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Common Cause Abduction: Its Scope and Limits

1. INTRODUCTION

More than a hundred years ago the American philosopher and logician Charles S. Peirce coined the puzzling concept of abduction in order to describe a kind of reasoning (argument)[1] which aims to form an explanatory hypothesis to account for the surprising facts. Philosophers have struggled long and hard with the fundamental questions about abduction: Does abduction amount to a logically valid inference (argument) or to a mere act of guessing? If abduction is a logically valid inference, then abductive conclusion must be true if all the premises are true; but this cannot be true, since abduction is ampliative[2], highly conjectural, and non-monotonic[3]? On the

[1] It is worth noticing that contemporary philosophers distinguish between the notion of argument and the notion of reasoning (inference). An argument is said to be a set of sentences divided into two parts: premises and conclusions; an argument is judged as valid or sound with respect to some principles of argument like *modus ponens* or *modus tollens*. On the other hand, the notion 'reasoning' or 'inference' is used to indicate the process of drawing conclusions from the premises, i.e., the process of extracting information from the premises. As it has been pointed by some philosophers, most notably by G. Harman (1986, pp. 1-6), the rules of argument do not become automatically the rules of reasoning (or rules for 'a reasoned change in view'), although they may be relevant to them. Interestingly, Peirce (1931-1958, CP 6.456) had a different terminology: by 'argument' he meant a process of reasoning, while by 'argumentation' a set of premises and conclusions. For present purposes, these distinctions make little difference.

[2] Abduction is an *ampliative* (*synthetic*) step of reasoning, i.e., its conclusion brings new information that is not contained—implicit or explicit—in the premises, and this new information is introduced by abduction as a kind of *conjecture*.

[3] Abduction is *non-monotonic* (*defeasible*) because an abductive conclusion drawn from a set of premises can be undercut if the premise set is supplemented with additional information; other words abduction, unlike deduction, lacks monotonicity because the set of abductive conclusions

other hand, if it is a mere kind of guessing, how is it possible that scientists armed with abductive mechanism 'guessed' so many true (realism), or empirically adequate (empiricism), theories about the world? These questions mark a tension between the conjectural, ampliative and non-monotonic character of abduction, on the one hand, and the possibility of a logical analysis of abduction (the possibility of constructing the *logica docens* for abduction), on the other hand. Philosophical opinions are sharply divided with respect to these questions. On the one hand, some philosophers argue, following Reichenbach (1938), Popper (1959), that if abduction constitutes the *context of discovery*, then it cannot be governed by rational rules, since the context of discovery cannot be logically analysed (in particular, as a logical argument); they add that, at best, abduction as a kind of guess can be analysed from a psychological point of view. On the other hand, it is argued that one can define rational rules for abduction that can be codified, for example, in various *logics for abduction.*[4] Both strategies have their standard arguments, and each regards its own arguments as compelling — the debate resembles the trench warfare of the World War I. One way to avoid a stalemate in this debate is to acknowledge that one can tackle the fundamental questions about abduction either *globally* or *locally*. The global strategy aims to answer these questions in general, apart from the types of abduction one may specify, and apart from the various contexts in which abduction can be used; it aims to resolve the basic dilemmas about abduction, and then apply these solutions to all the contexts in which abduction can be used. On the other hand, a more modest local strategy acknowledges that the fundamental questions about abduction cannot be answered in general; at best, one may tackle them with respect to a type of abduction (e.g., explanatory or instrumental abduction) or even with respect to a type of abduction in a particular context (e.g., explanatory abduction in law or science).[5] On this strategy, one can compare different answers to the core questions about abduction with respect to different types of abduction. It may happen then that one can define rational rules for the explanatory abduction, but fail to do this for the abductive reasoning in 'reverse' mathematics.

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does not grow monotonically while the premise set grows.

[4] Various logics and logical approaches to abduction have been proposed in the domain of artificial intelligence, cognitive science, philosophy of science and philosophical logic. For example, Aliseda (2006) has proposed a logical approach to abduction in terms of semantic tableaux; Meheus and Batens (2006) have defined logics for abduction based on ampliative adaptive logics; Carnielli (2006) has designed a logic for abduction based on a version of paraconsistent logic; Hintikka (1998) has proposed a logical approach to abduction in terms of his interrogative model of inquiry and interrogative logic.

[5] So, for example, on the local strategy, either one focuses on the nature of explanatory abduction, or on the nature of various non-explanatory or instrumental abductions like abduction in the so-called 'reverse' mathematics or abduction in interpretation. Moreover, it is possible that the justification of explanatory abduction is highly context-dependent (e.g., explanatory abduction in science and in law may differ essentially).

This article focuses on abduction from the perspective of the *local strategy*. It aims to scrutinise the nature of one version of the *explanatory abduction*, namely *common cause abduction*, which is based on *Hans Reichenbach's principle of the common cause*. First, it is claimed that common cause abduction can be regarded as a rational and powerful rule for abductive explanatory inferences from the observed surprising *correlations of events* to the *screening-off common cause* abductive hypothesis that explains this observed correlation. Three arguments are presented to bolster this thesis: the *argument form screening-off*, the *argument from likelihood*, and the *argument from simplicity*. The upshot of these three arguments is that common cause abductive hypotheses appear to be more plausible than the separate cause abductive hypotheses. Second, it is argued that we should not be so optimistic about common cause abduction. I shall argue that it is not always true that the common cause abductive hypothesis is more plausible than the separate cause hypothesis. All of these three arguments appear to be defeasible. Third, it is claimed that the defeasible nature of common cause abduction does not imply that this kind of abduction is unreasonable. As a consequence, I shall outline some general remarks of how to use common cause abduction in a reasonable manner.

2. THE EXPLANATORY ABDUCTION FOR THE CORRELATION OF EVENTS

Before diving into the body of discussion concerning the substantial theses of this article, I shall first clarify the concept of explanatory abduction by introducing its model, and then use this model to define the explanatory abduction for the correlation of events.

The idea of explanatory abduction is inherently connected with Peirce's conception of abduction. As it has been argued by Peirce, abduction aims to find an *explanans* that accounts for an *explanandum* which describes some surprising event or fact. One may say that abduction begins when ignorance comes, or that one's ignorance 'triggers' abduction. This means that we reason abductively, when we are faced with unknown surprising circumstances or, broadly speaking, with a cognitive problem that cannot be resolved on the basis of our background knowledge. Following Kapitan (1997, pp. 477-478), Peirce's conception of abduction may be characterised by the four theses:

Inferential Thesis:

Abduction is, or includes, an inferential process or processes.

Thesis of Purpose:

The purpose of scientific abduction is both (i) to generate new hypotheses and (ii) to select hypotheses for further examination; hence, a certain aim of abduction is to recommend a course of action.

Comprehension Thesis:

Scientific abduction includes all the operations whereby theories are engendered.

Autonomy Thesis:

Abduction is, or embodies, reasoning that is distinct from, and irreducible to, neither deduction nor induction.

