Hume's Analysis of Causality: Its Limitations and Implications

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We give a brief introduction of Hume's epistemology and his penetrating analysis of causality. It is pointed out that there are some flaws in his epistemology and his theory of causation. Alternative theories of causation are then briefly introduced. Partly inspired by Hume's analysis of necessary connexion, we present a new argument of causation. We argue that Hume's removing necessary connexion from causality can help to provide a promising way to unify the law of causality and indeterminism. We then propose a generalized principle of causality, according to which there are two kinds of causes: concrete causes and universal causes, and correspondingly there are two kinds of effects: lawful events and random events. Each actual effect is composed of both lawful element and random element. A detailed analysis of the motion of objects is also given to support the new principle.

1. Introduction

David Hume (1711-1776) is generally regarded as the most important philosopher ever to write in English and the last of the great triumvirate of "British empiricists". His major philosophical works -- A Treatise of Human Nature (1739), the Enquiries concerning Human Understanding (1748) -- remain widely and deeply influential. Hume challenged traditional philosophical beliefs in ways that shocked the readers of his day and have demanded the attention of philosophers ever since [1]. Several classic philosophical problems are now permanently associated with his name: the analysis of causality, the problem of induction, and the problem of personal identity. In this essay we will mainly discuss Hume's analysis of causality and its limitations and implications.

[1] For example, Hume greatly influenced Kant. Kant confessed that "the suggestion of David Hume was the very thing, which many years ago interrupted my dogmatic slumbers and give me investigations in the field of speculative philosophy quite a new direction." For some discussions of Kant and Hume, see Beck (1978) and Kuehn (1983).

The idea of causality is among the most familiar that we possess; it is involved in every exercise of human reasoning, and is presupposed in every form of argument and by every practical action. As thus, causality has been an important concept in philosophy generally and in the philosophy of science since the time of the ancient Greeks. Hume calls causality “the cement of the universe” -- implying that it holds everything together. Understanding what causes are helps us to understand how minds might (or might not) relate to bodies, how free will might (or might not) work, how ideas might (or might not) influence action, and how bodies might come to produce changes in other bodies.

As a matter of fact, all mankind by nature attributes to certain phenomena a causative action upon others. This natural attribution of the relationship of cause and effect to phenomena is anterior to all philosophical statement and analysis. Objects of sense are grouped roughly into two classes -- those that act and those that are acted upon. No necessarily conscious reflection seems to enter into the judgment that partitions natural things into causes and effects. But when we proceed to ask ourselves precisely what we mean when we say, for example, that A is cause and B effect, that A causes B, or that B is the result of A, we raise the question of causality. Whatever answer we put forward, it will be the statement of our conception of causation. However, when we attempt to formulate a satisfying answer to the question in philosophy, much more will be involved than we had at first sight thought.

Some philosophers before Hume regarded propositions about causation as necessary truths, capable of being known *a priori*. Such philosophers claimed to know not only that everything has a cause, but, in particular cases that that this will cause that, or that this was caused by that. The realm of causality and the realm of logic are conflated or run together. Thus a philosopher like Spinoza thought of metaphysics as a deductive account of the universe to be developed from a few definitions -- particularly that of substance as something that requires nothing outside itself to be or to be conceived, along with a number of self-evident assumptions (Curley 1985). So, the old account of causality had these features:

1. Propositions about causation are necessary truths.
2. Propositions about particular causes can be known a priori or prior to experience.

3. Propositions about particular causes involve logical as well as causal connections.
4. Because of the nature of causality, rationalist metaphysics of the kind practiced by Spinoza is possible.

The figure of Hume looms large in the philosophical analysis of causality. His two famous analyses, of human apprehension and of causality, were the most penetrating up to his time, and continue to have great influence. As the culmination of British empiricism, Hume's work is especially significant because he realized the importance of analyzing human apprehension both as a step in the development of a comprehensive philosophy, and in connection with the problem of causality. By Hume's time, causality had shifted from being primarily about things in the world, to being the way of guaranteeing the veracity of our perception of it. As a result, any attack on the principle of causality would inevitably have grave repercussions for knowledge about the world. There are thus two important aspects of Hume's analysis of causality: (a) the nature of causality as constant conjunction of disparate ideas; (b) the skeptical conclusions about our knowledge of the world following from this. In order to analyze Hume's analysis of causality, we need to first understand his epistemology.

2. Hume's epistemology

Epistemology is a field of philosophy that concerns itself with the nature and process of how knowledge is acquired (see, e.g., Miller 1992). Ever since philosophy was practiced by the pre-Socratics in ancient Greece, there has been an intellectual enterprise to discover how human beings come to know certain things whether they be material objects (such as the world), abstract objects (such as universals), or interactions (such as causal relationships) (Allen 1991). The philosophical subjects of epistemology would be very different than they are today if there had been no Hume. Hume developed epistemology more fully by applying the scientific methods of observation to a study of human nature itself. His goal was to establish "a science of human nature" that will put philosophy on a "solid foundation" of "experience and observation" (T, Introduction).

2.1 The copy principle

Hume's analysis of human knowledge begins with a careful distinction among our perecptions: impressions are the direct, vivid, and forceful products of immediate experience; ideas are merely feeble copies of these original impressions (E, II). Complex ideas are composed of simple ideas. For example, the background color of the screen at which I am now looking is an impression, while my memory of it is an idea. Hume offers this "general proposition" as his "first principle...in the science of human nature" (T, 7), which has become known as the "copy principle". Note that Hume presents the copy principle as an empirical thesis. He emphasizes this point by offering, in both the Treatise and the first Enquiry, as an empirical counterexample to the principle, "one contradictory phenomenon" (T, 5-6; E, 20-21) -- the infamous missing shade of blue.

While Hume's empiricism is usually identified with the copy principle, it is actually his use of its reverse in his account of definition that is really the most important element of his empiricism (see, e.g., Morris 2001). Hume supplies what is required with his account of definition, which offers a simple series of tests to determine cognitive content. First, find the idea to which a term is annexed. If none can be found, then the term has no content, however prominently it may figure in philosophy. If the idea is complex, break it up into the simple ideas of which it is composed. Then trace the simple ideas back to their original impressions: "These impressions are all strong and sensible. They admit not of ambiguity. They are not only placed in a full light themselves, but may throw light on their correspondent ideas, which lie in obscurity" (E, 62).

If the process fails at any point, the idea in question lacks cognitive content. When carried out successfully, it yields a full account -- a "just definition" -- of the troublesome idea or term; a Humean definition gives us its exact cognitive content. So, whenever we are suspicious that a "philosophical term is employed without any meaning or idea (as is too frequent), we need but enquire, from what impression is that supposed idea derived? And if it be impossible to assign any, this will serve to confirm our suspicion. By bringing ideas into so clear a light we may reasonably hope to remove all dispute, which may arise, concerning their nature and reality" (E, 22).

Hume's account of definition is not only the most important feature of his empiricism; it is also a brilliant strategic device. He regards it as "a new microscope or species of optics, by

which, in the moral sciences, the most minute, and most simple ideas may be so enlarged as to fall readily under our apprehension, and be equally known with the grossest and most sensible ideas, that can be the object of our enquiry" (E, 62).

