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Medical Reasoning in Public Health Emergencies: Below High Standards of Accuracy

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RESUMEN

La corrección de un razonamiento se define normalmente en términos de validez deductiva o fuerza inductiva. Estos aportan estándares altos de precisión, pero son voraces en recursos cognitivos y esto los hace inapropiados para las situaciones de emergencia. El razonamiento médico en situaciones de emergencia debe basarse en un equilibrio entre los agentes cognitivos, las metas cognitivas y los recursos cognitivos. Esto (parcialmente) explica por qué nuestras sociedades no están preparadas para funcionar con la incertidumbre cuando hay que tomar decisiones eficientes en una situación de emergencia. Debemos reconocer que hay formas correctas de razonamiento que están por debajo de los altos estándares de precisión y, en consecuencia, adoptar otros estándares.

PALABRAS CLAVE: *abducción, diagnóstico, emergencia, error, razonamiento médico*.

ABSTRACT

Correct reasoning is usually defined in terms of deductive validity or inductive strength. Although this provides high standards of accuracy, it consumes prodigious amounts of cognitive resources, thus making it inappropriate for emergency situations. Medical reasoning in such situations must attempt to strike the right balance between cognitive agents, cognitive targets and cognitive resources. This (partially) explains why modern societies are not prepared to cope with uncertainty in emergency situations in which there is a need for effective decision-making. It is important to acknowledge that there are correct forms of reasoning that fall below high standards of accuracy and, consequently, to adopt other standards.

KEYWORDS: *Abduction, Diagnosis, Emergency, Error, Medical Reasoning*.

I. INTRODUCTION

In 2020, during the Covid-19 pandemic, institutional agents (governments, healthcare systems, scientific communities, etc.) seemed to be completely powerless in the face of the ensuing public health emergency.

Institutional agents reason and make decisions on the basis of high standards of accuracy, but they suddenly lose their bearings when they find themselves overwhelmed by uncertainty. As a consequence, beyond lockdowns and hopeful expectations, almost no decisions have been made to weather the crisis. Accordingly, the aim of this paper is to explain, in part, this state of affairs from an argumentative and cognitive perspective. As will be discussed below, reasoning is understood here as being accurate when it is performed correctly and produces the right answers. For example, a generalisation whose conclusion is indefeasibly true (or true with a high degree of certainty) is accurate. What is understood here by "high standards of accuracy" are those that require a large amount of resources in order to obtain a correct answer. The high standards of accuracy normally pursued by institutional agents and scientists consume prodigious amounts of economic and cognitive resources. But these resources – e.g. time, data and information – are drastically limited in emergency situations, whereby the inappropriateness of those high standards. High standards of accuracy are sometimes related to standards of deductive validity or inductive strength, which can be defined in several ways. They are often intertwined with sophisticated methodological standards for the manipulation of probabilities or statistical data, like, for example, the standards of randomised controlled trials (hereinafter RCTs) in pharmaceutical research. Those deviating from such standards are usually accused of committing errors of reasoning. Nevertheless, alleged errors of reasoning should not always be judged from the perspective of deductive validity, inductive strength or other kinds of high standards of accuracy, especially when practical reasoning involving few resources is at stake. Indeed, statistical, probabilistic and Bayesian approaches, among others, provide the wherewithal for decision-making despite uncertainty. But, by calling for unavailable resources, such as time, data or the possibility of repeating an experience, they become completely inadequate when immediate (re-)action is required.

Errors of reasoning must be judged in light of cognitive economic and ecological considerations. According to Magnani (2017) p. 9, an eco-cognitive system is a triple of the form $<A, T, R>$, where A is an agent, T is a cognitive target (i.e. something the agent wishes to know or do) and R relates to the available resources (information, computational capacity, memory, time and so forth).[1] The adequacy and the conditions of attainment of a target are contextual, relating to the type of agent and his or her resources. Indeed, an individual agent with few resources appropriately sets less ambitious targets. A suitable strategy also consists in maximising the agent's resources in order to meet the target; that is, to do the best with less. From this perspective, scant-resource adjustment strategies, which are less costly and have more realistic targets, are sometimes better than stubborn quests for accuracy. Standards that make targets unattainable are intrinsically inappropriate, which is one of the reasons why institutional agents have not been able to react efficiently to the Covid-19 pandemic. The debate on the use of hydroxychloroquine to treat Covid-19 is symptomatic of this difficulty. On the one hand, medical practice is committed to acting almost immediately, despite uncertainty, while, on the other, institutional agents seek accurate results which would be obtained after the pandemic. In this context, the mistake is not to infer defeasibly inaccurate conclusions, but to adopt standards of reasoning that make targets unattainable.

In this paper, standards of reasoning are first addressed in the context of eco-cognitive systems by asking what an error of reasoning is, in order to draw a distinction between accuracy and aptness (Section II). This is then illustrated by explaining medical diagnosis in terms of abductive reasoning, an ignorance-preserving inference in which conclusions are nothing but hypotheses (Section III). Finally, the role of confirmation in medical reasoning, its implications for emergency reasoning and the controversy about the use of hydroxychloroquine are discussed (Section IV). To conclude, the more general thesis that the drastic reduction of resources in emergency situations hinders institutional agents and society as a whole in the field of practical reasoning is proposed.

II. STANDARDS OF REASONING

Accuracy is not aptness. Standards of reasoning defined in terms of deduction and induction are inappropriate in situations in which crucial resources are drastically limited. Aptness may be judged from the perspective of eco-cognitive systems, defined as triples of the form<*A*, *T*, *R*>. With respect to agents, the targets that they set and the (limited) resources available to them for meeting them, error avoidance is not always a general condition of cognitive success.[2] As noted by Woods (2013), p. 366, we thus look for a *third-way reasoning*, where cognitive economy—in which some practical balance is sought between cognitive aspirations and the cognitive resources available for achieving them — plays a fundamental role. Less costly forms of reasoning, involving errors and correction processes, are sometimes more appropriate than accurate but costly reasoning.