It is essential to Peirce's conception that abduction is an inference that aims to create, select and conjecture hypotheses. Some philosophers suggested, albeit in different ways, that we can make sense of two epistemological kinds of abduction: *creative abduction* and *abduction as inference to the best explanation* (*evaluative or selective abduction*).[6] Whereas creative abduction aims to generate hypotheses for further examination, abduction as inference to the best explanation leads to accepting a hypothesis on the grounds that it *best explains* some *explanandum* proposition. This distinction, however, does not comply with Peirce's *Thesis of Purpose* which states that any kind of abduction encompasses both the selective and the creative part. The question arises: How can we represent explanatory abduction in order to make sense of Peirce's theses?

A very promising way is to adopt the so-called *GW*-model of abduction proposed by D. M. Gabbay and J. Woods (Gabbay and Woods 2005, pp. 39-73). In comparison to various formal and quasi-formal representations of Peirce's idea of abduction presented in the literature, *GW*-model aims to provide a more general structure of abduction; it encompasses both the creative and the selective part, and it captures both the instances of explanatory and instrumental abductions. What is crucial for this model is that it is based on non-classical logic — the *practical logic of cognitive systems*.[7] This logic is a principled description of the conditions under which agents employ resources in order to perform their cognitive tasks. It is a non-classical logic in the sense that it does not restrict logic to modelling arguments as relations between linguistic structures (propositions, sentences, etc.), but it extends logic to model in a principled way the behaviour of agents who employ inferences. So, this logic finds the structure of abduction as more complex than the relation between an *explanandum* and an *explanans* proposition.

On *GW*-model, abduction is a *presumptive solution* to a cognitive agent's ignorance problem (IP). IP may be defined as follows:

Definition 2.1. (*Ignorance Problem* (IP)) IP exists for a cognitive agent iff he has a cognitive target *T* that cannot be attained from what he currently knows (his current

[6] This distinction is to be found in Magnani (2001), Schurz (2008), Fetzer (2004). Some philosophers regard Peirce's abduction as synonymous with inference to the best explanation; see, e.g., Harman (1965).

[7] This practical logic is an instance of the so-called Resource-Target Logic. This logic models a target-motivated and resource-dependent reasoning. A detailed analysis of this logic is to be found in Gabbay and Woods (2001).

knowledge base *K*) and from the accessible successor knowledge K^* of *K* (the extension of *K*).[8]

It is important to note that one's ignorance problem is always a matter of degree; that is to say, our cognitive targets are more or less attainable from what we currently know and from our accessible successor knowledge. Abduction offers a presumptive solution to IP, i.e., it leads to a hypothesis *H* which, if an agent knew it, would together with *K* solve his IP; and from this fact he *conjectures* that *H* is true (Gabbay and Woods 2005, pp. 42-47). More schematically, let *T* indicate an agent's cognitive target, *R* is the attainment relation on *T*, *K* is the agent's knowledge base, K^* is a closely accessible successor of *K*, R^{pres} is the presumptive attainment relation on *T*, *H* is a hypothesis, *K*(*H*) is a knowledge base revised by *H*, *C*(*H*) is a conjecture that *H*, and H^C is a discharge of *H*. Then, the schema for abduction runs as follows:

1. *T*! [declaration of *T*]
2. $\neg(R(K, T))$ [fact]
3. $\neg(\mathrm{R}\ (K^*, T))$ [fact]
4. $R^{pres}(K(H), T)$ [fact]
5. *H* satisfies some conditions that assess *H*'s plausibility [fact]
6. Therefore, *C*(*H*) [conclusion]
7. Therefore, H^C [conclusion]

The crucial fact about abduction that is implied by *GW*-model is that an agent who employs abduction as his response to IP does not attain his cognitive target on the basis of his knowledge *K* or K^* (this is indicated by line 2 and 3 in the above schema). By employing abduction, he proposes *H* such that his knowledge *K* revised by *H* would attain *T* (line 4), and after evaluating *H*'s plausibility (line 5), he conjectures that *H* (line 6), and decides to act on the basis of *H* (line 7), e.g. he decides to test or examine *H* in scientific inquiry. Conjecturing that *H*, however, does not constitute knowledge; abduction lowers an agent's epistemic aims with regard to *T*, since it does not offer knowledge that enables him to attain *T*, but only a conjecture that *H* is true.

This general *GW*-model for abduction may serve as a point of departure for studying the nature of various kinds of abduction that respond to a variety of abductive ignorance problems. In what follows, I shall focus on one species of *explanatory abduction*, namely abduction defined as a presumptive solution to *explanatory ignorance problems* (EIP) concerning a *correlation of events*.

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[8] It is important to notice that the accessible successor K^* of *K* is an extended knowledge-base that should be available to a cognitive agent in a way that enables him to attain the cognitive target without proposing a conjecture. Suppose that you have forgotten what the concept 'abduction' means, but you want to explain it. Then you may extend your current knowledge-base *K* to the accessible successor K^* by consulting the dictionary of philosophy or *The Collected Papers of Charles S. Peirce*. K^* then attains your cognitive target, and you are no more faced with the ignorance problem.

In general, one may define EIP as follows:

Definition 2.2. (*Explanatory Ignorance Problem* (EIP)) EIP exists for a cognitive agent iff he has a cognitive target that calls for explanation (E), and it can be explained neither on the basis of what he currently knows (his current knowledge base K) nor on the basis of his accessible successor knowledge K^* of K.

A majority of explanatory ignorance problems consists in finding an explanation for particular events, e.g., fossil evidence in biological sciences, a behaviour of the crime perpetrator in legal reasoning, physical phenomena. Much of past and current philosophical and logical theories of abduction center on finding rational rules for explanatory abduction for such EIP. The other, rather neglected, explanatory ignorance problems consist in finding an explanation not for particular events but for the *correlations of events*. There are many examples of interesting correlations of events that call for explanation in physics, chemistry, biological sciences, legal investigation, and in everyday reasoning. For example, there is a significant correlation between cancer and yellow fingers (Arntzenius 1990, p. 78), or a correlation between two lamps that go out suddenly in your room (Reichenbach 1956, p. 157). But, what does it mean that events are correlated? What do we mean when we say, for example, that there is a correlation between having a cancer and having yellow fingers? This question finds an interesting probabilistic answer. Probabilistically, one may define (positive) correlation between events A and B as follows:

Definition 2.3. ((*Positive*) *Correlation of Events*)[9] The events A and B are said to be (*positively*) *correlated* if the joint probability of A and B, $P(A\&B)$, is greater than the product of the single probabilities $P(A)$ and $P(B)$, i.e., if

$$P(A\&B) > P(A) \times P(B)$$

This condition can be equivalently stated as follows: if two events A and B have some positive probability of occurrence, i.e., $P(A) \neq 0$ and $P(B) \neq 0$, then there is a positive correlation between events A and B if $P(A|B) > P(A)$, or if $P(B|A) > P(B)$. As it is easy to observe, the probabilistic definition of a correlation of events does not state that a correlation of events A and B means 'An event A occurs whenever an event B occurs'. This would be too much. On the other hand, correlation does not mean a mere coincidence. It says that to find a correlation of events A and B is to observe that the occurrence of both A and B is more probable than their independent occurrence. So, we say that there is a (positive) correlation between cancer and yellow fingers if the probability of having a cancer among people with yellow fingers is

[9] It is also possible to define probabilistically a negative correlation of events. It runs as follows: The events A and B are said to be *negatively correlated* if the joint probability of A and B, $P(A\&B)$, is less than the product of the single probabilities $P(A)$ and $P(B)$, i.e., if $P(A\&B) < P(A) \times P(B)$. In a simple way a negative correlation may be transformed into a positive one just by replacing A by $\neg A$, or B by $\neg B$.

greater than the probability of having a cancer in general, say in some population. When one observes a correlation between events *A* and *B* one intuitively admits that the occurrence of both events is not independent. Other words, the idea of correlation among events is the idea of probabilistic dependence.