2.2 The principles of association

The copy principle accounts for the origins of our ideas. But our ideas are also regularly connected. As Hume put the point in his "Abstract" of the Treatise, "there is a secret tie or union among particular ideas, which causes the mind to conjoin them more frequently together, and makes the one, upon its appearance, introduce the other" (T, 662). A science of human nature should account for these connections. Otherwise, we are stuck with an eidetic atomism -- a set of discrete, independent ideas, unified only in that they are the contents of a particular mind, which fails to explain how ideas are "bound together".

According to Hume, each of our ideas and impressions is entirely separable from every other, and the apparent connection of one idea to another is invariably the result of an association that we manufacture ourselves (E, III). In other words, the principles required for connecting our ideas aren't theoretical and rational; they are natural operations of the mind, associations we experience in "internal sensation." Hume introduces "three principles of association": resemblance, contiguity, and cause and effect. As thus, ideas are linked to each other in one of three ways: resemblance, contiguity, or cause and effect. For example, this tree looks like that tree; this book is on that table; pushing this switch turns on the light. Hume's introduction of these "principles of association" is the other important feature of his empiricism, so important that in the Abstract he advertises it as his most original contribution: "If any thing can entitle the author to so glorious a name as that of an inventor, 'tis the use he makes of the principle of the association of ideas" (T, 661-662).

Experience provides us with both the ideas themselves and our awareness of their association. All human beliefs result from repeated applications of these simple associations. Hume further distinguishes between two sorts of belief (E, IV i). Relations of ideas are beliefs grounded wholly on associations formed within the mind; they are capable of demonstration because they have no external referent. Matters of fact are beliefs that claim to report the nature of existing things; they are always contingent. For example, mathematical and logical knowledge

relies upon relations of ideas; it is uncontroversial but uninformative. The interesting but problematic propositions of natural science depend upon matters of fact.

Since genuine information rests upon our belief in matters of fact, Hume is particularly concerned to explain their origin. How can such beliefs reach beyond the content of present sense-impressions and memory? Hume holds that, of the three principles of association, causation is the only principle that takes us "beyond the evidence of our memory and senses." It establishes a link or connection between past and present experiences with events that we predict or explain, so that "all reasonings concerning matter of fact seem to be founded on the relation of cause and effect."

However, as Hume notes, causation and the ideas closely related to it also raise serious metaphysical problems: "there are no ideas, which occur in metaphysics, more obscure and uncertain, than those of power, force, energy or necessary connexion" (E, 61-62). In order to develop a satisfying epistemology, we must fix the precise meaning of causation. This project provides a crucial experiment for Hume's metaphysical microscope, and it leads to Hume's penetrating criticism of the notion of causality.

3. Hume's analysis of causality

3.1 Causal reasoning

Hume examines all of the possible ways in which our causal reasoning might be based on reason. According to Hume, reasoning concerns either relations of ideas or matters of fact. He first establishes that causal reasoning is not reasoning concerning relations between ideas. Effects are distinct events from their causes; we can always conceive of one such event occurring and the other not. Besides, the sensible qualities of objects do not reveal their causes or their effects, and there is no known connection between them. So causal reasoning can't be a priori reasoning.

Therefore, when we find that particular objects are constantly conjoined with one another, causes and effects are discovered, not by reason but through experience. Furthermore, even after we have experience of causal connections, our conclusions from those experiences aren't based on any reasoning. They can only be based on our past experiences of similar cases.

But how can we justify extending our conclusions from past observation and experience to the future? The connection between a proposition that summarizes past experience and one that

predicts what will occur at some future time can only be established by adding a premise stating that nature is uniform -- that the future will be like the past. But how could we justify such a claim? Appeal to experience will either be circular or question-begging. For any such appeal must be founded on some version of the uniformity principle itself -- the very principle we need to justify. Whereas the connection is surely not an intuitive connection, it needs to be established by reasoning or argument. The reasoning involved must either be demonstrative, concerning relations of ideas, or probable, concerning matters of fact.

There is no room for demonstrative reasoning here. We can always conceive of a change in the course of nature. However unlikely it may seem, such a supposition is intelligible and can be distinctly conceived. It therefore implies no contradiction, so it can't be proven false by a priori demonstrative reasoning. Probable reasoning can't establish the connection either, since it is based on the relation of cause and effect. What we understand of that relation is based on experience and any inference from experience is based on the uniformity principle.

This exhausts the ways reason might establish a connection between cause and effect. The conclusion is that causal reasoning is not based on reason. Consider Hume's favorite example: our belief that the sun will rise tomorrow. Clearly, this is a matter of fact; it rests on our conviction that each sunrise is an effect caused by the rotation of the earth. But our belief in that causal relation or our causal reasoning is based on past observations, and our confidence that it will continue tomorrow cannot be justified by reference to the past. So we have no rational basis for believing that the sun will rise tomorrow.

Hume's argument shows that our causal expectations are not formed on the basis of reason. But we do form them, and "if the mind be not engaged by argument...it must be induced by some other principle of equal weight and authority" (E, 41). But what are these principles? Hume further holds that these unjustifiable beliefs can be explained by reference to custom or habit. That's how we really learn from experience.

When we examine experience to see how expectations are actually produced, we discover that they arise after we have experienced "the constant conjunction of two objects"; only then do we "expect the one from the appearance of the other." But when "repetition of any particular act or operation produces a propensity to renew the same act or operation...we always say, that this

propensity is the effect of Custom" (E, 43). For example, when I observe the constant conjunction of events in my experience, I grow accustomed to associating them with each other. Although many past cases of sunrise do not guarantee the future of nature, my experience of them does get me used to the idea and produces in me an expectation that the sun will rise again tomorrow. I cannot prove that it will, but I feel that it must.

So the process that produces our causal expectations is itself causal. Custom or habit "determines the mind...to suppose the future conformable to the past." Note that the association of ideas is a powerful natural process in which separate ideas come to be joined together in the mind. However, expecting that fire will warm isn't just conceiving of its warming, it is believing that it will warm. Belief requires that there also be some fact present to the senses or memory, which gives "strength and solidity to the related idea." In these circumstances, belief is "a peculiar sentiment, or lively conception produced by habit" that results from the manner in which ideas are conceived". So "all probable reasoning is nothing but a species of sensation" (T, 103). "It is more conformable to the ordinary wisdom of nature to secure so necessary an act of the mind, by some instinct or mechanical tendency" than to trust it "to the fallacious deductions of our reason" (E, 55).

Therefore, Hume's solution gives a descriptive alternative to philosophers' attempts to account for our causal reasonings by appeal to reason and argument. Our beliefs in matters of fact, then, arise from sentiment or feeling rather than from reason. For Hume, imagination and belief differ only in the degree of conviction with which their objects are anticipated. Although this positive answer may seem disappointing, Hume maintains that custom or habit is the great guide of life and the foundation of all natural science.