The intention of this section is to understand the precepts of third-way reasoning by first defining what an error of reasoning is from the perspective of Woods's theory of fallacies:

> **[RR-Rule Violation]** *E* is an error of reasoning if and only if there exists a truth-preserving prescription *R* for right reasoning or a probabilistically clinching prescription *R′* for right reasoning, and E violates *R* or *R′* [Woods (2013), p. 4].

This definition expresses a widespread view on fallacies which forms the essence of Woods's critical position; namely, *E* is an error of reasoning if it violates standards of deduction (*R*) or induction (*R'*). Those errors that cognitive agents nonetheless perceive as being correct have traditionally been listed under the concept of *fallacy*. The "Gang of Eighteen", as Woods calls them [(2013) p. 4], include the well-known fallacies of *ad populum*, *hasty generalisation*, *post hoc ergo propter hoc*, *affirming the consequent*, and so on. But, according to Woods, they are rarely committed and do not really fall within the traditional concept of fallacy. Since they can even possess some kind of cognitive virtue, Woods extends to induction Pollock's observation [(1987), p. 481] that "[a] common misconception about reasoning is that reasoning is deducing, and in good reasoning the conclusions follow logically from the premises". In fact, as Woods contends, the so-called fallacies are not incorrect forms of reasoning, a point evidenced in the light of cognitive systems.

Third-way reasoning is of a practical nature, that is, agent-based, goal-oriented and, therefore, resource-bound. This is why the standards established to determine its correctness must be stated in terms of the appropriateness of the goals set by agents and the resources available to them to attain them. It should be noted that the term "third-way reasoning" encompasses various kinds of reasoning, including certain forms of abduction (of which the Gabbay and Woods model introduced in Section III is only one possible form).[3] When saying that third-way reasoning is practical, this refers to agents with low resources and their relative goals. Be that as it may, this does not preclude its use for scientific purposes, insofar as a "theoretical abduction" may be performed by an individual researcher with limited resources. This can be explained by resorting once again to Woods (2013), p. 15, who distinguishes between two kinds of goals: *small tasks* requiring few cognitive resources and *big tasks* needing a lot. Usually, the former are performed by *individual agents* and the latter by *institutional agents* (NASA, Institut Pasteur, Consejo Superior de Investigaciones Científicas, etc.). The targets set by these two kinds of agents depend on their resources. To send astronauts to Mars over the next decade is a coherent target for Space X, but not for an individual agent. Agents are thus limited by the targets that they can afford to set and the resources available to meet them. As a result, cognitive tasks have inbuilt standards of success: standards of proof vary with the nature of the cognitive target and the level of resource adequacy. By and large, institutional agents with high targets and plenty of resources establish high standards of accuracy. Conversely, individual agents with lower targets and fewer resources, implement lower ones. From this perspective, the members of the Gang of Eighteen may be cognitively virtuous whenever they serve to maximise the *resources* available to an *agent* in order to attain a coherent *target*. The aptness of reasoning must be decided in terms of strategies for maximising scant resources by striking the right balance between targets and resources.

For example, according to Gigerenzer (2005), p. 196, 3-year-old children learning to speak who say "I gived", instead of "I gave", commit a *good error*. They first learn a general rule for the preterit and then correct themselves when they are told that it is an irregular verb. Although they act on the basis of a hasty generalisation, it is a good strategy from an eco-cognitive perspective. This example illustrates the distinction between accuracy and aptness. Albeit inaccurate, since it does not lead to grammatically correct sentences, this generalisation is nonetheless adequate, since it allows children to learn language, notwithstanding their limited resources. Indeed, given children's cognitive resources, an error-avoidance strategy would make the target unattainable. As a matter of fact, most of our knowledge is acquired through similar processes of error, feedback and correction, which are usually more appropriate than stubborn quests for accurate conclusions. Of course, this assumes error detection and management strategies. Third-way reasoning may be defeasible, since its premises support the conclusion, even though it is possible for the former to remain true and the latter to be revised in light of new information.[4] In general, conclusions need not be completely dropped, but they must be formulated with a certain amount of flexibility. This allows agents to correct them. For example, according to Woods (2013), p. 138, when agents reason generically, the conclusions that they draw should not be stated as universally quantified sentences, but in more elastic terms. When one generalises one's experience that ocelots are four-legged, one should not draw the conclusion that "all ocelots are four-legged", but rather something like "generically (or in general), ocelots are four-legged". And this would be perfectly consistent with the observation of an abnormal three-legged ocelot. *Post hoc ergo propter hoc* (*after* this, then *because* of this) fallacies may also possess some cognitive virtue. For instance, one of the members of a group of explorers in the Mexican desert drinks water extracted from an unknown cactus. After a while, when she begins to experience powerful hallucinations and to jabber cryptically, she suffers an anxiety attack. In the absence of further evidence, the other members of the group adopt a precautionary measure and refrain from drinking the water extracted from any cactus. An example of a scant-resource adjustment strategy, they are thirsty, but given their immediate experience, refrain from following their companion's example. Perhaps her crisis has another unknown cause, but in the absence of information to the contrary, they have arrived at the defeasible conclusion that the cactus has caused it.

