continuity as being extremely relevant in philosophy. It governs what logical hypotheses are to be entertained, and which are those that are to be further investigated.

systems such as those exhibited by societies, collective intentional behaviour and general intelligence systems (Poli, 2014). Rosen (1985) explains that the movement of primitive organisms towards darkness or the leaf fall, are also expressions of anticipation. Darkness indicates presence of moisture and absence of predators. As the day shortens, trees lose their leaves with the lowering of the temperature, anticipating the onset of Jack Frost. The behavioural trigger is the correlation between a biologically neutral state and possible future states that are biologically and evolutionarily significant to the organism. Like in abduction, to be able to perform such feats exertion of counterfactual force is involved.

But as Miller (2018) puts it: "the anticipation of trees or protozoa is not the same thing as anticipation by a cat or a human". Anticipation has different levels of complexity: Rosen's notion of anticipatory systems incorporates protozoaic as well as human conscious anticipation. Most basic form of anticipation is taken to be *strong* anticipation, which describes the connection between the system and its environment; any autonomous system exhibits such connections (Collier, 2008; Dubois, 2003). The strong type of anticipation is what (Butz et al., 2004) refers to as *implicit* as it does not need to not be recognized by the agent and can be applied to non-conscious anticipatory systems. Strong or implicit anticipation need not pass the threshold of awareness in order for the system to autonomously re-adjust its behaviour in accordance to environmental changes and expected outcomes. Aside from the example of trees and primitive organisms, withdrawing the hand from a hot stove characterises strong anticipation – the reflex happens in a split second after the burn before any conscious thought has been given to the incident. Brain scans confirm that the decision to withdraw is made in the brain before phenomenal and conscious experience of pain.[4]

Weak types of anticipation describe models agents have of their internal anticipatory systems (Dubois, 2003). The weak type is explicit and it builds on the strong type (Collier, 2008). It is a secondary layer of anticipation specific for example to complex living organisms. This type of anticipation is conscious; it is anticipation the agent is aware of having made and is therefore able to reason about it in a deliberate and voluntary fashion (Butz et al., 2004). Non-conscious anticipatory assumptions that belong to the strong type of anticipation are necessary components of more complicated anticipation, as they underline imaginative faculties relating to the future and its use in the present to bring about or exclude certain futures (Miller, 2018). When the hiker sees the bear, anticipation might be strong – instinctive or hardwired – but it can also give rise to further and conscious situational reasoning. A classic example of glancing at the sky in the morning that makes you decide to take umbrella (Poli, 2017) is a weak type of anticipation.

Anticipation is met in goal-orientated action, as there the considerations of the future outcomes and actions can be found, implicitly or explicitly, in the motivation of most actions (Poli, 2017; Rosen, 1985). Although the role of anticipation in decision-making might be more evident in the weak types in which agents are aware of the anticipatory process, it is nonetheless present also in the strong type. Thus according to Poli (2017), anticipation is crucial for any action. Given the definition of anticipatory systems and the concept of anticipation that stems from it, this is not surprising. Action presupposes capacity for anticipation. However, anticipation by no means guarantees a success of an action (Poli, 2017). Anticipation may provide advantages to complex adaptive systems to enable better fit with their environments, thus influencing the future in ways optimal for the system. Niche construction could serve as an evolutionary example of anticipating chances and being prepared for them. At the same time, future is not carved in stone but created by countless other agents in the past and in the present. An anticipatory system can, based on its knowledge, experience and imagination, anticipate future to some extent, but as the future does not really exist, neither the success of anticipation nor the success of the action motivated by it can be guaranteed. Coming back to example of the hiker and the bear, the decision and the chosen method of leaving the scene might not avoid the attack. Little in the action of the hiker can guarantee the outcome one is hoping for. The reasoning involved is fallible and insecure.

As futures are characterised by fundamental uncertainty and unknown unknowns, anticipation provides advantages over predictive and forecasting methodologies (Miller, 2018; Poli, 2017). But is there a way to assure oneself of its relative success in a somewhat stronger sense than when taking future as a non-extant anticipation of how things might turn out to be? Even if we set aside fundamental uncertainty, probabilistic risk assessment is no guarantee of total success either, as it can only assigning probabilistic and conditional values to current actions. As the type of reasoning involved in such approaches is deductive, a promising alternative for anticipatory systems is abduction.