Having the definition of the correlation of events at hand, we can now define an explanatory ignorance problem concerning such correlations:

Definition 2.4. (*Explanatory Ignorance Problem Concerning Correlations of Events* ($\mathrm{EIP_{COR}}$)) $\mathrm{EIP_{COR}}$ exists for a cognitive agent iff his cognitive target consists in finding an explanation for a correlation of events (E_{COR}), and it can be explained neither on the basis of what he currently knows (his current knowledge base *K*) nor on the basis of the accessible successor knowledge K^* of *K*.

What is then the explanatory abductive response to $\mathrm{EIP_{COR}}$? To state precisely explanatory abduction for E_{COR}, we must first introduce some important distinctions. First, it is important to recognise that explanations may come at least in two sorts: *causal* and *non-causal* explanations. A causal explanation of an event provides information about its causal history. An example of non-causal explanation is the reason-based explanation which says that an explanation provides a reason to believe the *explanandum*. There is a controversy in the literature about explanation as to whether we can make a theoretically significant distinction between causal and non-causal explanations. On the one hand, it is claimed that there is no such thing as non-causal explanation; the only relevant explanation is causal explanation, and all the alleged non-causal explanations are reducible to causal ones (Lewis 1986). On the other hand, it is argued that there are strong reasons for making room for both causal and non-casual explanations; causal explanation is not the whole story that can be said about explanation. For example, it is claimed that while empirical science is the kingdom of causal explanations, mathematics and other formal sciences require non-causal explanations (e.g., a mathematician may explain why Fermat's theorem is true, but his explanation would not cite causes) (Lipton 2004; Kitcher 1989). Putting this fundamental and interesting discussion aside, I shall, rather modestly, ask: what model of explanation should we assume for the explanatory abduction that aims to account for E_{COR}? My answer is that the model should be causal. But this is not to say that all kinds of the explanatory abduction should be based on the causal model of explanation; again, 'reverse' mathematics might be the kingdom of non-causal abductive explanations. The first reason for applying the causal model to the case of abductive explanation of E_{COR} is that such an abductive explanation should be asymmetric in the sense that the proposed *explanans* should explain the *explanandum* but cannot itself be explained by the *explanandum*. This reason is obvious, since abduction aims to resolve the ignorance problem by inventing conjecture which itself cannot be explained abductively by the phenomena that call for explanation. The required asymmetry in abductive mechanism can be established by characterising abductive hypotheses as causal hypotheses, since the relation of causal dependency is, at least on the predominant view, asymmetric. The second more particular reason is that causal explanations for the surprising correlation of events provide more ‘explanatory relevant’ reasons. For example, if one observes a surprising correlation, say that two lamps go out suddenly in the room, one provides a better understanding of the correlation by conjecturing a cause of the correlation than by conjecturing a law-like statements from which the correlation can be derived.

Second, one has to specify a model for assessing causal explanations’ plausibility (as indicated in line 5 of the *GW*-model). At least, two options are possible. First, one may want to assess a proposed abductive causal explanation on whether it is the best explanation from a set of possible explanations. This is, however, untenable. Such a model is susceptible to the infamous ‘bad lot’ argument, due to van Fraassen (1989, p. 143). It may be stated as follows: suppose an abducer has invented a set of hypotheses that offer potential explanations of some phenomenon, and then he has sorted out the best explanation from the set. Selecting the best explanation from the set of possible explanations involves the belief that the possible true hypothesis is to be found in that selected lot of hypotheses. But, the best explanation may well be the best from the bad lot, say from the lot containing false explanations. One way to avoid this problem would be to insist that this model presupposes a *principle of privilege* which states that nature predisposed scientists to formulate the right set of possible hypotheses. This is untenable as well. The second more promising option is to assume that the assessment of causal explanation’s plausibility is *contrastive*. Instead of asking whether a causal explanation is the best of the possible ones, we ask whether it is more plausible than its rival; we do not ask whether it should be favoured over all possible explanations. It might occur, then, that an explanatory hypothesis H_1 is favourable over H_2, but not over H_3.

Being endowed with the specifications stated above, the explanatory abduction for E_{COR} runs as follows:

Definition 2.5. (*Explanatory Abduction for the Correlation of Events*) Let E_{COR} indicate an agent’s cognitive target consisting in finding a causal explanation for a correlation of events, R is the attainment relation on E_{COR}, K is the agent’s knowledge base, K^* is a closely accessible successor of K, R^{pres} is the presumptive attainment relation on E_{COR}, H_E is a hypothesis that explains the correlation, $K(H_E)$ is a knowledge base revised by H_E, $C(H_E)$ is a conjecture that H_E, H_E^* is H_E’s rival, and H_E^C is a discharge of H_E. Then the schema for explanatory abduction for the correlation of events runs as follows:

1. E_{COR}! [declaration of E_{COR}]
2. $\neg(R(K, E_{COR}))$ [fact]
3. $\neg(R(K^*, E_{COR}))$ [fact]
4. $R^{pres}(K(H_E), E_{COR})$ [fact]
5. H_E is more plausible than H_E^* [fact]
6. Therefore, $C(H_E)$ [conclusion]

7. Therefore, H_E^C [conclusion]

One may find many significant instances of EIP_{COR} in cases of scientific discoveries. One of the classic examples discussed in the textbooks of philosophy of science is the famous Semmelweis' case (Hempel 1966, pp. 3-6; Lipton 2004, pp. 74-76). Ignaz Semmelweis was a Hungarian physician who discovered the cause of childbed fever working during 1844-1849 at the Vienna hospital. Semmelweis observed that a much higher percentage of women in the First Maternity Division contracted childbed fever than in the Second Division. When he was searching for the cause of the increasing mortality rate of women who contracted childbed fever, he noticed a surprising correlation between the symptoms of those who contracted childbed fever and the symptoms of his colleague's disease. Semmelweis' colleague Kolletschka who was performing autopsies in the First Maternity received a puncture wound from a scalpel, and died displaying the same symptoms as the victims of childbed fever. Other words, in this case the probability of the occurrence of both these events was greater than the probability to be expected if they occurred independently, i.e.:

P(symptoms of childbed fever in the First Maternity Division & symptoms of Kolletschka's disease) > *P*(symptoms of childbed fever in the First Maternity Division) × *P*(symptoms of Kolletschka's disease)

Furthermore, Semmelweis was faced with EIP_{COR}, since any of the theories that had explained childbed fever before and during Semmelweis' time failed to explain this specific correlation. For example, a popular in Semmelweis' time theory which explained a childbed fever by postulating some 'atmospheric-cosmic-telluric changes', though providing a plausible explanation for the disease of women in the First Maternity Division, was unable to explain Kolletschka's disease.