Judging the correctness or incorrectness of reasoning depends on the cognitive system. The same level of accuracy should not be expected from a grammarian, who is studying language with practically unlimited information, computation and time resources, as from a child who is learning language. Although children who hastily generalise the application of grammatical rules to irregular cases are wrong and making a mistake, their strategy is cognitively appropriate for learning language in view of their own limited resources. The same may be said of the *post hoc ergo propter hoc* fallacy described above. The standards cannot be the same for a botanist in a laboratory as for an explorer in the middle of a desert. The relative adequacy of standards of reasoning explains not only why the so-called fallacies are committed and why they are attractive, but also why they are cognitively virtuous. According to Woods (2004), p. 354, a fallacy is an argument that is good and bad relative to different levels of access to the necessary cognitive resources.[5] There are good hasty generalisations and *post hoc ergo propter hoc* fallacies, although they are also bad in a relevant sense, because they fail to meet the standards of deduction and/or induction. The appropriateness of those standards does not depend on their absolute accuracy, but on their adequacy with respect to given cognitive systems. Whereas institutional agents usually attempt to avoid errors, individual agents leverage scant-resource adjustment and error management strategies.

III. Abductive Medical Diagnosis

> Absolute certainty in diagnosis is unattainable, no matter how much information we gather, how many observations we make, or how many tests we

> perform. A diagnosis is a hypothesis about the nature of a patient's illness, one that is derived from observation by the use of inference [Kassirer (1989), p. 1489].

Should we blame physicians for acting despite uncertainty? The inferential form of medical diagnosis is abductive. Abduction does not meet the standards of deduction or induction; it is intrinsically defeasible and its conclusions can always be revised in light of new information. Physicians never fully overcome their initial state of ignorance and must take action despite uncertainty. If their practice is judged from the perspective of the standards of deduction and induction, then most of them commit errors of reasoning. But the question should be posed in other terms: Is medical reasoning appropriate with respect to physicians' targets? Medical practice aims at identifying the cause of a pathology, proposing a possible therapy and treating the patient, if need be, with limited resources. As such, it begins with a medical diagnosis, which takes the shape of abduction, as in Peirce's schema [CP 5.189]:

> The surprising fact, *C*, is observed;
>
> But if *A* were true, *C* would be a matter of course,
>
> Hence, there is reason to suspect that *A* is true.

For example, a physician observes that a patient has a temperature, a headache and breathing problems, plus other symptoms. This is a surprising fact (*C*) in the sense that it is not the normal (healthy) state of the patient. But, if this patient had influenza (*A*), his state (*C*) would be normal. So, the physician suspects that the patient has caught influenza. According to Peirce (CP 5.146), "Abductive and Inductive reasoning are utterly irreducible, either to the other or to Deduction, or Deduction to either of them." If this were a deduction, the physician would be committing an affirming the consequent fallacy, to wit, inferring *A* from *if A, then C* and *C*. Moreover, the conclusion is no more than a defeasible hypothesis, since other illnesses might explain the symptoms. If the physician had heard that a new virus coming from Wuhan affected people in a very similar way, she would probably reassess her diagnosis, thus arriving at another hypothesis, like, for example, that the patient has Covid-19. As stressed by Peirce [CP 2.102], "probability power has nothing to do with the validity of abduction", and that a hypothesis needs not be inductively strong to be accepted. Indeed, that the probability of suffering from influenza might have been higher than that of catching Covid-19 would not prevent anyone from considering the latter hypothesis as perfectly adequate.[6]

The uncertainty of medical diagnosis is not tantamount to an error of reasoning. The mistake would be to believe that standards of deduction or induction are being applied and to neglect the hypothetical character of the conclusion. As nicely put by Woods (2013) p. 376, "Deductive inference is truth-preserving. Inductive inference is likelihood enhancing. Abductive inference is ignorance-preserving." According to the model proposed by Gabbay and Woods (hereinafter GWm) – following Gabbay and Woods (2005) – abduction is a response to an ignorance problem. A question to which an agent has no answer acts as a cognitive irritant that forces him to formulate a hypothesis that may serve as a basis for new actions, despite his persisting state of ignorance. With respect to a cognitive system $<A, T, R>$, this can be understood as a scant-resource adjustment strategy. The agent has not sufficient resources to meet the target, but conjectures that, if it were true, this would allow him to do so. Then, and this is perhaps one of the more salient features of the GWm when applied to medical diagnosis, that conjecture may serve as the basis for new actions, even in the absence of an answer to the ignorance problem. Let Q be a question we cannot answer with our present knowledge and which acts as a cognitive irritant. Three situations are possible:

- Subduance. New knowledge removes ignorance (e.g. empirical discovery).
- Surrender. We give up without looking for an answer.
- Abduction. We establish a hypothesis as the basis for new actions.

To put it in Woods's terms: "[w]ith subduance, the agent overcomes his ignorance. With surrender, his ignorance overcomes him. With abduction, his ignorance remains, but he is not overcome by it." Abduction leads to a hypothesis that could be revised in light of new information. It "is a response that offers the agent a reasoned basis for new action in the presence of that ignorance" [Woods (2013), p. 368].