3.2 Necessary Connection

According to Hume, our causal reasoning is a custom or habit acquired by experience: having observed the regularity with which events of particular sorts occur together, we form the association of ideas that produces the habit of expecting the effect whenever we experience the cause. But something is missing from this account: we also believe that the cause somehow *produces* the effect. Even if this belief is unjustifiable, some explanation for the fact that we do hold it must be offered. In short, it remains for Hume to "confirm and illustrate" his positive

account by providing a precise definition of our idea of causation. In doing so, he accounts in his own terms for the necessary connection which is an essential component of the idea of causation. His technique was again to search for the original impression from which our idea of the necessary connection between cause and effect is copied.

There are two possible sources from which the idea of necessary connection could be derived from sense impressions of external objects or from the impressions we have of the operations of our own minds. In either case the idea of necessary connection might be derived (a) from the cause, (b) from the effect, or (c) from the relation between the cause and the effect. Hume begins with the our impressions of external objects and remarks: "In reality, there is no part of matter, that does ever, by its sensible qualities, discover any power or energy, or give us ground to imagine, that it could produce any thing, or be followed by any other object, which we could denominate its effect. Solidity, extension, motion; these qualities are all complete in themselves, and never point out any other event which may result from them" (E, 63). What this means is that in effect, we have no impression of necessary connection which derives from impressions of things in the external world.

Hume then turns to consider whether we may get the ideas of cause and necessary connection from the operations of our own minds. In particular, Hume is interested in the claim that "...we are conscious of internal power; while we feel, that, by the simple command of our will, we can move the organs of our body, or direct the faculties of our mind" (E, 64). This idea of power is an idea of reflection, since it comes from reflecting on the powers of our own minds. Hume proposes to examine this claim.

He begins by pointing out that though the influence of volition over the organs of the body is plainly a fact, it is equally plain that this fact is known only by experience "and can never be foreseen by any apparent energy or power in the cause which connects it with the effect and renders the one the infallible consequence of the other" (E, 64-5). So we are conscious that the motions of our bodies follows upon the command of our will, but "the means, by which this is effected...of this we are so far from being immediately conscious, that it must forever escape our most diligent inquiry." Hume goes on to give a variety of reasons why this is so. To know a power, Hume tells us, "We know the very circumstances in the cause, by which it is enabled to produce

the effect. For these are supposed to by synonymous. We must, therefore know the cause and the effect and the relation between them." But we simply don't know the human soul in this way. We have no idea what this power of the will is to move our bodily organs or to direct our thought; we only know that there is such a power. Second, the command of the mind over itself and the body are limited and it is only by experience that we come to know these limits. We cannot "assign the ultimate reason of these boundaries, or show why the power is deficient in one case and not in another."

Therefore, Hume comes to a conclusion: "All events seem entirely loose and separate. One event follows another; but we never can observe any tie between them. They seem *conjoined*, but never *connected*. And as we can have no idea of anything, which never appears to our outward sense or inward sentiment, the necessary conclusion *seems* to be, that we have no idea of connexion or power at all, and that these words are absolutely without any meaning, when employed either in philosophical reasoning, or in private life." (E, 74) But why does Hume say that this *seems* to be the necessary conclusion? The answer is that we still have to give an account of why we are using such terms in the wrong ways in which we do.

The idea of necessary connection does not arise from our objective experience of the events themselves. All we observe is that events of the "cause" type occur nearby and shortly before events of the "effect" type, and that this recurs with a regularity that can be described as a "constant conjunction." Concretely speaking, when we examine a single case of two events we regard as causally related, our impressions are only of their conjunction; the single case, taken by itself, yields no notion of their connection. When we go beyond the single case to examine the background of experienced constant conjunctions of similar pairs of events, we find little to add, for "there is nothing in a number of instances, different from every single instance, which is supposed to be exactly similar" (E, 75). In short, although this pattern of experience does encourage the formation of our habit of expecting the effect to follow the cause, it includes no impression of a necessary connection. Then how can the mere repetition of conjunctions produce a connection?

Hume holds that, while there is indeed nothing added to our external senses by this exercise, something does happen: "after a repetition of similar instances, the mind is carried by

habit, upon the appearance of one event, to expect its usual attendant, and to believe that it will exist." We feel this transition as an impression of reflection, or internal sensation, and it is this feeling of determination that is "the sentiment or impression from which we form the idea of power or necessary connexion. Nothing farther is in the case" (E, 75). Although the impression of reflection -- the internal sensation -- is the source of our idea of necessary connection, that experience wouldn't have occurred if we hadn't had the requisite impressions of sensation -- the external impressions -- of the current situation, together with the background of memories of our past impressions of relevant similar instances. All the impressions involved are relevant to a complete account of the origin of the idea of necessary connection, even though they seem, strictly speaking, to be "drawn from objects foreign to the cause."

Hume sums up all of the relevant impressions in not one but two definitions of cause. The first definition, which defines a cause as "an object, followed by another, and where all objects similar to the first are followed by objects similar to the second" (E, 76), accounts for all the external impressions involved in the case. His second definition, which defines a cause as "an object followed by another, and whose appearance always conveys the thought to that other" (E, 77) captures the internal sensation -- the feeling of determination -- involved. Although the relation between these definitions has been a matter of considerable controversy, the definition of cause Hume claims to provide is expressed only by the conjunction of the two: only together do the definitions capture all the relevant impressions involved.

We can now see some of the negative conclusions which follows from Hume's analysis. Let's return to the list of claims about causal propositions given earlier:

1. The claim that propositions about causation are necessary truths.
2. Propositions about particular causes can be known a priori or prior to experience.
3. Propositions about particular causes involve logical as well as causal connections.
4. Because of the nature of causality, rationalist metaphysics of the kind practiced by Spinoza is possible.

The claim that propositions about causation are necessary truths, Hume rejects as going beyond what we can discover from experience. We cannot know propositions about particular