The question that arises in cases like Semmelweis' one is whether one can find an interesting inferential rule that enables us to make rational causal abductive explanations for explanatory targets like the surprising correlations of events. In other words, one can ask: Is there a kind of *logica docens* for abduction that aims to explain such correlations? In the next section, I shall propose an inferential rule for such abduction, namely Reichenbach's Principle of the Common Cause.

3. THE PRINCIPLE OF THE COMMON CAUSE AND COMMON CAUSE ABDUCTION

3.1. The Principle of the Common Cause

In his ground-breaking *The Direction of Time*, Hans Reichenbach proposed a principle which governs non-deductive inferences from observed correlated effects to an unobserved cause. He dubbed this principle *the principle of the common cause*

(PCC). Vaguely stated, PCC states that if there is a correlation between events *A* and *B* and a direct causal connection between the correlated events is excluded, then there exists a common cause of this correlation. Consider one of Reichenbach's examples:

> Or suppose several actors in a stage play fall ill, showing symptoms of food poisoning. We assume that the poisoned food stems from the same source — for instance, that it was contained in a common meal — and thus look for an explanation of the coincidence in terms of a common cause. There is also a common effect of the simultaneous illness of the actors: the show must be called off, since replacements for so many are not available. But this common effect does not explain the coincidence. (Reichenbach 1956, p. 157)

Reichenbach was not the only one who discovered the importance of explanations in terms of the common cause. Before Reichenbach, also I. Newton and B. Russell noted the significance of common cause explanations.[10] But unlike Newton and Russell, Reichenbach proposed a precise analysis of PCC in terms of the probabilistic relationships that obtain among a postulated common cause and its joint effects.

Reichenbach's definition of PPC may be presented as follows:

Definition 3.1.1. (*Reichenbach's* PCC) If the events *A* and *B* are (positively) correlated, i.e., if

(1) $P(A\&B) > P(A) \times P(B)$

then there exists a common cause *C* for these events such that the triplet of events *A*, *B* and *C* forms a conjunctive fork *ACB* (Figure 1), i.e., the triplet of events satisfies the following conditions:

(2) $P(A|C) > P(\mathrm{A}|\text{not-}C)$
(3) $P(B|C) > P(\mathrm{B}|\text{not-}C)$
(4) $P(A\&B|C) = P(A|C) \times P(B|C)$
(5) $P(A\&B|\text{not-}C) = P(A|\text{not-}C) \times P(B|\text{not-}C)$

[10] In his *Principia* Newton described one of his rules of philosophy as follows: '*Therefore to the same natural effects we must, as far as possible, assign the same causes*. As to respiration in a man and in a beast, the descent of stones in Europe and in America, the light of culinary fire and of the sun, the reflection of light in the earth and in the planets' (Newton 1962, p. 398). Russell in his *Human Knowledge* wrote: 'A group of individuals simultaneously have very similar visual experiences. It is possible that each individual, independently, is hallucinating, or that the individuals happen to be looking at distinct, though similar, physical objects. But given the similarity of the experiences, it is more plausible to think that they trace back to a common cause—the individuals are all perceiving a single physical object' (Russell 1948, p. 480).

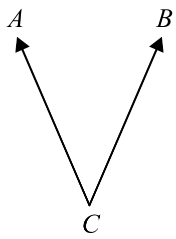

Figure 1. The conjunctive fork *ACB*

Reichenbach showed that the conditions (2)-(5) taken together imply the condition (1), i.e.:

Theorem 3.1.2. (*Reichenbach's Theorem*) Conditions (2)-(5) imply the condition (1) which means that if events *A*, *B* and *C* are such that they satisfy conditions (2)-(5), then there exists a positive correlation between *A* and *B* defined by condition (1).

Reichenbach's theorem says that if a cause *C* is positively correlated with event *A* and event *B* (conditions 2-3), and if this cause *C* makes them conditionally probabilistic independent (conditions 3-4), then postulating *C* implies that the two events will be correlated (condition 1). The essential part of Reichenbachian PCC consists of the conditions (4) and (5). They express what Reichenbach called the *screening-off* property of a common cause:

Definition 3.1.3. (*Screening-off Common Cause*) A common cause *C* (and also not-*C*) does screen-off the correlation of events *A* and *B* if it renders the two events *A* and *B* probabilistically independent, i.e., conditionalizing the joint probability *A* and *B* upon *C* (or not-*C*) transforms the probabilistic dependence of correlates into their probabilistic independence.

One may think of the screening-off property as follows. Take the case where *C* does screen-off the correlation. Then, one can rewrite the condition (4) as follows:

(6) $P(A|B\&C) = P(A|C)$
(7) $P(B|A\&C) = P(B|C)$

These conditions may be interpreted as saying that if one knows the cause *C*, then this suffices to predict the probability of event *A* (or *B*), and the additional information about the probability of *B* (or *A*) is irrelevant for predicting this probability. Take Reichenbach's example of actors becoming sick. When we say that the actors' states of health are positively correlated we say that one actor's state of health is a very good basis for predicting the state of the other actor. Also, when we know whether actors' shared food is poisoned or not, i.e., whether we know the common cause, this helps us predict whether a given actor is sick. Postulating a screening-off common cause in this example means that if we know whether the shared food was poisoned or not, then knowledge about one actors' state of health provides no additional predictive help for saying what is the state of health of the other actor (Sober 1988). So, *prima facie* surprisingly, the screening-off common cause for a correlation of events transforms the probabilistic dependence of correlates into their probabilistic independence, i.e., it makes the correlates uncorrelated. For Reichenbach the screening-off property is an explanatory virtue by which a common cause explanation should be adopted as a legitimate guide for making non-deductive inferences. To see why the screening-off mechanism of PCC is explanatorily valuable, consider W. Salmon's example (Salmon 1978, pp. 691-692). Suppose there are two brothers who suffer from a colour-blindness. Let *A* indicate that brother *A* has a colour-blindness and let *B* stand for *B*'s colour-blindness. There is a positive correlation between *A* and *B*. Let *C* stand for a common cause for this correlation, say a genetic factor carried by the mother. If *C* satisfies the screening-off conditions, then it follows that knowing just the genetic factor present in the mother suffices to explain the colour-blindness of each one separately; the correlation between them is no more explanatory relevant. It is very intuitive because the inheritance between the mother and a son should depend upon the genetic relationship between them and not upon such relationship between her and the other son.