3. Abduction

Turning from the futures studies to the philosophy of science, we see similar issues arising in discoveries concerning intellectual hopes that the hypotheses will turn out the way imagined, as, for example, in the drafting of future scenarios and in narrating their counterfactual links with the present states of the world. Scientific inquiry faces fundamental uncertainty characteristic to reasoning about the futures. To cope with uncertainty and ignorance, scientific inquiry appeals to abduction. Abduction, as we will argue next, is a methodology to recover rational decisions under the conditions of fundamental uncertainty.

Abduction is one of three major reasoning modes, the other two being deduction and induction. Deduction describes reasoning from a general rule to the specific instance. Its results are drawn from the rule, and when conducted according to leading principles of deduction, produce results that are necessarily true. Mathematics, logic and physics make use of this reasoning mode but are not limited to it. Deduction is needed in the process of looking for and finding out new laws of physics, and it is of some but limited help

[4] See e.g. Maldonato (2014). Cognitive neuroscientists call the phenomenon *predictive consciousness*, which is an element of the *predictive brain*. Neurobiologically, the explanation is that in order for the brain to create coherent representations of events in its rapidly changing environment, it invents states that attempt to predict both the sources of the sensory inputs as well as their immediate implications. The respective mental states are *hypotheses* about what may happen in the chain of dynamically unfolding events, before those predictions would actualise.

when predicting some basic and fundamental aspects of the world and its future.

Induction is reasoning from specific instances to the general rule. The more observations, evidence and specific instances are witnessed, the more confidence accumulates in the correctness of the rule that has been concluded. This is statistical induction; statistics itself is an example of this reasoning mode. When reasoning is probabilistic, it may be inductive or deductive. The conclusion may follow necessarily with a certain probability, which is deduction. Most of our knowledge about the world tends to derive from induction. It is ampliative, but its conclusions do not adduce new ideas. The fruitfulness of induction hovers between deduction and abduction. Inductive reasoning about the futures may be useful in providing insights into the general tendencies of what the future could be. However, it is important to keep in mind that both deduction and induction are rooted in the past and current knowledge, and that they predict and model the future from the standpoint of the past. For example, one of the leading principles of such modes is *ergodicity*. Such principles do not allow for significant disruption, novelty or surprises to happen, as both deduction and induction presume that things will be as they have been in the past.

In contrast, while deduction concludes that something must be and induction says that certain things are operational, abduction suggests, in the very least, that something *might be* the case. The three are not altogether separate, however, as abduction, induction and deduction are the three main stages of inquiry that are also importantly interrelated in ways explored in the literature.[5]

Peirce's famous early example of abductive reasoning (hypothesis) was this:

Rule. — All the beans from this bag are white.

Result. — These beans are white.

∴ Case. — These beans are from this bag. (EP 1: 188)

The conclusion that beans are from this specific bag is a guess, subject to corroboration. The beans might also come from any other source. Unlike probabilistic risk-based assessment methods, abduction deals with the plausibility of hypotheses rather than their probability. It deals with the *may-be*'s and produces conclusions that might or might not be true (Kaag, 2013). At the same time, these conclusions are stronger than a mere possibility.

Like anticipation, processes of inferring abductively are not immune to the influence by the future states of affairs. This influence is by counterfactual (subjunctive) links between what might, could or would be the case on the one hand, and the unexpected events that are rendered comparatively unsurprising and natural by that link on the other. We are dealing with a form of reasoning that is productive and meaningful in the senses in which deduction and induction are not. Peirce took it to be the only mode of reasoning that suggests ideas with novelties and value in their vigour and productiveness (Peirce, 1913).

Abduction is known to have many schemes proposed for it. The most widely spread is the one from Peirce's (1903) Harvard Lectures:

1 A surprising fact A is observed.
2 If C were to be the case, then A would be the matter of course.
3 Therefore, there is reason to suspect that C is true. (EP 2: 231)

This is not Peirce's ultimate version of abduction, however, or even the one that he would have remained satisfied with. Yet it has been the standard reference in secondary literature (Kapitan, 1997). There are pros and cons to presenting abduction in this way. An advantage is its simplicity, leaving room for further interpretations and development. The conditional in the second premise is explicitly the subjunctive one ("If A were to be the case, then C would be the matter of course"), and the qualities of surprise and observation are added to the first premise. The downside is that the true nature of the proposed conclusion remains debatable. "Suspicion to take A true" may be too strong a formulation of what this insecure mode of reasoning can accomplish.