More formally, let T be an agent's epistemic target at a specific time, K the agent's knowledge base at that time, K^* an immediate successor of K, R an attainment relation for T (that is, $R(K,T)$ means that knowledge base K is sufficient to reach target T), while $\rightsquigarrow$ denotes the subjunctive conditional connective (for which no particular formal interpretation is assumed), and $K(H)$ is the revision of K upon the addition of H. $C(H)$

denotes the conjecture of H and H^C its activation. Let $T!Q(a)$ denote the setting of T as an epistemic target with respect to an unanswered question Q to which, if known, a would be the answer. The GWm has the following general structure:

1. $T!Q(a)$ (fact)
2. $\neg R(K,T)$ (fact)
3. $\neg R(K^*,T)$ (fact)
4. $H \notin K$ (fact)
5. $H \notin K^*$ (fact)
6. $\neg R(H,T)$ (fact)
7. $\neg R(K(H),T)$ (fact)
8. $H \rightsquigarrow R(K(H),T)$ (fact)
9. H meets further conditions $S_1, \ldots; S_n$ (fact)
10. Therefore, $C(H)$ (sub-conclusion (1,7))
11. Therefore, H^C (conclusion (1,8))

An attempt will now be made to explain the model by applying it to medical diagnosis. A patient has a temperature, a headache, breathing problems and so forth. The physician's agenda is to treat the patient or at least to alleviate his pain. The physician does not know what ailment is causing the patient's discomfort. In other words, she has an ignorance-problem, for which reason her target is to discover its nature so that, if she knew it, it would solve the problem. The starting point is $T!Q(a)$ (Step 1), in which target T is the discovery of an illness a that would allow the physician – provided that she knew it – to answer question Q and to treat the patient accordingly.

The resources required for reaching the target are unavailable to the physician. She only knows the symptoms and other related information (the patient's account and so forth) (Step 2). In her encyclopaedic knowledge, she may be aware that Covid-19 causes these symptoms, but without being totally sure that the patient is actually suffering from it. Nor is she capable of finding any immediate successor to answer the question (Step 3). Indeed, she may not have the necessary resources for discovering such an answer in a timely fashion before the end of the consultation. For example, there is no sufficiently decisive symptom (it might be influenza) or she is unable to test the patient. If the physician were able to find a solution, this would lead to subduance, thus halting the abductive process. Nonetheless, neither are tests ever infallible nor is subduance so absolute.

Despite lacking an answer, the physician suspects that the patient is suffering from Covid-19. As a hypothesis, her suspicion does not pertain to her knowledge base (Step 4) or to any immediate successor (Step 5). Therefore, her ignorance-problem remains unresolved and the target unattained (Step 6), even when combined with her knowledge base (Step 7). In order to avoid misunderstandings, K is a knowledge base that can be regarded as holding for a set of propositions known by the agent (without excluding other forms of knowledge). It should not be confused with Hintikka's (1962) epistemic operator in sentences like $K_a\varphi$, whose intended meaning is that 'a knows that φ' and which is true in a corresponding modal framework if and only if φ is true in every state of affairs compatible with a's knowledge. This would lead to an inconsistent reading of Step 7, given that if the agent knew H, then T would be attained. But this is clearly not how K has been defined, by contrast with $H \in K$. In the GW scheme, $K(H)$ holds for the revision of K, a set, upon the addition of H, a hypothesis, without assuming that the resulting (revised) set be another knowledge base — as would be the case with a successor K^* of K in subduance, but in which case no abduction would be triggered.

Yet, the subjunctive relation $H \rightsquigarrow R(K(H),T)$ (Step 8) holds, since if H *were* true, then it *would* play a role in the attainment of T. As such, H is worth being conjectured and $C(H)$ can be concluded (Step 10). These steps are of particular importance insofar as they are the keystone of ignorance-preserving abduction. They express precisely how Gabbay and Woods understand the subjunctive in the second premise of Peirce's schema and, subsequently, the "hence" of the conclusion. In order to avoid confusion, it should be stressed that H may be true, even though the agent is unaware of the fact. Since the relation is only subjunctive, however, the truth of H does not entail $R(K(H),T)$ by some kind of *modus ponens*. $R(K(H),T)$ would follow if the conditional were understood indicatively, and this would obviously conflict with $\neg R(K(H),T)$ (Step 7).

Moreover, subjunctive conditional H $\rightsquigarrow R(K(H),T)$ should not be understood as the expression of a sufficient condition H for the attainment of target $R(K(H),T)$ either. Indeed, the truth of H is obviously insufficient for the attainment of T, given that if the agent does not know H, the target will not be reached. In order for the antecedent to express a sufficient condition for $R(K(H),T)$, a stronger formulation is needed, as in 8':

8' $H \in K \rightsquigarrow R(K(H),T)$

Although 8' might express an acceptable fact if the conditional were deductively or classically understood (i.e. inferring $R(K(H),T)$ from $H \in K$), it is inappropriate to express the conditions of acceptability of a hypothesis. Indeed, abduction is not deduction, and just as Step 8 would be committed to the conjecture of H from $H \rightsquigarrow R(K(H),T)$, so too would 8' be committed to the conjecture of $H \in K$ — it should be recalled that in Peirce's schema what is suspected to be true is antecedent A of the subjunctive conditional "if A were true, C would be a matter of course". That is, instead of inferring that we have reasons to suspect the truth of H, it would infer that we have reasons to suspect that we know the truth of H. But this is clearly the conclusion we refrain from drawing in the ignorance-preserving GWm of abduction.[7]

Thus, given certain conditions – yet to be specified – met by H (Step 9), hypothesis H can be conjectured (Step 10).[8] Let us assume that our physician suspects a case of Covid-19. Abduction does not end there. Indeed, the physician now has three possibilities:

1. The hypothesis is confirmed – e.g. by means of a PCR test – and a new piece of (defeasible) knowledge is obtained. This is subduance.
2. The hypothesis is not confirmed or is invalidated – e.g. by means of a negative PCR test – and the physician gives up. She can thus look for another hypothesis (e.g. influenza).
3. The hypothesis is not confirmed, but she maintains it anyway.