3.2. Ontological vs. Epistemological Interpretation of the Principle of the Common Cause

Reichenbach's PCC may be interpreted at least in two different ways (Sober 1988). First, it can be interpreted *ontologically* as saying that for every pair of correlated events there *exists* an event — their screening-off common cause. This ontological interpretation has been endorsed especially by Salmon who used PCC to argue for scientific realism. Salmon argued that scientific explanation based on PCC can lead to postulating the existence of unobservable events in cases where it is hard to find common causes among the observables (Salmon 1984). Not only does the ontological interpretation of PCC face serious problems with respect to EPR phenomena in the area of quantum mechanics (van Fraassen 1982), but also it makes abduction based on PCC susceptible to scientific realism; this is, however, highly controversial, since abduction was supposed to be a general methodological device independent of the realism/empiricism controversy.

A more promising reading of PCC is *epistemological*. On this interpretation, PCC states that for every pair of correlated events, it is *reasonable to believe* that a screening-off common cause hypothesis is true. This interpretation has the advantage that it is not undermined by examples like EPR phenomena in quantum mechanics; such examples show only that PCC as an epistemologically interpreted inferential mechanism is not universally valid. A second advantage is that the epistemological interpretation of PCC is immune to the realism/empiricism controversy, at least if this controversy is about the existence of unobservables. The epistemological PCC is not a claim about the existence of observable or unobservable causes; it is a claim about a reasonable causal *explanans*.

3.3. Common Cause Abduction

For Reichenbach, PCC was primarily a tool for resolving the problem of the direction of time. According to Reichenbach, PCC establishes a temporal asymmetry, since conjunctive forks point towards the future and cannot point towards the past (Reichenbach 1956, pp. 162-163). Other words, whenever a conjunctive fork exists, an event C (a common cause) occurs before the events A and B, and never after these events. PCC, however, is not limited only to providing a tool for resolving the problem of the 'arrow of time'. Also, it may be treated as a general inferential mechanism for non-deductive inferences, especially when it is interpreted epistemologically. In particular, PCC provides an inferential rule for the explanatory abduction that aims to explain the correlation of events. Let me call the explanatory abduction for a correlation of events based on PCC the *common cause abduction* (CCA). In general, CCA is a solution to $\mathrm{EIP}_{\mathrm{COR}}$. The schema of CCA may be presented as follows:

Definition 3.3.1. (*Common Cause Abduction*) Let E_{COR} be an agent's cognitive target concerning an explanation of a surprising correlation of events, R be the attainment relation on E_{COR}, K is the agent's knowledge base, K^* is a closely accessible successor of K, R^{pres} is the presumptive attainment relation on E_{COR}, H_{CC} is a screening-off common cause hypothesis that explains the correlation, $K(H_{CC})$ is a knowledge base revised by H_{CC}, H_{SC} is a hypothesis that postulates separate causes for the correlation of events (hereafter, separate cause hypothesis), $C(H_{CC})$ is a conjecture that H_{CC}, and H_{CC}^{C} is a discharge of H_{CC}. Then the schema for CCA runs as follows:

1. E_{COR}! [declaration of E_{COR}]
2. $\neg(R(K, E_{COR}))$ [fact]
3. $\neg(R(K^*, E_{COR}))$ [fact]
4. $R^{pres}(K(H_{CC}), E_{COR})$ [fact]
5. H_{CC} is more plausible than H_{SC}
6. Therefore, $C(H_{CC})$ [conclusion]
7. Therefore, H_{CC}^{C} [conclusion]

This schema for CCA incorporates three essential steps of abduction described in Peirce's theses. First, the *creative* part consists in generating a hypothesis that postulates a screening-off common cause for the correlation of events. Second, the *selective* part says that this common cause hypothesis is more plausible than a competing separate cause hypothesis. Notice that the selective part is designed to be contrastive.[11] CCA aims to infer that H_{CC} is more plausible than H_{SC} from the fact that it is a better explanation than H_{SC}. It is important to bear in mind that it does not test H_{CC} against other alternatives like, e.g., $(\neg H_{CC} \wedge \neg H_{SC})$ a *catch-all* hypothesis which says that none of the competing hypotheses explain E_{COR}. And third, the *conjectural* part states that the common cause abductive hypothesis is to be conjectured as an explanation on the basis that it is more plausible than the separate cause one.

So far, so good. The question, however, arises: why does common cause abductive hypothesis appear to be more plausible than the separate cause one? The schema for CCA does not itself provide a justification of why one should prefer a common cause abductive hypothesis over a separate cause abductive hypothesis.

4. JUSTIFYING COMMON CAUSE ABDUCTION

In this section, I shall present three arguments that may be proposed in support of the thesis than common cause abductive hypothesis should be regarded as more plausible than the separate cause abductive hypothesis. Call the first of them the *argument from screening-off*, the second the *argument from likelihood*, and the third the *argument from simplicity*.

4.1. The Argument from Screening-off

The argument from the screening-off says that for the reason that the common cause abductive hypothesis has the screening-off property, and thereby it renders the correlates probabilistically independent by making the correlation less of a surprise, it is more plausible than the separate cause abductive hypothesis which lacks the screening-of property. Here, the presupposition is that making an *explanadum* less of a surprise counts in favour of a hypothesis's plausibility. This finds a support in the following passage from Peirce:

> …What is good abduction? What should an explanatory hypothesis be to be worthy to rank as a hypothesis? Of course, it must explain the facts. But what other conditions ought it to fulfil to be good? The question of the goodness of anything is whether that thing fulfils its end. What, then, is the end of an explanatory hypothesis? Its end is, through subjection to the test of experiment, to *lead to the avoidance of all surprise* … (Peirce 1931-1958, CP 5.198)

The argument from screening-off has the following structure:

1. If hypothesis H_1 makes the surprising correlation less of a surprise, and H_2 does not, then H_1 is more plausible than H_2 (premise)
2. If a hypothesis is a screening-off hypothesis, then it makes the surprising correlation less of a surprise (premise)

[11] Here, the common cause and the separate cause hypotheses are understood as *types* of hypotheses.

3. If a hypothesis is not a screening-off hypothesis, it does not make the surprising correlation less of a surprise
4. Common cause abductive hypothesis is a screening-off hypothesis (premise)
5. Separate cause abductive hypothesis lacks the screening-off property (premise)
6. Common cause abductive hypothesis makes the surprising correlation less of a surprise (conclusion by modus ponens from 2 and 4)
7. Separate cause abductive hypothesis does not make the surprising correlation less of a surprise (conclusion by modus ponens from 3 and 5)
8. Common cause abductive hypothesis is more plausible than the separate cause abductive hypothesis (conclusion by modus ponens from 1, 6, and 7).