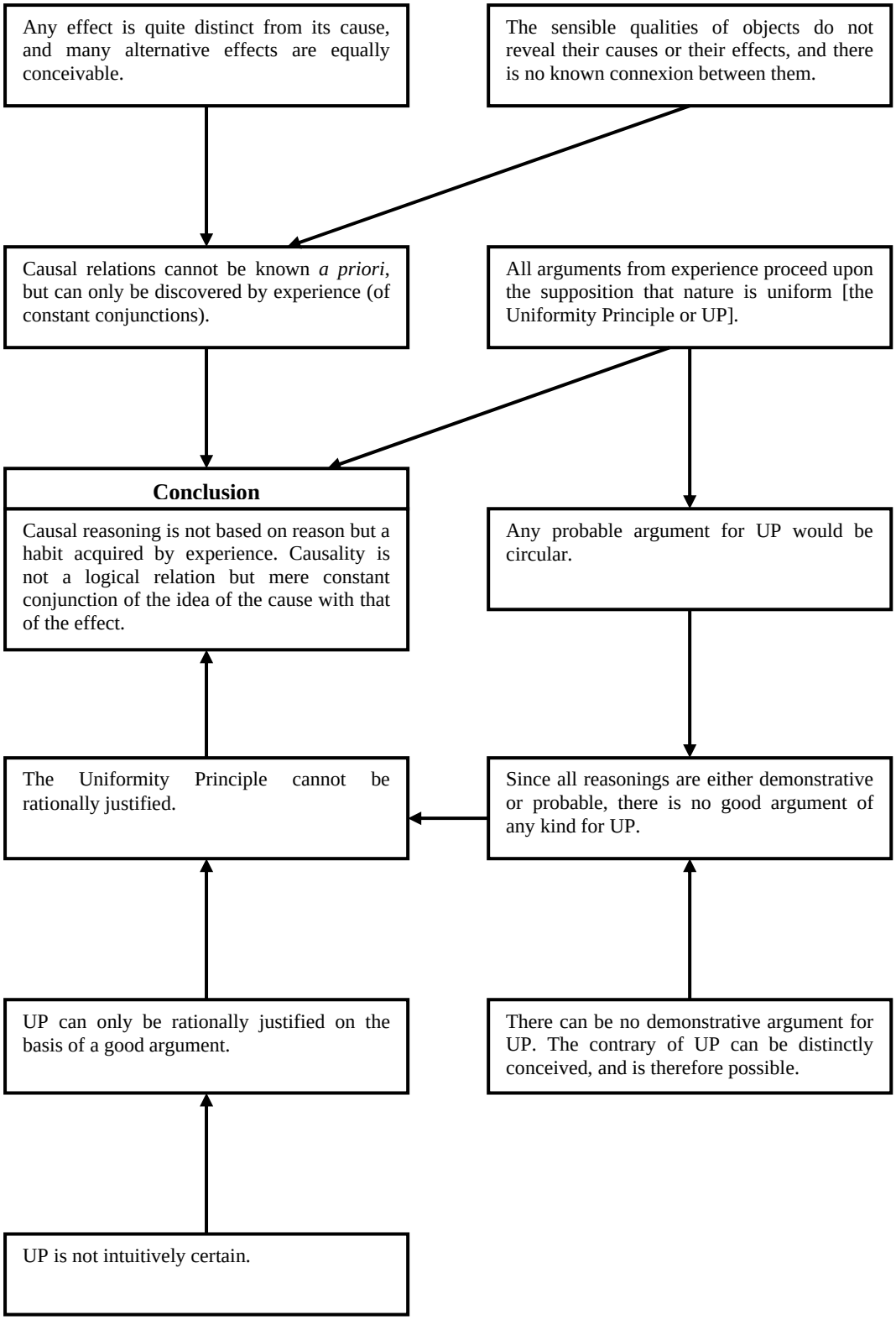
causes prior to experience. The first time we experience a conjunction of a cause and and effect is just that, our first experience of such things. We cannot look at the cause a priori and deduce what the effect will be. Since we know only the conjunction and not the necessary connection between cause and effect, causality is purely a matter of experience and not a logical relation.

Hume's account of causation provides a paradigm of how philosophy, as he conceives it, should be done. He goes on to apply his method to other thorny traditional problems of philosophy and theology: liberty and necessity, miracles, design. In each case, the moral is that a priori reasoning and argument gets us nowhere: "it is only experience which teaches us the nature and bounds of cause and effect, and enables us to infer the existence of one object from that of another. Such is the foundation of moral reasoning, which forms the greater part of human knowledge, and is the source of all human action and behaviour" (E, 164). Since we all have limited experience, our conclusions should always be tentative, modest, reserved, cautious. This conservative, fallibilist position, which Hume calls mitigated scepticism, is the proper epistemic attitude for anyone "sensible of the strange infirmities of human understanding" (E, 161). We should humbly accept the limitations of human knowledge while pursuing the legitimate aims of math and science.

4. Critiques of Hume's analysis of causality

Hume's metaphysics and epistemology, whether true or false, represent the bankruptcy of eighteenth-century reasonableness. He starts out, like Locke, with the intention of being sensible and empirical, taking nothing on trust, but seeking whatever instruction is to be obtained from experience and observation. But having a better intellect than Locke's, a greater acuteness in analysis, and a smaller capacity for accepting comfortable inconsistencies, he arrives at the disastrous conclusion that from experience and observation nothing is to be learnt. There is no such thing as a rational belief: "If we believe that fire warms, or water refreshes, 'tis only because it costs us too much pains to think otherwise." We cannot help believing, but no belief can be grounded in reason.

We can summarize Hume's analysis of causality in the following schema:


Any effect is quite distinct from its cause, and many alternative effects are equally conceivable.
The sensible qualities of objects do not reveal their causes or their effects, and there is no known connexion between them.
Causal relations cannot be known *a priori*, but can only be discovered by experience (of constant conjunctions).
All arguments from experience proceed upon the supposition that nature is uniform [the Uniformity Principle or UP].
Conclusion
Causal reasoning is not based on reason but a habit acquired by experience. Causality is not a logical relation but mere constant conjunction of the idea of the cause with that of the effect.
Any probable argument for UP would be circular.
The Uniformity Principle cannot be rationally justified.
Since all reasonings are either demonstrative or probable, there is no good argument of any kind for UP.
UP can only be rationally justified on the basis of a good argument.
There can be no demonstrative argument for UP. The contrary of UP can be distinctly conceived, and is therefore possible.
UP is not intuitively certain.

We will first present a general critical analysis of Hume's theory of causality. The analysis does not depend on the details of his argument. To begin with, Hume's conclusion of causal reasoning as a habit is not mathematical or logical knowledge which relies upon relations of ideas, but a belief in matters of fact. It is essentially a proposition about the operating mechanism of mind. Then according to Hume, such a belief in matters of fact is always contingent. Thus his conclusion itself is also contingent, and cannot be justified by reason. In short, Hume's conclusion -- no belief can be justified by reason -- cannot be justified by reason either. Therefore, Hume actually defeats himself using his own weapons. This is very similar to the fate of logical positivism. The keystone of logical positivism -- that nothing is true unless it has been verified empirically -- cannot be verified empirically. So logical positivism kills itself. Secondly, Hume's argument is a combination of induction and deduction. Although his theory is basically a structure of deduction, the presuppositions in his theory are not logically self-evident; they mainly come from experience. This induction element, according to Hume, will also result in the contingency of his conclusion. In the last place, Hume's theory is essentially based on a cognitive model of mind. The research field is called cognitive science today. Many great advances have been made in this field since Hume's times. So it is not unexpected that there exist some flaws or even errors in Hume's model of mind. This will further provide some concrete reasons why Hume's theory fails in some respects.

We then analyze the details of Hume's argument. As Bertrand Russell noted (Russell 1946), Hume's theory of causality has two parts: one objective, and the other subjective. The objective part says: when we judge that A causes B, what has actually happened, as far as A and B connected, is that they have been frequently observed to be conjoined, i.e. A has been immediately followed by B; we have no reason to say that A must be followed by B, or will be followed by B on future occasions. Nor have we any ground for supporting that, however often A followed by B, any relation beyond sequence is involved. In fact, causality is definable in terms of sequence, and is not an independent notion.