One standard line of criticism to this 1903 schema has also been its apparent circularity, as the proposition C of the conclusion is mentioned already in the second premise (Frankfurt, 1958). This charge was dispelled by Anderson (1986) who argued that there is no such circularity since C is the antecedent of the subjunctive conditional, which is obtained simultaneously as C in the conclusion. We may add that C is asserted in a different mood in the conclusion than in the antecedent in the conditional premise – a much neglected fact which nevertheless was made explicit in Peirce's slightly later revisions to this 1903 schema (Peirce, 1905).

On the other hand, we often find in the literature (including some of Peirce's own, earlier formulations) that reasoning abductively is to conclude a possibility, a "may-be" of the case stated to obtain. This is a rather weak formulation of the conclusion. It does not suggest what the further values by which one could go about selecting among rival hypotheses would be. It is abduction that falls short of the important qualities of the economy of research, which we will describe in the next section. The weak formulation is of no use in enriching anticipation, either, as it lacks the information by which possibilities are to be resolved into conditional resolutions to act. Likewise, a scientist who is allowed to conclude mere possibilities would be no wiser while struggling to narrow down an endless search space of alternative hypotheses and trying to guess which hypotheses among countless others would be best to be submitted to the test. The import of abductively concluding a conjecture must thus be stronger than an entertainment of a set of ideas.[6]

[5] Discussion about the interrelatedness of the three modes of reasoning is out of the scope of this paper; this issue has been explored in Pietarinen and Bellucci (2014) among others.

[6] In another occasion, we have suggested a pragmatic enrichment of what is known as the Gabbay-Woods schema of abduction (Chiffi & Pietarinen, 2018; Chiffi & Pietarinen, 2019). That enrichment lists a number of conditions under which one can justifiably assert the abductive conclusion, and which in this way is presented as a plausible course of action. That enrichment makes the relevant illocutionary forces explicit and

As a stronger form of abduction, Peirce in his later works coined the term "investigand" to capture the special mood under which abductive conclusions are to be asserted (Peirce, 1905). He took abductive conclusions to be drawn in this special, co-*hortative mood* (Ma & Pietarinen, 2018). Such conclusions are, in terms of Peirce's theory of signs, "representative interpretants" that represent abduction as a form of reasoning that can convey a general conception of the truth. It is not the truth that is asserted in abduction; abduction delivers the *idea* of a matter of course, rendering that idea comparatively simple and natural, hence assuring us of its justified assertibility (Chiffi & Pietarinen, 2018).

Hence, abductive reasoning is at home in addressing "how possible" questions in our intellectual pursuits. Such questions add to mere possibilities a recommendation to proceed further in their investigation. Indeed, "how possible" questions are important in science, which is rarely in the business of looking for new laws. Abduction, like anticipation, concerns how things might, could or would conceivably be such that under its auspices they can be plausibly asserted and acted upon.

Thus, process of abduction does not end up with the creation of hypotheses – it calls for a formulation of conditional resolutions to act in certain ways in certain types of circumstances. It endears an interrogative mood to its conclusions and, as Peirce had put it, such conclusions do "not mean the mere idle entertainment of an idea" (Peirce, 1905). The interrogative mood is a suggestion to investigate matters much further. Questions are reasonable requests for further information. Questions of hypotheses are reasonable requests for money, too. In scientific contexts, actions are typically manifested in the experimental testing of hypotheses. Sometimes abduction already lends the answer to the question of whether it would be wise to go to some length in order to continue pursuing the preliminary hypotheses. In other instances, it narrows down and suggest elaborations on hypotheses. Which one among the bountiful others should be tested is the question of the economy of research, which we turn to in the next section.