To give a picture of how this argument works, recall Semmelweis' case. As an explanation of the surprising correlation between the symptoms of childbed fever in the First Maternity Division and the symptoms of Kolletschka's disease, Semmelweis proposed a common cause hypothesis. He conjectured that both symptoms were due to 'cadaveric matter' that was brought by doctors and students into mothers' blood during medical research and that was brought into Kolletschka's blood stream while his finger has been punctured during the autopsy he was performing. Semmelweis' common cause hypothesis was abductive, since the germ theory it presupposed was not known earlier. The common cause explanation proposed by Semmelweis has the screening-off property: knowing just the 'cadaveric matter' common cause suffices to predict the probability of contracting childbed fever; information about Kolletschka's disease is irrelevant (or knowing just the cadaveric matter common cause suffices to predict the probability of Kolletschka's disease; information about childbed fever is irrelevant). Therefore, Semmelweis' 'cadaveric matter' hypothesis makes the correlation less of a surprise; by making the correlates probabilistically independent it makes the correlation no longer relevant to the explanation of the occurrence of both correlates. Consider, now, a possible separate cause abductive hypothesis, say the hypothesis which says that Kolletschka's disease was due to 'cadaveric matter' which was brought into his blood stream while his finger has been punctured during the autopsy he was performing, and that the symptoms of childbed fever in the First Maternity Division were caused by something else. This hypothesis does not make the correlation less of a surprise; we still cannot explain and we are puzzled why such correlation occurred. In such a case, the argument from screening-off allows us to say that the common cause abductive hypothesis is more plausible than the separate cause one.

4.2. The Argument from Likelihood

Sometimes it is said that a hypothesis's plausibility is due to its explanatory power; an explanatory powerful hypothesis provides a better understanding of evidence, data, phenomena, etc. However, the notion of explanatory power is vague and cries out for an explanation. A very promising account of hypothesis's explanatory power comes from the *likelihood* paradigm in the philosophy of statistical inference.[12] Its main idea is that if we want to assess a hypothesis's plausibility we may be interested how probable the hypothesis makes an *explanandum* (observations, evidence, events, facts, correlations). This value of hypothesis is its *likelihood*. The likelihood of a hypothesis H is the probability it confers on the evidence E, and it is represented as $P(E|H)$; it is not the probability the evidence E confers on the hypothesis H which is denoted as $P(H|E)$.[13] So, a hypothesis may be more plausible than its rival, since it has the higher likelihood, i.e., it makes evidence E more probable that its rival. Intuitively, a hypothesis which says that the evidence was to be expected is more likely than the hypothesis which says that this evidence was hardly to be expected. The idea of likelihood operates in an important way in the philosophy of statistical inference called *Likelihoodism*. Likelihoodism sets up the question about the relation between evidence and a hypothesis as follows: what does evidence tell us about one hypothesis's plausibility versus the other? It answers this question by means of the Law of Likelihood (Hacking 1965; Edwards 1992):

Definition 4.2.1. (*The Law of Likelihood*) The evidence E favours H_1 over H_2 iff $P(E|H_1) > P(E|H_2)$. The degree to which E favours H_1 over H_2 is given by the likelihood ratio $P(E|H_1)/P(E|H_2)$.

The Law of Likelihood is the law of favouring one hypothesis over the other. A likelihoodist wants to know what evidence says about the competition between these hypotheses using only information about how probable these hypotheses make this evidence.

It is a remarkable fact that Peirce saw the idea of likelihood as a serious criterion for the assessment of an abductive hypothesis's plausibility:

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[12] The concept of likelihood has been introduced by the statistician R. Fisher (1956). It is important to notice that the likelihood of a proposition differs from the probability of a proposition. For example, whereas the probability of a proposition and its negation sum to one, the likelihood of a proposition and its negation can be less or more than 1.

[13] The confusion of the likelihood of a hypothesis H, given evidence E, with the probability of the same hypothesis, given the same evidence is known as the *fallacy of the transposed conditional* (Diaconis and Freedman 1981). The fallacy occurs, roughly, when from the fact that if A has occurred, then B occurs with a high probability, it is erroneously concluded that if B has occurred, then A occurs with the high probability. Consider an example: Someone has seen Mr Smith running away from the house where a crime has been committed. Let E be the proposition 'Mr Smith was running away from the scene of the crime at the time when it was committed', and H the hypothesis 'Mr Smith committed the crime'. One may reasonably believe that the likelihood $P(E|H)$ is high, but not necessarily $P(H|E)$ is high as well. If Mr Smith actually committed the crime, it is likely that he would want to run away from the scene of the crime; H is a good explanation of the evidence. However, the fact that he was running away from the house does not, by itself, make it very probable that he committed the crime; there are many other possible explanations of that fact.

> The explanation must be such a proposition as would lead to the prediction of the observed facts, either as necessary consequences or at least as very probable under the circumstances. A hypothesis then has to be adopted which is likely in itself and renders the facts likely (…) (Peirce 1931-1958, CP 7.202)

How does the idea of likelihood in the framework of the Law of Likelihood enter into the assessment of a common cause abductive hypothesis's plausibility? On this model, one asks whether a surprising correlation of events favours the common cause abductive hypothesis over the separate cause one. In answering this question one takes into account how probable these hypotheses make the *explanandum* correlation. In Semmelweis' case, the abductive explanation that postulates 'cadaveric matter' as a common cause for the correlation between the symptoms of childbed fever and Kolletschka's disease makes this correlation more likely than the hypothesis that postulates separate causes; although some separate causes can make each correlate very probable, they make the whole correlation to be hardly expected. And since the likelihood covers a hypothesis' plausibility, the 'cadaveric matter' common cause abductive hypothesis is more plausible than the separate cause one.

4.3. The Argument from Simplicity

Philosophers of science often claim that the simplicity (or parsimony) considerations matter to the epistemic value of a hypothesis, i.e., to its plausibility. On this view, simplicity is not just a pragmatic or aesthetic value of the hypothesis, but it plays a substantial role in determining the hypothesis's plausibility. The idea is that choosing the simple hypothesis means regarding it as more plausible than its more complex rival (see, e.g., Reichenbach 1938; Popper 1959; Forster and Sober 1994).

The idea of parsimony can be used in many different ways of which Ockham's razor is perhaps the most representative.[14] Roughly speaking, Ockham's dictum says that entities should not be postulated without necessity (*entia non sunt multiplicanda praeter necessitatem*). So, if a common cause abductive hypothesis explains the correlation of events by postulating just one cause while the separate cause abductive hypothesis does the same but by postulating two causes, it is the former that is simpler. And, if the common cause abductive hypothesis is simpler that the separate cause one, then it is more plausible, since hypotheses than are simpler are more plausible. This conclusion finds an attractive support in the theory of probability. The axioms of probability guarantee that if A and B are mutually independent causes, then the occurrence of the conjunction of A and B is less probable than the occurrence of A. And, if probability covers plausibility, we may say that the occurrence of a simple cause (A) is more plausible the occurrence of the more complex cause (the conjunction of A and B).

[14] For an excellent survey of different uses of the idea of simplicity, see Sober 1981.

Do these three arguments in support of the common cause abduction ensure that the common cause abductive hypothesis is always more plausible than a separate cause abductive hypothesis? In the next section, I shall argue that they don't.