The third possibility leads to *full abduction*: the physician activates the conjecture (Step 11), by employing it as the basis for new actions, despite her persisting state of ignorance. By contrast, *partial abduction* would end at step 10. Depending on the context, different strategies may be adopted. Indeed, if there is no time (owing to the risk of contagion or death) or if there are no material resources (money, test, scanner, etc.) available, the physician may be prompted to act swiftly in the absence of confirmation. Thus, she would perform a full abduction by activating the conjecture, without prior confirmation. For example, if she suspected Covid-19, she would lose no time in isolating and treating the patient, even in the absence of reliable tests. If a test were performed – i.e. a PCR for Covid-19 – after Step 10, this would lead to a *post-partial abductive* confirmation. When acting, albeit in an ignorance-preserving manner, a *post-full abductive* confirmation may also be obtained. This occurs, for example, when a surgeon opens a patient to treat appendicitis and, when visually confirming the infection, discovers that his diagnosis was correct.

In relation to the ignorance-preserving aspect of abduction, it should be noted that abduction is evidentially inert. In other words, it does not provide any grounds for the truth or falsity of its conclusion. It does not even oblige the reasoner to believe this conclusion, as stressed by Peirce (1992), p. 172, who considers that the introduction of an abductive hypothesis is a form of guessing [CP 6.530]. Abduction is an inferential process during which the reasoner is justified in introducing a hypothesis as the basis for new actions, possibly in accordance with the GWm. Of course, many filters, such as plausibility and reliability, among others, may come into play when introducing the hypothesis. But none of them are either sufficient or necessary, as shown by Gabbay and Woods (2005), Chapters 3 to 7. Therefore, the legitimacy of an abductive conclusion should not be judged in terms of levels of evidence or degrees of belief. For instance, Planck did not accept the quantum hypothesis. He did not believe in it and even wished that it was not true. In this regard, the falsity or absence of evidence of an abductive conclusion or the degree of belief for it, should not be considered as a criterion for the correctness of an abduction. As it stands, the GWm does not provide the means to discriminate between degrees of correction; nor does deductive classical logic, for example, provide the wherewithal to distinguish between different degrees of validity. The selection of hypotheses, whether during the abductive process for their introduction or when comparing different abductive conclusions, is certainly an important issue. But this does not substantiate the definition of abduction, a correct form of reasoning in which a hypothesis serves as the basis for new actions, despite the persisting state of ignorance. We might be tempted to approach the selection of abductive hypotheses in Bayesian terms. Nevertheless, beyond all the difficulties inherent to Bayesianism, care should be taken not to confuse abduction with induction. Perhaps this would be an interesting strategy for those who think of abduction in terms of *inference to the best explanation*, but this is not our case. Abduction is not concerned with degrees of belief or corroborating hypotheses, but with putting forward the latter.

Agents may even adopt hypotheses that are inconsistent with their beliefs or knowledge. If it is assumed that knowledge is defeasible, then an agent may know P, but nonetheless consider that $\neg P$ is worth conjecturing. In fact, actual knowledge bases are almost never consistent. An agent may also know P without being aware (perhaps at the moment of conjecturing $\neg P$) that he knows P, thus conjecturing $\neg P$ without experiencing any kind of cognitive dissonance. An agent may even be fully aware of all of this but may still consider that $\neg P$ is worth conjecturing. Of course, this assumes a concept of knowledge different from *justified true belief* and implies parting company with epistemic principles such as positive introspection (i.e. that if an agent knows that φ, then he knows that he knows that φ).[9] Thus, nor is consistency a condition for the acceptability of a successfully abduced hypothesis H, for the logic of abduction should be combined with a paraconsistent logic in order to avoid explosion and triviality [see e.g. Batens (2007), Beirlaen and Fontaine (2016), Fontaine and Barés (2019), Barés and Fontaine (2020), Carnielli (2017)]. According to Gabbay and Woods (2005), p. 150, conjecture is "acceptance for premissory work in future inferences, subject to the possibility of recall. Another way of saying this is that conjecture does not report a doxastic state." Its susceptible productiveness may be a sufficient reason to adopt a hypothesis, even when it is implausible, not believed, not explanatory or even apparently impossible. For example, action at a distance was impossible for Newton. But, from an instrumentalist point of view, it has proved to be an extremely fruitful hypothesis. The value of a hypothesis may indeed be related to its potential productiveness, as a basis for creativity, invention and discovery.[10]

We thus adopt, perhaps only temporarily, a sceptical stance towards the definition of conditions that should be spelled out in Step 9. Although we recognise that filters may play a role in selecting hypotheses, we only see reasons to reject most of them (consistency, plausibility, possibility, explicability, etc.) as good candidates in the formulation of the necessary or sufficient conditions for successful abductions. Worse still, it seems that the call for defining precise conditions for the selection of hypotheses inevitably leads to scepticism towards abductive inference in general. Indeed, if such conditions substantiated correct abduction, then we might be obliged to conclude that Planck's quantum hypothesis and Newton's action at a distance are not good hypotheses. We thus adopt a moderate scepticism and acknowledge the correctness of a number of abductions, without being able to provide a rational justification in terms of the conditions imposed on the selection of hypotheses. The selection of hypotheses is still a problem to which there is currently no satisfactory solution.