It is not uncommon for abduction to be described as inference to the best explanation (IBE, Douven, 2017). However, this approach does not bode well with Peirce's original argumentation, which indicated that abduction is a separate reasoning mode distinct from deduction and induction. Among many of his unpublished writings on this issue, we find an important relevant description of abduction as follows:

> "[It is the] kind of reasoning by which, upon finding ourselves confronted by a state of things that, taken by itself, seems almost or quite incomprehensible, or extremely complicated if not very irregular, or at least surprising, we are *led to suppose* that perhaps there is, in fact, *another definite state of things*, because, though we do not perceive any unequivocal evidence of it, nor even of a part of it (or independently of such evidence if it does exist), we yet perceive that *this supposed state of things would shed a light of reason* upon the state of facts with which we are confronted, *rendering it comprehensible*, *likely* (if not certain), or comparatively *simple* and *natural*." (MS 855, 1911, added emphasis)[7]

This description accounts quite well for the famous stories on scientific discovery. Take the invention of penicillin, for example, and Fleming's nursing of bacterial colonies. Flemming's observation that some of the microbial colonies were infested with mould and that in such colonies bacteria had died was not new – such things happened all the time and were observed by many scientists before (Fleming, 1944). What made his observation significant was his interest in antibacterial substances. Fleming drew the connection between the microbial colonies and the antibacterial properties of the mould. The reasoning was abductive: bacteria disappearing around the mould was an irregular fact that would nevertheless be rendered comprehensible and facile if that type of mould would produce some antibacterial substance. This was an invitation to further investigation, and ultimately to testing and experimenting whether the mould in question actually produces such substances and whether other underlying causes might explain the same phenomena.

Although abduction deals with the plausibility values of hypotheses, defining abduction as the best explanation fails to capture its core nature. True, some hypotheses might end up being proven correct and even the best current explanations of the underlying phenomena. This may have happened in the famous case of the discovery of penicillin. However, there is no way to know that before further testing of the hypotheses has taken place. Fruitfulness of abduction is also found in the disproven and unproven hypotheses that give further information concerning the phenomena – and often more useful and bias-free than the strictly positive findings –serving as invaluable pointers to alternative hypotheses. Peirce (1905) called abduction "Reasoning from Surprise to Inquiry", as well as the inverse type of "reasoning from consequent to antecedent". Both epitomize the abductive mode better than IBE does.

The definition of abduction as IBE is not meaningful in the context of anticipatory reasoning about the future, either. When reasoning about the future we are rarely looking for the scenario that is the best in the sense of having the best claim for it to become actualized. Rather, we ought to imagine a variety of wildly different and conflicting scenarios that might be used as a guidance towards favourable outcomes in the future. Those outcomes may be something entirely unexpected. What matters is the thoughtful exercise of conducting the inquiry backwards, *from the future to the present*, and the experience of learning that takes place during the creation of those counterfactual narratives. Indeed abduction is also inverse reasoning from effects to causes. In futures research, such links are not causal but rather manifest various virtual and narrated subjunctive conditionals. Second, IBE is not a meaningful approach in the present context, either, as the inherent and fundamental uncertainty of futures makes it in fact impossible to

(*footnote continued*)
articulates the non-epistemic justificationist elements involved in abduction. Under this view, the target of justification in abductive reasoning are the linguistic acts of asserting (the content of) hypotheses, not knowledge. The enriched schema thus supports what is known as the "ignorance-preserving" or "mitigating" interpretation of abduction. In addition, the eco-cognitive model of abduction was proposed by Magnani (2009,2018) to address the issue.

[7] Manuscript held in the Houghton Library of Harvard University, as identified by Robin (1967).

justifiably assert what the best explanation in that sense could be.

Returning to the main technical point of our thesis, the workings of the logic of abduction is in Peirce's pragmatistic theory grounded in perceptual experience. Perception is not a singular, instantaneous act of perceiving; it involves temporality spread both to the past and to the future. A pragmatist mind, as we remarked Peirce to have argued, lies partly in the past and partly in the future, making conjectures about the reality as it experiences the world. The deeper reasons for such claims derive from the continuity of the material upon which perceptions are built, namely the *synechistic* character of the perceiver's mind. If synechism is accepted as a guiding regulative principle (or a fundamental non-epistemic value) in philosophy, then an important consequence is that those hard-and-fast thresholds between conscious and non-conscious content of perception also evaporate. And thus, the distinction between 'instinctive', or involuntary and unconscious processes of abduction on the one hand, and voluntary and deliberate parts of it on the other, is seen as an equally contrived dichotomy. (In other words, what is sometimes in the literature taken to be the dichotomy between 'heuristic values' and 'logical schemas' of abduction.) We can thus conclude that anticipation, as a manifestation of such integrated abductive reasoning, may not be split into its weak and strong parts without doing violence to its very nature located on a continuum of perceptual experiences.[8]

Some important consequences follow from this Peircean understanding of the future-oriented character of perception and the underlying synechism. One of them is that to possess an intellectual concept readily means to anticipate. Concepts are signs whose objects show generality. Such generality means that the concept inherits meanings both from the past and from the *anticipation of its conceivable future consequences*. There are no real conceptions without reference to such conceivable future resolutions to act upon them.