5. DEFEASIBILITY OF COMMON CAUSE ABDUCTION

The argument from screening-off is susceptible to the following counterexample. Not only do common causes screen-off, there are separate causes that screen-off as well. Consider the case of the correlated separate causes (Sober 1988). Suppose that two separate causes Csc_1 and Csc_2 are perfectly correlated, i.e., $P(Csc_1 \& Csc_2) > P(Csc_1) \times P(Csc_2)$. This suffices to show that such separate causes may screen-off one correlate from the other just like common cause would do. The correlated separate causes satisfy Reichenbachian screening-off conditions:

Proposition 5.1. (Reichenbachian Screening-off Conditions for Correlated Separate Causes) If two separate causes Csc_1 and Csc_2 are perfectly correlated, i.e., $\mathrm{P}(\mathrm{Csc}_1 \& \mathrm{Csc}_2) > \mathrm{P}(\mathrm{Csc}_1) \times \mathrm{P}(\mathrm{Csc}_2)$, then
(1) $P(A\&B|\mathrm{Csc}_1 \& \mathrm{Csc}_2) = P(A|Csc_1 \& \mathrm{Csc}_2) \times P(B|Csc_1 \& Csc_2)$
(2) $P(A\&B|\text{not-}(Csc_1 \& Csc_2)) = P(A|\text{not-}(Csc_1 \& Csc_2)) \times P(B|\text{not-}(Csc_1 \& Csc_2))$

So, postulating an explanation in terms of the correlated separate causes suffices to show that conditionalizing on their occurrence or non-occurrence makes the correlation probabilistically independent. Therefore, the screening-off justification is not a sufficient rationale for favouring a common cause abductive hypothesis over a separate cause one. Moreover, there are cases in which a common cause hypothesis may lack screening-off property, and still it would be regarded as plausible. To illustrate this point, let me change Semmelweis' case in a way that shows that a common cause 'cadaveric' common cause abductive hypothesis is plausible even if it does not screen-off.

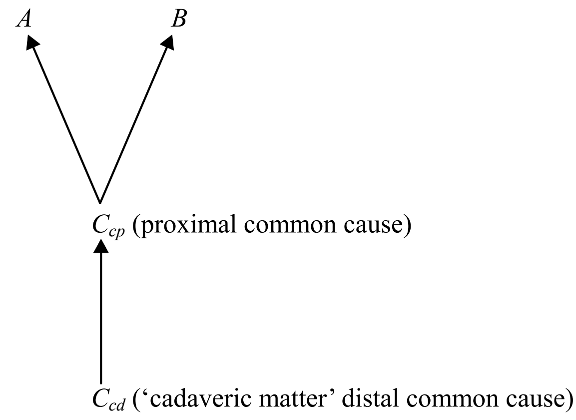

Figure 2. Proximal and distal common cause

Suppose that Semmelweis' 'cadaveric' common cause is a distal cause of the correlation, and the common cause that says that the correlation is caused by the infection of the blood system is a proximal cause of the correlation (Figure 2). Suppose, further, that the proximal cause screens-off one correlate from the other, and that it screens-off the distal cause from both correlates. It follows, then, that the distal 'cadaveric matter' common cause does not screen-off the correlates from each other. Since the proximal cause, perhaps a very peculiar infection of the blood, makes a difference in the probability of the occurrence of both correlates, it is not sufficient to know just the distal common cause to predict the probability of the occurrence of each of the correlates. Can we say that such a non-screening-off 'cadaveric matter' common cause abductive hypothesis is less plausible than the separate cause one? Here, it seems that the non-screening-off 'cadaveric matter' common cause hypothesis may still be judged as plausible even if it lacks the screening-off feature.

To see why the argument from likelihood is defeasible, consider the Bayesian analysis of hypotheses' plausibility. Bayesianism models statistical inference by using Bayes' theorem. To introduce Bayes' theorem, assume that $P(H)$ is the *prior probability*[15] of a hypothesis H, i.e., the probability that H has before new observation or new evidence E, $P(H|E)$ is the *posterior probability* of the hypothesis H, i.e., probability that H has in the light of the evidence E, $P(E)$ is the probability of evidence E and $P(E|H)$ is the *likelihood* of H, i.e., the probability that H confers on E. Then, Bayes' theorem may be presented as follows:

Definition 5.2. (*Bayes' Theorem*) $\mathrm{P(H|E)} = \dfrac{P(E|H) \times P(H)}{P(E)}$, provided $P(E) > 0$.

Bayes' theorem may be also stated in a way that enables us to compare hypotheses' plausibility. If H_1 and H_2 are competing hypotheses, the Bayesian assessment of their posterior probability is given by:

(*Comparative Bayesianism*) $P(H_1|E) > P(H_2|E)$ iff $P(E|H_1) \times P(H_1) > P(E|H_2) \times P(H_2)$

Bayesians say that, in the light of evidence E, the hypothesis H_1 is more probable than H_2 iff the product of H_1's likelihood and prior probability is greater than the product of H_2's likelihood and prior probability. The idea of likelihood is, however, decisive. If after observing evidence E, the likelihoods of H_1 and H_2 are the same, their posterior probabilities will be equal to their prior probabilities. If, on the other hand, evidence makes a difference in their likelihoods, then their posterior probabilities would be different from the priors. But, is really likelihood the whole story that could be said about a hypothesis's plausibility? Bayesianism maintains that, besides a hypothesis's likelihood, one also should care about a hypothesis's prior probability. This idea is very intuitive, since the question of how probable a hypothesis makes

[15] Notice that 'prior' here does not mean *a priori*, i.e., independent from an empirical input; it means 'before empirical input comes'.

evidence (the likelihood) is different form the question of how probable this hypothesis is; it might occur that the hypothesis with the high likelihood is very improbable. Bayesians argue that likelihood is not a hypothesis's overall plausibility; to count as a hypothesis's overall plausibility, the likelihood must be conjoined with the hypothesis's prior probability. To see why the argument from likelihood may fail to justify common cause abductive hypothesis, consider Sober's brilliant example of Venetian sea levels and British bread prices (Sober 1988; Sober 2001). Suppose that sea levels in Venice and bread prices in Britain have monotonically increased in the past eight years. You have made the data set (Figure 3) in which you have specified in some unit, for each of the eight years, the average Venetian sea levels and the average British bread prices.

Year	Venetian Sea Levels	British Bread Prices
8	31	20
7	30	19
6	29	15
5	28	14
4	25	10
3	24	6
2	23	5
1	22	4

Figure 3. The average Venetian sea levels and the average British bread prices (Sober 2001)

As a result, you observe that higher than average sea levels are correlated with higher than average bread prices:

P(higher than average sea level in year *i* & higher than average bread prices in year *i*) > *P*(higher than average sea level in year *i*) × (higher than average bread prices in year *i*)

This is true, since both Venetian sea levels and British bread prices have above average sea levels and bread prices exactly half of the years (years 5-8). So, the probability that both sea levels and bread prices are above the average is 0.5, which is greater than the product of the probability that sea levels are above the average and the probability that bread prices are above the average (0.5 > 0.5 × 0.5). Suppose this correlation forms an explanatory ignorance problem EIP_{COR}. As a response, you may use CCA to account for E_{COR}. But, intuitively, given your background knowledge base *K*, you are not inclined to say that the common cause explanation for this correlation is more plausible than the separate cause explanation. Your background knowledge *K* tells you that you cannot rule out the possibility that the increase of sea levels and bread prices is due to two separate causes, say local weather conditions in Venice and local economic conditions in Britain. So, one my say that both the common cause and separate cause hypotheses are not so sharply different in their likelihoods; both could make the correlation very likely. But given also your background knowledge, these hypotheses may differ sharply in their overall plausibility. In the Bayesian framework, this difference may be embodied in extremely different prior probabilities for these hypotheses. And, if two hypotheses have the same likelihoods, then the hypothesis which has the higher prior probability is overall more plausible. So, if the separate cause abductive hypothesis for the correlation of Venice sea levels and British bread prices has, in the light of our background knowledge, the higher prior probability than the common cause one, it is overall more plausible, i.e., it is more plausible given the likelihood and prior probability. Therefore, in cases like that CCA might be defeasible.