According to Magnani (2017), even if ignorance is not overcome by abduction, it is never left intact.[11] A belief that mitigates the initial cognitive irritant is produced. Abduction can thus be "ignorance-mitigating" or "knowledge enhancing", depending on the context.[12] In any case, as we understand abduction, it cannot be accounted for in terms of inference to the best explanation, which involves an inductive process and (possibly) probabilistic reasoning. Moreover, although Peirce speaks of abduction in terms of "the process of forming explanatory hypotheses" [CP 5.171], this cannot provide a general characterisation of abduction.[13] Abduction cannot be restricted to the application of filters in order to select hypotheses either. Abduction can be *selective* or *creative*. This can be very clearly seen in medicine when physicians may either select a known illness from their encyclopaedic knowledge or introduce a new illness that has yet to be classified. The former involves the cut-down problem, to wit, selecting one hypothesis from a set of already available ones. Filters doubtless play a cognitive role when selecting hypotheses but specifying them is a very complex task.[14] While the latter involves the fill-up problem, namely, explaining how new hypotheses are generated. Even if creative abduction requires much more discussion, it can be explained within Magnani's eco-cognitive model of abduction (hereinafter ECm), which is to a certain extent compatible with the sentential GWm. According to the ECm, agents performing abductions are embodied in distributed cognitive systems, that is, cognition is embodied and the interactions between brains, bodies and external environments are its central aspects. Guessing new hypotheses is a process that occurs in a complex distributed system in which a constant exchange of information occurs. There are interactions between the brain – not only conscious intellectual activity, but also the unconscious kind – and the manipulations of the environment or artefacts (e.g. diagrams). How information is processed is very important. For instance, an error of judgement (in medical diagnosis) may be based on the fact that a piece of information has not been perceived, perhaps because it was not salient. Sometimes, the manipulation of information may render it easier to process. At any rate, abduction is highly contextual and conclusions should always be evaluated with respect to particular targets and scant resources.

The GWm explains why absolute certainty is unattainable in medical diagnosis. Uncertainty is not inherent to any kind of error of reasoning, but to the form of reasoning underlying medical diagnosis. Therefore, acting despite a persisting state of uncertainty is not a medical error. Error should be judged in light of the triple$\langle A, T, R \rangle$, where resources may be very restricted and the target is a diagnosis, therapy or monitoring strategy, which serves as the basis for new actions. It is a scant-resource adjustment strategy whose aim is to save patients' lives or to protect their health. A consequence of the situatedness of abduction is that a response may be appropriate in one context but not in another. For example, it is worth administering quinine on the basis of the hypothesis that someone who has fever in the midst of Amazon rainforest is suffering from malaria, but other hypotheses will be explored in a city; and before prescribing chemotherapy, expensive tests will be run. In the main, physicians make judgements by balancing the cost, risks and benefits of a therapy, but whatever the battery of tests that they perform, they can never fully overcome their initial state of ignorance.

IV. Confirmation and Emergency Situations

The distinction between post-partial and post-full abductive confirmations parallels that between Steps 10 and 11 of the GWm. But things appear to be more complex. How confirmation occurs in medical reasoning can be clarified by means of the Select and Test Model of medical reasoning (hereinafter STm) proposed by Magnani (1992). Medical reasoning involves strings of abductive hypotheses, intertwined with deductive and inductive phases, for confirmation. Such a confirmation does not necessarily have to follow standards of induction as strict as those of other fields, like, for example, pharmaceutical research. This is probably the key to understanding the controversies arising during the Covid-19 pandemic, the difficulty in making decisions and, more generally, why our societies are not prepared to cope with uncertainty. Medical reasoning is sometimes judged from an erroneous perspective, following inappropriate standards.

According to the STm, medical reasoning begins with the *abductive phase* and the selection of hypotheses on the basis of the patient's data (abduction). Following this, the *deduction-induction phase* deals with the process of evaluation. Deduction is used for predicting expected consequences and evolution (i.e. prognosis). As stressed by Magnani (1992), p. 24, induction should be understood here as an ampliative process of generalising knowledge with which hypotheses can be confirmed or rejected. In other words, hypotheses whose expected consequences turn out to be consistent with the patient's data are corroborated by induction, the other are rejected. In both cases, new or refined hypotheses may be introduced. Once a hypothesis is established (for example, a diagnosis, a therapy, or a monitoring strategy), certain predictions derived at a time t_1 (the presence of a certain symptom, the development of consequences, estimates of a particular evolution) can be revised at a time t_2: the conclusions are defeasible. Diagnosis, therapy planning and monitoring can all be explained by the STm, namely, by first selecting a hypothetical diagnosis, therapy or monitoring strategy, which is usually ranked (parsimony, danger, cost, curability, etc.), and then by testing it in the deductive-inductive phase.

Although it may seem that a partial abduction is first performed, before testing hypotheses, the way in which these different phases intertwine in medical reasoning is more complex. First and foremost, medical diagnosis is not always based on selective abduction. Indeed, if data and background knowledge are lacking, it is occasionally necessary to consider a set of symptoms as an indication of an unknown illness or syndrome. For example, before identifying SARS-CoV-2, physicians have to identify the signs and symptoms of an unknown illness, different from influenza. This can be related to creative abduction, since a new piece of information is added to their encyclopaedic knowledge. As stressed by Barés (2018), pp. 1715-1716, creative diagnoses were already performed in ancient medical practice. The āšipu (the Akkadian medical practitioner) normally selected a demon corresponding to a set of symptoms from his handbook. But if the symptoms could not be related to an existing demon in the aetiology, he had to create a new one and, therefore, a new illness.[15] Creation also occurs for different reasons, like, for example, when pharmaceutical companies promote their drugs by disease-mongering [González-Moreno et al. (2015)]. Secondly, the confirmation phase does not prevent the STm from being compatible with full abduction. Once the diagnosis had been established, a therapy may be conjectured without its confirmation. A full abduction involving both the diagnostic and therapeutic hypotheses is performed and then deployed in a deduction-induction phase. If predictions as to the consequences of the treatment are not corroborated (i.e. amelioration), then not only the therapy, but also the initial diagnosis, may be rejected. For instance, if quinine does not cure a patient with fever, it may not have been caused by malaria, but by something else. In point of fact, partial abduction almost never occurs in medical reasoning. Indeed, when Covid-19 is suspected, a monitoring strategy, such as a lung scan, might be considered. As before, this is a full abduction given that a monitoring hypothesis is introduced on the basis of former hypotheses. As highlighted by the ECm, abduction is multimodal and involves a constant exchange of information between cognitive agents and their internal aspects and external environment. Information crosses the boundaries of different cognitive devices. And different but complementary inferential processes intertwine, so that seeking the confirmation of an abductive hypothesis does not preclude a full abductive process.