The subjective part of the theory says: the frequently observed conjunction of A and B causes the impression of A to result in the idea of B. But if we define 'cause' as is suggested in the objective part of the theory, we must reword the above as follows: it has been frequently observed

that the frequently observed conjunction of A and B has been frequently followed by occasions on which the impression of A was followed by the idea of B. This statement might be true, but it is hardly the scope that Hume attributes to the subjective part of his theory. He contends, over and over again, that the frequent conjunction of A and B gives no reason for expecting them to be conjoined in the future, but is merely a cause of this expectation. If the objective part of Hume's theory is right, the fact that associations have frequently formed in the past is no reason for supposing that new ones will be formed in similar circumstances in the future. Thus Hume actually believes in causation in the subjective part, which he tries to refute in the objective part.

Let us take an illustration (Russell 1946). I see an orange, and expect that, if I eat it, I shall experience a certain kind of taste. According to Hume, there is no reason why I should experience this kind of taste; the law of habit explains the experience of my expectation, but does not justify it. But the law of habit is itself a causal law. Therefore if we take Hume seriously we must say: although in the past the sight of an orange has been conjoined with expectation of a certain kind of taste, there is no reason why it should continue to be so conjoined: perhaps the next time I see an orange I shall expect it to taste like ice cream.

Therefore, Hume's theory of causality can be formulated as follows: the proposition 'A causes B' means 'the impression of A causes the idea of B'. But if Hume's objective theory is right, we have no better reason for expectations in psychology than in the physical world. In other words, Hume holds that causal laws exist in the subjective world, but they do not exist in the objective world. Yet there is no reason for such an asymmetry. This indicates that Hume's theory of causality cannot explain our belief of causality in a consistent way.

In the following, we will present a further analysis of Hume's major presuppositions in his theory of causality.

(1). Perceptions are entirely loose and separate (perception atomism)

It has been argued that Hume's perception atomism does not permit the existence of causal connections. So Hume's disastrous conclusion is only a consequence of his perception atomism to some extent. If perception atomism is not true in reality, then Hume's theory may collapse. We give two experimental evidences which refute perception atomism. First, experiments shows that rats find it much easier to learn an association between eating a certain food and nausea, and a

loud flash and an electric shock, than the complementary pairings (Garcia and Koelling 1966). In the terms of our approximation we can say that natural selection has projected a regularity in the world of rats, so that any given rat, contrary to Hume, does not experience some types of phenomena as "entirely loose and separate". Note that the projected regularity here is not an 'invariable uniformity of sequence'. Secondly, the work of developmental psychologists already tells us a lot about the causal (in this cognitive sense of causal) expectations of children around 3 months old, who are surprised when apparently cohesive objects seem spontaneously to fragment, to pass through one another, or not to exhibit a single trajectory through space and time (Spelke et al 1995). Other work (Baillargeon et al 1995) indicates that at the same age infants are disposed to find apparently unsupported objects that fail to fall surprising. Some headway is being made with the difficult question of what features of an object's behavior and/or structure lead children to regard it as capable of self-motion, either at all or of various particular sorts (Gelman et al 1995). Here too it seems that phenomena of some sorts are not experienced as 'entirely loose and separate'.

(2) All ideas come from antecedent impressions (the copy principle)

In Hume's view, the way to clarify ideas, including the idea of causation, is to determine what impressions they derive from. An idea without an impression will be dismissed as "without any meaning". This is a very important strategic device in Hume's theory, without which Hume cannot reach his disastrous conclusion. As some opponents argue, however, an idea without an impression is not to be dismissed as "without any meaning" but is actually counter-evidence against Hume's whole empiricism. If we produce an idea, like *power* or *necessary connection*, that we maintain is not derived from an antecedent impression, it is incumbent upon Hume to produce the impression or abandon his empiricism. Until Hume shifts the burden of proof, his own work provides some of the best evidence against empiricism. As we think, ideas without impressions really exist. For example, the idea of a high-dimensional space in math has no corresponding impression. Such high-dimensional spaces are defined by abstract algebraic relations. We simply have no its impression.

(3) The conceivable must not result in logical contradiction.

As we think, this presupposition alone will result in the contingency of any belief. A belief and its contrary are both conceivable and thus are all logically possible. As an example, Hume's notion of causality as constant conjunction is also contingent. Another notion of causality is also conceivable. So this presupposition, which is required for Hume's argument, may actually make his argument invalid. Besides, this presupposition is evidently unreasonable, for reason is rejected simply because unreason is also conceivable.

(4) Causation as constant conjunction.

This is one of the most important notions in Hume's theory of causality. But it has two flaws at least. To begin with, our causal thinking is not recognizably 'Humean' on any strict construal of 'Humean'. A strictly Humean notion of causal thinking would require that effects followed causes infallibly – and Hume does write of an effect being "infallibly" produced by a cause (E, 75). He also offers that 'similar objects are always conjoined with similar. Of this we have experience' (E, 76). This is a 'constant conjunction' view of our cognitive processes. However, there is ample evidence that we do not think in terms of constant conjunctions at all, but rather in terms of multiple chains of influence similar to directed causal graphs, or Bayes nets. Young children (between the ages of 3 and 5) already show the ability, among other things, to reason to unobserved causes, to plan suitable novel interventions in response to requests to prevent a process they had only observed in operation (i.e. one that they had never seen prevented), and to make inferences about the 'direction' of causal dependence in cases of simultaneous change (see, e.g., Gopnik et al 2004). The data are inconsistent with any simple conditioning or associationist view where 'invariable uniformities of sequence' are what is learned, effectively demanding recognition of a human capacity to construct causal models at least broadly equivalent to Bayes nets. Ongoing scientific work will tell us more about causal cognition. Secondly, constant conjunction of two events does not always imply the existence of a causality relation between these events. A widely used example is the atmospheric electrical event that causes lightening and thunder. Since we always see lightening before we hear thunder, it appears that "lightening causes thunder. But in fact, lightening does not cause thunder. Lastly, we stress that Hume's argument of causation as constant conjunction does not eliminate the actual possibility that there is a necessary

connection between cause and effect in reality. Hume's conclusion, if true, only means that we cannot know the necessary connection and justify our belief in it.

(5) The uniformity principle (UP) cannot be rationally justified.

In the subjective part of Hume's theory of causality, the argument of causation as constant conjunction actually relies on the uniformity principle. If the uniformity principle cannot be rationally justified, then there is no reason why present conjunctions must infallibly sustain in similar circumstances in the future. As thus, Hume's argument of causation as constant conjunction will collapse. On the other hand, if the uniformity principle can be rationally justified, then Hume's argument of causation will be also invalid. Therefore, it seems that Hume's argument of causation may inevitably fail. We have reached a similar conclusion in the above analysis.

5. Regularity theory and its alternatives

Most contemporary philosophical work on causation still pays homage to Hume's ideas. Hume considers one billiard ball pushing against another and says that we can observe the movement of the first ball and the subsequent movement of the second ball, but we cannot observe any pushing, necessitating, or bringing about -- in short, any *causal connexion* -- between the two movements. According to Hume, causality is not a logical relation but mere constant conjunction of cause and effect; causes are invariably followed by their effects.