Finally, the argument from simplicity rests on a very puzzling idea that the simplicity of a common cause abductive hypothesis matters to its plausibility. For example, Peirce saw the importance of simplicity considerations in determining the choice of an abductive hypothesis, but he was not convinced whether they support a hypothesis's plausibility. He maintained that simpler hypotheses contain fewer concepts, and that they are the most "instinctive" or "natural", at best (Peirce 1931-1958, CP 2.740, CP 6.477). But, even if simplicity matters to a common cause abductive hypothesis's plausibility, it is not clear how it does. It would be odd to claim that, although a common cause abductive hypothesis has the lower likelihood, but is simpler than a separate cause hypothesis, it is overall more plausible. My conjecture is that simplicity considerations should be subsidiary, at best. They should be taken into account in determining a hypothesis' plausibility only when other more essential factors like explanatory power or likelihood do not provide a sufficient basis for preferring one hypothesis over the other. Therefore, the argument from simplicity cannot alone provide a sufficient rationale for common cause abduction.

Although all of the above arguments are defeasible, it is important to realise that they fail in an instructive way: they fail because common cause abduction is intrinsically ampliative, non-demonstrative, and non-monotonic. But, even if Reichenbachian principle of the common cause governs abduction in a fallible way, it does not follow that this way is unreasonable. Beware: defeasibility does not imply irrationality.

6. HOW TO USE COMMON CAUSE ABDUCTION IN A REASONABLE WAY?

The fact that common cause abduction is a defeasible reasoning does not provide a sufficient reason for claiming that it is an irrational method of reasoning. By analogy, the fact that inductive reasoning is governed in a defeasible way, does not give scientists a reason to abandon the whole inductive practice. But, in order to use common cause abduction in a reasonable manner, we have to be aware of its limits. In particular, we have to be aware of the factors that should be taken into account when we decide to prefer the common cause abductive hypothesis over the separate cause one. Of course, it is not possible to define the complete list of factors that should be taken into account. Nevertheless, some general remarks can be formulated.

First, it is important to keep in mind that the overall plausibility of a common cause abductive hypothesis is sensitive to the informational content of one's background knowledge. This is a consequence of the more general idea that there is no assessment of plausibility, except in the light of background knowledge (Sober 1988). So, for example, our decision to prefer a common cause abductive hypothesis just on the basis that it has the high likelihood cannot be rational. Something more is required. We have to know that the assessment of its likelihood is done in the light of background knowledge. This idea operates in an important way in Bayesianism. This philosophy of statistical inference teaches us that a common cause abductive hypothesis's likelihood taken in insolation to one's background knowledge does not suffice to capture a hypothesis' overall plausibility. A hypothesis's likelihood should be conjoined with one's background knowledge which Bayesians represent by the idea of prior probability. As it has been indicated in the discussion of Sober's example of Venetian sea levels and British bread prices, common cause abductive hypotheses may have the high likelihood and, at the same time, they may be very improbable (have the low prior probability). This may be true of the majority of common cause abductive hypotheses since, as it has been pointed out at the beginning of the article, abductive hypotheses as being highly conjectural introduce new information to our background knowledge. It might even occur that they are inconsistent with our background knowledge (see, e.g., Carnielli 2006). Such abductive hypotheses then will have relatively low prior probabilities. In the light of this, it is rational to claim that both likelihood and prior probability of a hypothesis, which captures the assessment of a hypothesis' plausibility in the light of background knowledge, should contribute to a hypothesis overall plausibility. The role of a prior probability is crucial. When hypotheses have the same likelihood or when they differ slightly in their likelihoods, e.g., they both make the correlation very probable, then their prior probabilities will be decisive to the question of which one of the hypotheses is overall more plausible.

Second, it is important to recognize that some factors taken in favour of a common cause hypothesis do not contribute to its overall plausibility in a primary way. Take again the picture of scientific inference proposed by Bayesians. It is important to note that Bayesian prior probabilities can play many functions; they are not only restricted to represent the informational content of one's background knowledge. Prior probabilities may also reflect a hypothesis's simplicity (or parsimony). Now, suppose that both common cause and separate cause abductive hypothesis have the same likelihood, and further that the informational content of background knowledge does not discriminate between these two hypotheses. In such cases simplicity may be decisive. It may be reflected in the prior probabilities of these hypotheses; a common cause abductive hypothesis will have the higher prior probability, since it is more parsimonious. Moreover, if simplicity influences a hypothesis's plausibility, then a common cause abductive hypothesis may be judged as more plausible than the separate cause one, even if both are equally likely. But this works only if simplicity is taken as a subsidiary reason in favour of one of the hypotheses in cases when the hypotheses at hand are equally likely. We are not justified in general to take simplicity as a primary reason for a hypothesis' plausibility, since we are not sure whether simplicity necessarily contributes to its plausibility. As long as we are Bayesians, we may rationally argue that a common cause abductive hypothesis's simplicity contributes to its overall plausibility *via* prior probabilities. But, if we change the framework from Bayesianism to the other one, say to Likelihoodism, it is no more clear how simplicity enters into the assessment of a hypothesis's plausibility.

7. CONCLUDING REMARKS

In commenting Peirce's concept of abduction, J. Hintikka emphasized:

> It is sometimes said that the highest philosophical gift is to invent important new philosophical problems. If so, Peirce is a major star on the firmament of philosophy. By thrusting the notion of abduction to the forefront of philosophers' consciousness he created a problem which — I will argue — is the central one in contemporary epistemology. (Hintikka 1998, p. 503)

This article has tried to tackle Peirce's problematic concept of abduction from the perspective of the local strategy. It has been argued that an explanatory abduction for the correlation of events is not an act of mere guessing, but it can be regarded as a powerful inferential mechanism when governed by Reichenbachian principle of the common cause. The basic picture this article has tried to develop is that common cause abduction leads to the acceptance of the screening-off common cause abductive hypothesis that explains a surprising correlation of events better than the separate cause hypothesis. Based on the idea of likelihood, it has been argued that a common cause abductive hypothesis which makes the correlation at hand less of a surprise has the higher likelihood. Also, it has been claimed that common cause abductive hypotheses are more plausible then the separate cause ones since the former are simpler than the latter. Further, it has been shown that screening-off, likelihood and simplicity arguments for CCA have their limits. Finally, it has been claimed that even if Reichenbachian principle of the common cause governs abduction in a fallible way, it does not follow that this way is unreasonable.

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