Regardless of its success, the controversy about the treatment of Covid-19 with hydroxychloroquine and azithromycin – proposed by the

French professor Didier Raoult and his team at the IHU Marseille – is an interesting case study. These researchers began with a diagnosis, involving clinician-observed symptoms and tests, before introducing a hypothetical therapy with a combination of hydroxychloroquine and azithromycin. This decision was not baseless inasmuch as this drug combination had often helped to reduce the viral load of other kinds of coronavirus and to treat respiratory infections, besides being cheap and with a low risk of side effects. Indeed, patients had already been treated with this therapy, even though its effectiveness had yet to be confirmed. Following this, during the monitoring phase, data were gathered. Finally, the paper's authors claimed that the expected prognosis had been confirmed [Gautret et al. (2020)]. This study has been criticised mainly because it did not meet the standard requisites of RCTs: the sample was small, not randomised, and both the physicians and patients knew the treatment, meaning that the placebo effect could not be measured. In addition to treating patients despite a lack of certainty, the authors of the lambasted paper have been accused of having made a sort of hasty generalisation. In particular, Rosendaal (2020) points out that the method employed by them "shows a lack of understanding of basic statistics". In 10 critical points, he mainly highlights their disrespect for the methodological standards of RCTs. However, although these standards are adequate for medical and pharmaceutical research, they should not be regarded as essential when judging a study of medical practice. Ultimately, Rosendaal's criticism misses the mark.

In order to avoid any confusion, it is important to clarify our position here. Our question is the following: Is there any error of reasoning in the paper published by Gautret et al.? When speaking of error of reasoning, we are not judging the truth or falsity of their conclusions. In retrospect, the very least that we can say is that their conclusions have not been corroborated by the rest of the scientific community. But correctness of reasoning should not be judged in terms of the truth of the conclusions, as is clearly the case with abduction. Gautret et al.'s study involved an inductive phase, based on observations of the evolution of the patients. However, as highlighted in the STm, medical reasoning and its confirmation do not stop at such an induction phase. In light of new information, it is always possible to introduce new hypotheses or to refine old ones. The authors' mistake, if they did indeed make one, was to consider hypotheses for what they are not – namely known truths[16] – and these observations as an absolute confirmation of the therapy's effectiveness. On the contrary, they cannot be blamed for having infringed the standards of pharmaceutical research, which requires a huge quantity of resources. Gautret et al.'s conclusions might be faulty for many reasons which cannot be discussed here because of space restraints. Although they may also be false, the authors certainly cannot be blamed for having infringed such methodological standards, which were inappropriate in the midst of a public health crisis.

Indeed, is it desirable to set targets with high standards of accuracy, like in RCTs, during such an emergency situation? In such situations, at least two resources are lacking: data and time. Looking for certainty on the basis of data is a mistake, because those data are not available. Waiting for (reliable) data is another mistake, for there is no time for their collection. Bayesian approaches may explain how we could cope with the high degree of uncertainty inherent to emergency situations. Gautret et al.'s conclusions should therefore be treated with extreme caution given their weak statistical basis.[17] What is probably worse is the lack of time, which urges those responsible to act without further confirmation. The fact that people are being infected and dying poses an ethical dilemma:

- We maintain high standards of proof and refrain from taking action,

or

- We look for less costly standards and take action, despite uncertainty.

Whether or not infected patients should be treated with therapies whose effectiveness has not been proven is a burning issue. If the target is to find ways of taking action before the end the pandemic, then high standards of accuracy are inappropriate. Since they require unavailable resources, they make the target unattainable and are irrelevant for the agenda of physicians. Indeed, by the time that those high standards have been met, most of the infected patients in need of care will have died. At the same time, risk aversion discourages physicians from acting hastily. Indeed, the cure cannot be worse than the disease.

What is to be done then? What are the correct standards? On the one hand, we uphold a negative thesis: the standards of RCTs or statistical methodology cannot be applied, otherwise we would not be able to take action. On the other, we maintain a positive thesis: appropriateness must be judged from the perspective of cognitive systems. This leads us to third-way reasoning, whose standards of accuracy may be spelled out in terms of different kinds of logics (defeasible, default, abductive and so forth). Insofar as it struck a balance between costs, benefits and risks, and notwithstanding the fact that it might have been unsuccessful and the study conclusions were erroneous from the perspective of the high standards of accuracy established for medical and pharmaceutical research, it may seem unreasonable to claim that the strategy implemented by the IHU Marseille was a mistaken, hasty generalisation. From the perspective of a cognitive system<*A*, *T*, *R*>, the maximisation of available resources for attaining a target, the error of reasoning is not obvious. This is even more striking when bearing in mind that when their study was published in March 2020, there was no alternative hypothesis on the basis of which treatment could have been provided. The only available alternative was to refrain from taking action. The scientific community has made two mistakes: overlooking the hypothetical character of Gautret et al.'s research and judging it based on the high standards of pharmaceutical research. Medical practice in emergency situations is one thing; research aimed at patenting molecules is quite another. Less costly forms of reasoning must be adopted if we want to be able to act in emergency situations. In such situations, standards of appropriateness should at least involve the possibility of taking action with a view to attaining the target. And this is precisely what the standard methodology of RCTs does not allow.