Our final point is that as perceptual experience, abduction is a process involving conceivability and imagination. In the same vein, anticipation is an effective procedure thanks to the principles of economy that apply to it.

4. Economy of research

Anticipation works by means of the resources provided not only by abduction but also as abduction that takes into account important economic considerations of scientific research. Our explication of anticipation in scientific inquiry can thus take on board the normative facets of both risk and uncertainty in science.

Abduction is a form of reasoning that suggests new hypotheses to be further tested, without providing additional ground to assert that the abducted hypothesis is the best one to explain the surprise, complication, or irregularity. Given the uncertainty that permeates scientific knowledge and ignorance, the range of alternative and competitive hypotheses is innumerably large. It is impractical or impossible to test very many of them in order to determine which hypothesis could after all be considered as the best. Limits of time, energy and resources fundamentally curtail the practice of science. We have to establish values (which often have both epistemic and non-epistemic facets) that guide the decision by giving priority, *in the present tense*, to a limited range of hypotheses so that they may enter the process of empirical testability, based on the potentiality of their *future consequences*.

The range of futures is therefore readily restricted and controlled by these accepted values. Such regulative principles significantly shape the scientific endeavour. Likewise, we *anticipate* the future in the present by ranking the alternative scenarios based on their potential contribution, and giving priority to the ones that we expect to be the most consequential, *given our present values*. Notice that the expectation is not merely a *fictional* mental representation of imagined futures influencing present decisions. Nor is it grounded on simple practical credibility, such as the *intention* of putting a hypothesis into practice (Beckert, 2013). In our framework, expectations arise from normative and economic considerations. They regard the potential impact of a hypothesis in the presence of scarce resources of time, energy and money.[9]

A recognized philosophical problem of the cost-benefit methodology is the characterization of the options to be evaluated. Cost-benefit evaluations are comparative among different options or hypotheses. Integrating abduction with values may help us to restrict the range of testable hypotheses and rank their order of testability. However, the value-based considerations may change the intended meaning of our hypotheses. Therefore, integrating abduction with values should be done in a critical way

In general, an act of anticipation appeals to abduction in order to come up with a large set of hypotheses *plus* the selection of those hypotheses showing a potential impact, no matter how implausible they are. Here, both epistemic and value-based considerations enter the picture. This, we submit, now explains why anticipation in science, even when we attempt to *justify* hypotheses, is not independent of value-based considerations. Values can be interpreted in epistemic or moral senses (as, for instance, in Rosen, 1985), as well as through senses related to social, political, and strategic aspects of scientific inquiry.

Values, it is worth noting, may also block the road of inquiry, since according to some accepted normative standards implausible hypotheses may be considered devoid of any real ground, even if later on they turn out to have been indispensable for the progress of

[8] Connections among perception, abduction and anticipation, as understood in the Husserlian manner, have been pointed out in Magnani (2009). The definition of anticipation used in that work focusses on various forms of spatial representation.

[9] Peirce's observation was that "now economy, in general, depends upon three kinds of factors; cost; the value of the thing proposed, in itself; and its effect upon other projects. Under the head of cost, if a hypothesis can be put to the test of experiment with very little expense of any kind, that should be regarded as a recommendation for giving it precedence in the inductive procedure" (CP 7.220, 1901). On Peirce's economy of research, see e.g. Haack (2018); Paavola (2004); Rescher (1976); Wible (2008). Magnani (2009) has introduced related concepts of eco-cognitive openness, optimization of situatedness and eco-cognitive model of abduction and can be used in explaining further the phenomenological aspects of creativity in scientific reasoning.

scientific inquiry. For this reason, as aptly observed by Peirce: "new money should mainly go to opening up new fields; because new fields will probably be more profitable, and, at any rate, will be profitable longer" (CP 7.160). Funding several competing research groups working on roughly similar problems driven by "who gets there first" is not conducive to the real advancement of inquiry. Nor is the research driven by singular values and grievances. Since values are not fixed, a change in the set of values or desirable consequences concerning our decision to test may correspond to a different set of hypotheses selected for statistical test. "Powerful actors" (Beckert, 2013) such as governments, corporate think tanks, special interest groups and social networks, influence our decisions on acceptable values despite everyone's best efforts to impose a rigorous methodology of hypothesis selection and testing to guarantee epistemic and objective goals of science. The very accepting and rejecting of hypotheses, which lies at the core of intellectual inquiry, is thus an action influenced by specific values.