Attempts to analyze causation in terms of invariable patterns of succession are usually referred to as "regularity theories" of causation. Hume's theory is a regularity theory of causation[2]. The regularity theory analyzes causation in terms of nothing but regular sequence (together, in Hume's case, with priority in time and contiguity in time and space). The point of the theory is to

[2] Note that there is still a puzzle concerning Hume's 'other words' appended to his first definition of cause in the *Enquiry* ('Or in other words *where, if the first object had not been, the second never had existed*.' – E, 76), which have often been interpreted in a counterfactual manner that seems straightforwardly to conflict with the definition that they supposedly paraphrase (Vesey 1986). The extent to which Hume himself adhered to the regularity theory has come into dispute (see, e.g., Broackes 1993). At any rate, Hume never explored the alternative counterfactual approach to causation. In this, he was followed by generations of empiricist philosophers. The chief obstacle in empiricists' minds to explaining causation in terms of counterfactuals was the obscurity of counterfactuals themselves, owing chiefly to their reference to unactualised possibilities.

dispense with any mysterious causal necessity, and also to distinguish causal connections from logical connections: one event cannot logically necessitate another. The resulting picture is that what happens at one time does not really have an impact on what happens later. Nothing really brings anything else about. When we call something a cause we just represent it in relation to what happens in other similar situations; we subsume it under obtaining patterns or regularities of the form: such-and-such events are always followed by such-and-such events. The theory is therefore reductionist in nature, and versions of it appeal to empiricists and positivists.

Regularity theories may have some plausibility if they are taken as just claiming that causal statements can be replaced by certain other statements, in which no reference to causal connexions is made. One may hold that 'A caused B', at least for certain purposes, can be replaced by 'A as well as B occurred, and all events like A are followed by events like B'. But if there were no causal connexions, then probably there would not be any of the regularities to which the regularity theory refers. Furthermore, the theories also pose other difficulties. An obvious difficulty is that most causes are not invariably followed by their effects. For example, it is widely accepted that smoking is a cause of lung cancer, but it is also recognized that not all smokers develop lung cancer. In addition, the asymmetry of causation may also pose a problem for regularity theories. If *A* causes *B*, then, typically, *B* will not also cause *A*. Smoking causes lung cancer, but lung cancer does not cause one to smoke. It seems very difficult for regularity theories to explain this asymmetry of causation.

Whereas there are a number of difficulties with regularity theories, many alternatives have been proposed. We give an example to illustrate these different theories. If one hits a piano key, one usually hears a sound. While it may seem obvious that hitting the key (H) causes the sound (S), different theories give different explanations of the content of this claim. On the regularity theory of causation, ascribed to Hume and espoused by empiricists such as Carnap and Quine, 'H causes S' merely asserts the regular succession of hitting piano keys and hearing sounds. On Salmon's and Dowe's process theory, by contrast, 'H causes S' implies the existence of particular processes and interactions: mechanical energy is transferred from finger to hammer, then to a string, then via the surrounding air to the ear, where it is perceived as a musical sound. On Lewis's counterfactual theory, causal claims reflect counterfactual dependencies: 'H causes S'

means that there is a chain of counterfactually dependent events between H and S (if the key had not been hit, or the hammer had not been set into motion, etc., no sound would have resulted). On the so-called agency theory of causation, defended by von Wright and by Menzies and Price, 'H causes S' means that a free agent can bring about a musical sound by hitting the piano key. All these views reflect particular intuitions one might have with respect to causation.

There are three promising alternatives to Humeanism among the current philosophical attempts to understand causation. The first are probabilistic theories of causation (see, e.g., Hitchcock 1997); the second is systematic dependence accounts of causality (Woodward 2003); the third is Mechanism (Machamer, Darden and Craver 2000; Glennan 1996, 2002). Probabilistic theories of causation are more sophisticated versions of the regularity theory. The central idea behind probabilistic theories of causation is that causes *raise the probability* of their effects; an effect may still occur in the absence of a cause or fail to occur in its presence. Thus smoking is a cause of lung cancer, not because all smokers develop lung cancer, but because smokers are *more likely* to develop lung cancer than non-smokers. This is entirely consistent with there being some smokers who avoid lung cancer, and some non-smokers who succumb. Probabilistic theories of causation can solve the problems of imperfect regularities and asymmetry of causation in a more consistent way.

The systematic dependence approach takes it that causes make a difference to their effects. This difference-making is cashed out in counterfactual terms: the relationship among some variables (or magnitudes) *X* and *Y* is causal if, if an intervention changed the value of *X* appropriately, the relationship between *X* and *Y* would remain invariant *and* the value of *Y* would change. According to Woodward it is the possibility of intervention and manipulation that is essential to causation and explanation. The approach maintains a variant of the traditional idea that regularity is crucial to causality, but the regularities it believes to be characteristic of causal processes differ from those of standard Humean accounts. For one thing, they are counterfactual regularities which obtain among ideal interventions on factors belonging to the system which produces the effect to be explained, and the results which would ensue if the interventions occurred. Furthermore, because the required regularities typically hold only for some interventions, the generalizations which describe them need not qualify as genuine Humean laws.

The mechanistic approach takes it that two events are causally related if and only if there is a *mechanism* that connects them. Mechanisms are taken to be complex systems, which are composed of parts, have internal structure or organization and certain spatio-temporal locations. The mechanism has a characteristic behavior in virtue of the properties, dispositions or capacities of its parts as well as in virtue of how these parts are organized and interact with each other. What the mechanism is doing (its characteristic activity, its behavior or its output) is caused and explained by the details of how it is doing it. These details include the internal workings of the mechanism. Mechanism is an even more drastic departure from Humeanism. It maintains that a causal explanation must describe the system which produces the effect of interest by enumerating its components and what they do to contribute to the production of the effect. Mechanists acknowledge that some mechanisms operate with great regularity, but they do not believe that the understanding we get from a causal explanation derives from its description of actual or counterfactual regularities.

The above approaches are, in a sense, anti-metaphysical. They concentrate on how causal relations can be understood and established, if we take on board the ways scientists themselves try to discover and establish causal connections and causal facts. Though there may be dissenting voices from within each approach, they all take it that they do not offer an *analysis* of causation, and in particular an analysis of causation in non-causal terms.

6. A generalized principle of causality

So far we have considered how the theory of causation works under the assumption of determinism. But what about causation when determinism fails? Lewis (1986) argues that chancy causation is a conceptual possibility that must be accommodated by a theory of causation. Indeed, contemporary physics, especially quantum mechanics, tells us the actual world abounds with probabilistic processes that are causal in character. Quantum mechanics is a fundamental scientific theory with quite serious repercussions for the philosophical debate about causal explanation. It seems to us that anyone who proposes a general theory of causation and scientific explanation should explicitly discuss how it fares within the quantum domain. Salmon, for example,

acknowledged the failure of his causal-mechanical model in this respect, a result that he took very seriously (Salmon 1997).

The regularity theory of causation is incompatible with indeterminism: if an event is not determined to occur, then no event can be a part of a sufficient condition for that event. The success of quantum mechanics has shaken our faith in determinism. Thus it has struck many philosophers as desirable to develop a theory of causation that does not presuppose determinism. Since probabilistic theories of causation require only that a cause raise the probability of its effect, these theories are compatible with indeterminism. This seems to be a potential advantage over regularity theories. It is unclear, however, to what extent this potential advantage is actual. In the realm of microphysics, where we have strong (but still contestable) evidence of indeterminism, our ordinary causal notions do not easily apply. This is brought out especially clearly in the famous Einstein, Podolski and Rosen thought experiment (Einstein et al 1935). On the other hand, it is still unclear to what extent quantum indeterminism 'percolates up' to the macroworld of smokers and cancer victims, where we do seem to have some clear causal intuitions.