V. Conclusion

Errors of reasoning, cognitive strategies or even decision-making should be judged contextually with respect to the agents, targets and resources involved. Individual agents with few resources cannot afford to set the same targets as institutional agents with plenty of them. This relative adaptation of targets to agents intrinsically impacts how standards of attainment must be set, above all by taking into account the maximisation of resources. From this perspective, accuracy is not aptness. We cannot define standards of aptness for any particular situation, but it is obvious that those standards that make targets unattainable are inappropriate, and this should be understood as the essence of our criticism of those who accuse Gautret et al. of not having respected the high standards of RCTs. Reasoning and knowledge of practical agents are defeasible, while error management strategies are usually more efficient than those based on error avoidance.

Abduction is a prominent scant-resource adjustment strategy, owing to the fact that it allows agents to act on the basis of hypotheses, despite their persisting state of ignorance or uncertainty. The creation and selection of hypotheses merit further research, but a conceptual understanding of abduction in terms of the GWm or the ECm can shed light on how it operates. Hypotheses can always be revised, and confirmation is not intrinsic to abduction. But confirmation and hypotheses intertwine in complex processes involving different but complementary inferences. In the constant information flow inherent to cognitive systems, it is not always possible to delineate clearly the boundaries of these different phases.

If the STm is relevant for medical reasoning, then medical practice must learn to cope with uncertainty. Although they usually form part of large institutions (e.g. hospitals), physicians often act as individual agents; that is, they make decisions with few resources. They almost always act and treat patients, despite their persisting ignorance. They cannot be blamed for that, given that if diagnosis is abductive, then it is intrinsically ignorance-preserving — even if ignorance is never left intact.

Things go from bad to worse in emergency situations. The controversy about the use of hydroxychloroquine to treat Covid-19 illustrates the lack of adequate standards for such situations, in the absence of which decision-making is all but impossible. Whereas individual agents promptly resort to error detection and management strategies, institutional agents have a very high degree of risk aversion and constantly seek to avoid errors. Decisions made by institutional agents concern society as a whole and their responsibility compels them to adopt high standards of accuracy. A treatment is not authorised if its effectiveness and safety do not meet high standards of inductive strength. These standards curb the creativity of scientists, who may be tempted to censure themselves when putting forward new hypotheses. The drastic lack of crucial resources forces institutional agents into the realm of individual agents, in which they must learn to navigate through the fog of uncertainty. And this is something for which they are not prepared.

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NOTES

[1] Financial resources may also be taken into account.

[2] The accuracy-aptness distinction may also be related to the notion of agenda relevance defined, following Gabbay and Woods [(2003), p. 74], as a causal relation defined over triples <*I*, *X*, *A*> of *information*, *cognitive agents* and *agendas*.

[3] According to Woods (2013), p. 223, "there seems to be no want of candidate logics for the analysis of third-way reasoning — non-monotonic logics, truth maintenance systems, defeasible inheritance logics, default logics, autoepistemic logics, circumscription logics, logic programming systems, preferential reasoning logic, abductive logics, theory-revision logics, belief change logics and whatever else."

[4] Note that if third-way reasoning may be defeasible, all defeasible reasoning is not third-way (e.g. induction).

[5] Another nuanced view of fallacies, beyond the incorrect-correct dichotomy, can be found in Vega (2014).

[6] In this example, both illnesses have already been identified and classified. But this is not always the case, as evidenced by the distinction between selective and creative abductions below.

[7] We are indebted to John Woods – who wonders if such a conclusion would be permitted by Peirce's epistemology – for his fruitful and profound comments on how to understand the GWm.

[8] Interestingly, authors such as Olmos (2019) stress that the evaluation of these clauses in the context of argumentative interaction may be essential for evaluating abduction. Barés and Fontaine (2017) account for these conditions in terms of argumentative commitment in a dialogical framework, and also Fontaine and Barés (2019) and Barés and Fontaine (2020) in terms of defeasible commitment.

[9] Woods' (2013) causal-response (CR) model, for example, accounts for dark and automatic processes in the acquisition of knowledge, which do not assume justified true belief or positive introspection.

[10] Concerning Peirce's value of *uberty* regarding the potential productiveness of hypotheses, see also Chiffi and Pietarinen (2009), p. 234.

[11] Woods (2017), p. 244, acknowledges that in the causal-response model of knowledge – according to which knowledge is not justified true belief – there is room for knowledge-enhancing abduction. But this is a matter of epistemology. It does not mean that abduction is not evidentially inert. For further information on the causal-response model, see Woods (2013).

[12] On ignorance in abduction, see also Magnani (2019).

[13] As regards this issue, see Hintikka (1998). For non-explanatory abductions concerning the underlying rules of an argumentative game, see also Fontaine and Barés (2019) and Barés and Fontaine (2020).

[14] In addition to previous comments in this respect and for further critical discussion, see Gabbay and Woods (2005).

[15] For further details, see also Scurlock and Andersen (2005), p. 505.

[16] Of course, a hypothesis could prove to be true, but it should not be taken as a truth while it is still hypothetical.

[17] We would like to thank the anonymous reviewer for calling our attention to this Bayesian account of uncertainty.

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Principios de una filosofía de la técnica

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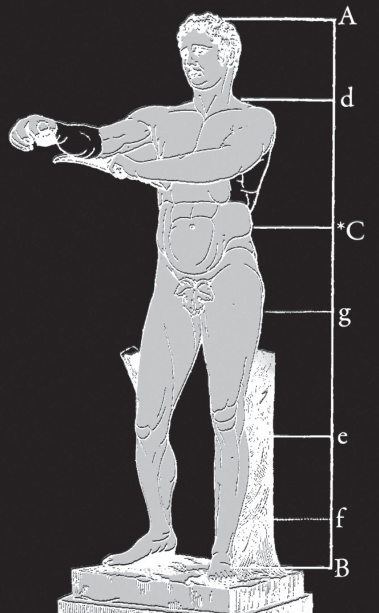

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