A classic example in hypothesis testing concerns inductive risk (Hempel, 1965) - the rates of acceptable false positive and false negative results in a statistical test (conventionally, 0.05 and 0.2). Usually these two error rates can be reduced, though not completely eliminated, when the sample size of the study increases. But working with a large sample sizes and the methodology of Randomized Controlled Trials is an energy-intensive, time-consuming and resource-rich affair. Economic considerations contribute to deciding acceptable rates of statistical errors. In a similar vein, these considerations shape the future in a way that tends to favour false positives over false negatives.

Abductive methodology applies to the generation and selection of scenarios under fundamental uncertainty, which probabilistic risk assessment cannot properly deal with. Traditional scenario planning likewise cannot accommodate futures shaped by fundamental uncertainty (Fuller, 2018): planning invariably requires some measure of uncertainty to be at hand. Now, economy of research is not to be taken only in the standard cost-benefit analysis sense as we lack such probabilistic measures in abductive scenario building. We briefly review three alternatives proposed in Hansson (2016): (i) *possibility analysis*, which is similar to scenario planning and in which only possibility arguments are analysed; (ii) *the three-party model*, in which uncertainty is assessed through evaluating decisions that take into account not only risk-exposed decision-makers but also the "counter-affected" persons, i.e. people who are adversely affected by measures taken to reduce the consequences of uncertainty; (iii) *hypothetical retrospection*, i.e. when we consider making a decision, we should try to figure out how we will regard our decisions in retrospect, taking into account the values that were known when the decision was taken. In (iii), it is those decisions that retrospectively arises as permissible in *every* retrospective history that are justified and, as we should say, can be anticipated to be 'materialized' as the futures from the points of views of which our decisions appear just (such as morally or economically just).

The hypothetically retrospective form of ethical argumentation may be the most promising of the three in aiding us in futures studies and in decision-making but it is not immune to criticism. For instance, it becomes quickly unviable to enumerate all hypothetically retrospective histories. Second, the meaning of values adopted at the moment of decision is unlikely to be persistent and remain the same when the consequences of the decision are imaginarily evaluated in the future. Third, as shown in Chiffi and Pietarinen (2017), it is unlikely that there exists a simple association between the level of uncertainty and the (moral) permissibility of actions. But these qualms notwithstanding, the proposed methodologies to deal with decisions under fundamental uncertainty – and hypothetical retrospection in particular – show interesting similarities with abduction and are sensitive to economic and value-based considerations in a like fashion.

In conclusion, principles of economy of research are of normative importance both in abduction and in anticipation. This shows that the two should be embraced in unison, as a mode of reasoning about futures that is called for whenever our scenario-building perceptual experiences, imagined observations and narrations have their job to do under severe uncertainty.

5. Conclusion

The background theory guiding the argumentation in the present essay has been Peirce's pragmaticism. According to it, the meaning of intellectual concepts is in their conceivable experiential bearings on our resolutions to act upon them. Naturally, this leads to favouring abduction as the primary logical engine of anticipation. According to our application of this notion, abduction arises from the ability to perceive counterfactual relationships, and that in turn means that experiences happen at an interval, not in an instant. Such judgments concerning the relationships that we observe in perception are linked to historical past and are drawn from episodic memories as much as from actively and continually expecting future events to unravel. We observe continuity in the temporality as it is conceived in the present tense. Ability to draw those persistent perceptual judgments is the ability to reason abductively. Likewise, in order to make sense of how inquirers are engaged with the future as well as being able to reason about it, principles of economy of research need to be applied to anticipation just as they are applied to abduction. Economic and value-based considerations should be better embedded into an abductive framework in order to prioritize certain hypotheses that may be statistically tested in the future, expediting the inquiry. The shortage of resources, time and energy, and the persistent and perpetual uncertainty can be exploited by anticipating futures.

Declaration of Competing Interest

The authors declare no conflict of interest.

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