In fact, indeterminism not only poses difficulties to usual theories of causation, but also poses serious problems to the ordinary notion of causality itself. Most modern philosophers seem to wisely avoid this thorny puzzle. To our surprise, however, bravely facing this puzzle may give us unexpected payoffs; for example, a further analysis of indeterminism will affirm the notion of causality as necesssary connection. In the last part of this essay, we will present a new *analyis* of causation, especially in terms of indeterminism.

Hume rejects the rationality of the law of causality, and removes the essential necessary connection from causality. In this way, he degrades causality to mere constant conjunction of events or regularity. This viewpoint is strongly supported by Russell (1913). He characterized the "law of causality" as a harmful "relic of a bygone age", and even urged the "complete extrusion" of the word 'cause' from the philosophical vocabulary. As we have seen, however, Hume's argument is not convincible. If there were no causal connection, or, if one event does not logically necessitate another, then why does regularity of events exist? Probably there would not be any regularity. In response to this objection, Hume holds that natural laws are not certain but contingent. So there is indeed no reason why the regularity exists. This is a disastrous conclusion

for rationalists. Especially, it makes the universe unintelligible. In the following, we will argue that our reason is not so much weak. Moreover, Hume's notion of causality can actually help to provide a promising way to unify the law of causality and indeterminism. We call this unified law generalized principle of causality. Although it may be very tempting, as Russell argued, to suppose that causality is just an apparent display of natural laws, and it does not exist in reality, our analysis will show that causality can function as a useful tool to analyze the origin of laws. In this meaning, the generalized principle of causality is a more fundemantal law of nature.

To begin with, we will present a heuristic refutation of the viewpoint that natural laws are all contingent. Consider the proposition "All natural laws are contingent", which is also a law of nature. If the proposition is right, then all natural laws will be contingent. Since the proposition itself is a natural law, it is also contingent, not certain. This immediately leads to a contradiction. Thus the proposition "All natural laws are contingent" must be wrong[3]. As a result, some natural laws must be certain, not contingent. This means that these laws have logical necessities, which can explain why the regularities in these laws exist. Then is the law of causality a certain natural law? Does causal necessity really exist? No doubt a detailed analysis is needed to solve these problems.

The principle of causality has been one of the most influential beliefs in science and philosophy. Especially, it makes the natural world comprehensible. Many believed that reason could provide an absolute justification for this law, while others, notably Hume, argued that logic is incapable of providing a foundation in reason for the principle of causality. On the other hand, indeterminism, which is the doctrine that there are some events which have no cause, also has a long history. It can be traced back to Epicurus, according to which causality is limited by the spontaneous "swerve" of atoms that happens purely by chance (see, e.g., Englert 1987). With the discoveries in the realm of physics concerning quantum theory, especially Heisenberg's principle of indeterminacy, most people begin to accept that the principle of causality must be given up in the subatomic realm. However, the basis of indeterminism still needs to be established by purely logical considerations.

[3] In a similar way, we may reach the conclusion that some knowledge about matters of fact can be certain by analyzing the proposition "No knowledge about matters of fact is certain".

As Einstein remarked, the most incomprehensible thing about the universe is that it is comprehensible (Einstein 1936). The principle of causality is comprehensible, but it seems to be not true in the actual world. On the other hand, indeterminism or the existence of uncaused events, which evidently contradicts the principle of causality, is probably true, but it appears to be irrational and incomprehensible. This results in an extremely embarrassing phase of history in science. Those who insist on the comprehensibility of nature uncompromisingly reject indeterminism, while the pragmatic hail indeterminism as one of the most profound discoveries of modern science, although they don't *understand* it either. Then who is right? How to choose between the principle of causality and indeterminism for a rational man? Such a dilemma must be solved if the universe can be understood by reason.

In the following, we will argue that the existence of uncaused events is logical and comprehensible. To illustrate this viewpoint, we will take the motion of objects as a typical example. It is demonstrated that the motion of objects may be essentially random. Furthermore, it is shown that there may exist a universal cause that results in the existence of such random motions. As a result, the existing principle of causality is not complete, and will be replaced by a generalized principle of causality, according to which there are two kinds of causes: concrete causes and universal causes, and correspondingly there are two kinds of effects: lawful events and random events. The new analysis may not only provide a logical basis for indeterminism, but also further deepen our understandings of causality.

6.1 A general analysis

According to the principle of causality, no events or changes can happen without cause, while indeterminism asserts that there are some events which have no cause. These two beliefs seem to be utterly incompatible. In this section, we will argue that indeterminism is rational, and can be unified with the principle of causality to form a generalized principle of causality.

It is logical that a cause will result in a lawful change, whereas a random change requires no cause. Then if there is no cause, there should exist two possible effects: one is that no change happens, the other is that a random change happens. The former accords with the existing principle of causality, while the latter is also logically possible as we will argue below. First, since a random change also requires no cause, the effect of random change cannot be excluded in logic.

Secondly, we can always assume the existence of a universal cause which results in the happening of random changes. Such a universal cause, which is irrelevant to time, cannot determine concrete change, and thus change is random. As a consequence, the happening of random changes without cause may be logical from stem to stern. This lends further support to the above conclusion. Thirdly, it is possible that random changes must happen for some situations due to a certain universal cause. Although the happening of random events without cause is logical, it still needs to be determined that which of the above two possible effects will happen in an actual situation. If the random changes must happen due to a certain universal cause, then it is impossible that no change happens when there is no cause. This will determine which of the two possible effects will happen in reality. Lastly, the actual existence of random processes will confirm the above conclusion in experience. In a word, even if no concrete causes exist, changes can still happen as long as the changes are completely random.

In order to further understand the above argument, it is necessary to distinguish two kinds of causes: concrete causes, which relate to time, and universal causes, which are irrelevant to time. The former are our familiar causes appearing in the principle of causality. A concrete cause will result in a lawful change at a concrete time. The latter are similar to Aristotle's final cause. A universal cause can result in ceaseless random changes. As a consequence, both lawful changes and random changes have their causes. We call this conclusion the generalized principle of causality. According to the principle, there are two kinds of causes: concrete causes and universal causes, and accordingly there are two kinds of events: lawful events and random events. As an inference, a real event will be generally composed of a lawful element and a random element, and the law of nature will be a combination of deterministic elements and random elements.

6.2 A typical example

To illustrate the generalized principle of causality, we will take the motion of objects as an example. The following analysis will provide a specific demonstration of the generalized principle of causality.

As we know, an object will continue to move after it is put into motion. This is the familiar phenomenon of inertial motion[4]. It is well summarized in Newton's first law of motion or the law of inertial motion for macroscopic objects. According to the law, a free object can move or change its position, and no external causes are needed to sustain its motion. It appears that the inertial motion can be understood in the framework of classical mechanics that assumes that objects move in a continuous way. A free object should hold its velocity, since there is no cause leading to the change of its velocity. Thus the object must continuously move in a straight line with a constant speed as the law of inertial motion requires. However, a further analysis will show that this explanation may be improper. In the following, we will show that no cause determines the position change of an object, and the motion of objects should be random.

We first consider the motion of a free object. (1) There are no external causes such as the influence of other objects to determine the position change of the free object. The free object moves without any external influence. (2) There are no internal causes such as velocity to determine the position change of the free object. The velocity of an object is defined as the limit of the object's average velocity as the time-interval around the point in question tends to zero. Thus the object at one instant has no velocity to hold for determining the position of the object at the next instant. (3) The object cannot hold its previous position either. It moves during the course of inertial motion. Therefore, we conclude that no cause determines the position change of a free object. Since changes without cause should be random, the position change of a free object will be random in nature (Gao 2001, 2003, 2006).

We stress again that the velocity property, even if it exists, cannot determine the change of the instantaneous position of the object. This is the crux of the above argument, thus we will present a more detailed analysis. On the one hand, velocity may not exist for some forms of motion such as the Brown motion. Its valid definition requires that motion is continuous and the trajectory is differentiable relative to time. But it is still unclear whether or not the motion of objects is continuous, and thus the continuity of motion and the existence of velocity should not be a precondition when we analyze how objects move. On the other hand, even if velocity may exist

[4] It should be noted that pure inertial motion does not occur in nature. According to the existing physical theory, it can only occur at an infinite distance from all sources of gravity.

for the motion of an object, it does not count as part of the instantaneous state of the object (cf. Albert 2000; Arntzenius 2000; Butterfield 2005). Thus velocity cannot determine the change of instantaneous state such as position. The orthodox definition of velocity is that the instantaneous velocity for an object is the limit of the object's average velocity as the time-interval around the point in question tends to zero. As a consequence, the orthodox velocity is local but temporally extrinsic (Butterfield 2005). The object's instantaneous velocity at an instant codes a lot of information about what its velocity and location is at nearby times. The information is given precisely by the limit definition of velocity. For example, the information is given in spacetime terms by saying that the nearby history of locations (the local segment of the worldline) must be smooth enough to have a tangent vector (a 4-velocity determined by the velocity) at the instant (Butterfield 2005). In a word, even if the orthodox velocity exists for the motion of an object, it is not an instantaneous intrinsic property of the object in essence, and thus velocity cannot determine the change of the instantaneous position of the object.

We then consider the motion of an object under the influence of interaction with another object. Can the influence determine the position of the object at each instant and thus change the random motion to deterministic motion? The answer is negative. The essential reason lies in that a completely random process cannot be changed to a deterministic process in principle. If the influence is not random, then it is evident that the motion of an object under this influence is still random. If the influence is also random, then since the combination of two random processes still leads to a random process, the motion of an object under this influence is also random. Accordingly the motion of an object under the influence of interaction with another object is still random.

In fact, we can reach the above conclusion by a more general argument. The argument does not rely on the experience of inertial motion. It only relies on the standard assumption that space and time intervals consist of smallest sized intervals such as 0-sized points, and a moving object is in one position at each instant during the course of motion. First, the properties defined during infinitesimal time intervals such as velocity cannot determine the position change of an object. In fact, these properties are determined by the position change of the object during an infinitesimal time interval according to the definition. Secondly, the properties defined at instants

such as position cannot determine the position change of an object either. Such properties at one instant only contain the information about the object at the instant, and contain no information about the positions of the object at other instants. In short, an object's instantaneous state should not imply, in virtue of logic and definition alone, any constraints on its instantaneous states at other times (cf. Albert 2000; Arntzenius 2000). Therefore, no properties or causes determine the position change of an object at each instant, and the motion of objects must be random.

Note that the above argument concerning instantaneous states is very similar to Hume's argument that there is no necessary connection between cause and effect. According to Hume, causes contain nothing within themselves that could enable them to act on anything else; one event cannot logically necessitate another. In this meaning, it seems that Hume's argument can lead to indeterminism. If two events are logically irrelevant, then their connection cannot be causal and regular, but must be completely random. Yet Hume did not reach this conclusion due to the limitation of his empiricism. As we think, this might be the most important one among Hume's positive influences; his doubt about the law of causality can actually lead us to indeterminism.

It can be further shown that there may exist a universal cause that results in the existence of such random motions. This will provide a cogent argument for the generalized principle of causality. It is a natural assumption that an object influences another object only by contact[5]. Since different objects are not in contact, motion is needed to make objects contact to generate the influences. If objects can only move as a result of the influences of other objects, the objects would not be able to move without such influences, but, on the other hand, the influences cannot be generated if there is no motion. Thus either everything is immobile or there exist uncaused, spontaneous motions. In short, if objects cannot move in a spontaneous way, all objects will be resting, and all interactions between them will be also non-existent. Furthermore, since the properties of an object such as mass depend on its interaction with other objects, objects will be devoid of any properties, and will not exist either. Accordingly it seems that objects must move spontaneously and stochastically in order to exist. This means that the universal cause for the

[5] This assumption is also consistent with the existing quantum field theory of interactions, according to which the interaction between two particles is transferred by other moving particles, and the transfer particles influence the particles by contact.

random motion of objects may be the existent need of objects. Such a cause is independent of time and concrete motion processes.

Lastly, we note again that there are abundant evidences of random motion in the actual world, especially in the microscopic world. For example, the alpha particles can spontaneously move out from the radioactive isotopes without any external influence. Such a phenomenon is well known as radioactivity or spontaneous decay, which universally exists in the microscopic world. During the spontaneous decay process, the decay time of each radioactive atom in the substance is completely random. In fact, all microscopic processes contain randomness as the quantum theory (e.g. Heisenberg's principle of indeterminacy) and the experiments reveal. The actual existence of random motion will lend further support to the generalized principle of causality.

7. Conclusions

Hume is most famous for his penetrating analysis of causality. He notices that cause cannot logically necessitate effect, i.e., that causal necessity has no reason, and our belief in it is unjustified. However, his scope is limited by his sheer empiricism; he removes necessary connexion from causality, but still keeps regularity in causality. In fact, if Hume were able to go beyond empiricism, he could reach a more satisfying conclusion. Now that one event cannot logically necessitate another, their connection cannot be causal and regular, but must be completely random. As thus, Hume's doubt about the law of causality can actually lead us to indeterminism, and his analysis can also make indeterminism or the existence of uncaused events logical and comprehensible.

Furthermore, as we have argued, the principle of causality and indeterminism can be unified in a generalized principle of causality. To illustrate this viewpoint, we analyze the motion of objects in detail. It is demonstrated that the motion of objects may be essentially random. It is also shown that there may exist a universal cause that results in the existence of such random motions. Thus causal necessity does not exist at the most fundamental level. As a result, the existing principle of causality is not complete, and will be replaced by a generalized principle of causality, according to which there are two kinds of causes: concrete causes and universal causes,

and correspondingly there are two kinds of effects: lawful events and random events. Each actual effect is composed of both lawful element and random element. This conclusion might appeal to Hume, whose goal is to establish a *science* of man.

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