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A LOGIC FOR 'BECAUSE'

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Abstract. In spite of its significance for everyday and philosophical discourse, the explanatory connective 'because' has not received much treatment in the philosophy of logic. The present paper develops a logic for 'because' based on systematic connections between 'because' and the truth-functional connectives.

§1. Introduction.

1.1. The project. In the philosophy of logic, the natural language connectives 'and', 'or', 'not', and 'if ... then' are widely discussed and so are their formal counterparts, such as the truth-functional connectives of classical logic or counterfactual and strict conditionals in modal systems. Considerably less attention has been paid to the explanatory connective 'because'.

One simple reason may be that 'because' is quite complicated to handle. 'Because' is obviously not an extensional operator: the truth of the two clauses in a 'because'-sentence is compatible both with the truth of the sentence (JFK died because he was shot) and with its falsity (JFK died because Chernobyl exploded). But not only is 'because' nonextensional, it is even hyperintensional: necessarily equivalent clauses are not substitutable *salva veritate* in its context. This immediately follows if (i) some true 'because'-sentences have a main clause expressing a necessary truth, and (ii) not all necessary truths are explained by exactly the same things. For, assume that *S* expresses a necessary truth (e.g., that {2} contains a prime number), and that there is at least one true instance of $\ulcorner S$ because $\phi \urcorner$ (e.g., '{2} contains a prime number because it contains 2 and 2 is prime'). If 'because' was at most an intensional operator, *S* could be substituted *salva veritate* with any necessarily equivalent clause, that is, with any sentence expressing a necessary truth. Hence, any 'because'-clause that would explain *S* would equally explain any other necessary truth. (An analogous reasoning applies to necessarily true 'because'-clauses of 'because'-sentences.)

But necessary truths are not the only cases that illustrate the hyperintensionality of 'because'. To wit, the majority of philosophers in the debate about truth accept the Aristotelian insight that the following schema is valid for true instances of 'p':[1]

Truth That p is true because p (but not vice versa).

Given this insight, 'because' must be hyperintensional. For, the two clauses 'p' and 'that p is true' agree in truth-value with respect to every possible world. Since the clauses are furthermore *cognitively* equivalent (a speaker who understands them normally has to adopt the same epistemic stance towards them), the example yields the yet stronger result that

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[1] Cp. Aristotle's *Metaphysics*, book Θ 10: $1051^b 6$–9. For some recent attempts of justifying **Truth**, see Künne (2003, pp. 150–157), Hornsby (2005, p. 43f.), and Rodriguez-Pereyra (2005).

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even cognitively equivalent clauses are not always substitutable *salva veritate* in the scope of ‘because’.[2] The connective indeed creates a highly opaque context.

Moreover, the use of ‘because’ seems particularly sensitive to pragmatics. Contrastive stress, for example, is usually regarded as a pragmatic phenomenon, but apparently the truth-values of some explanatory statements depend on it.[3] Assume that Adam was hungry and had to choose whether to eat the apple or the pear before him. Because he disliked pears, he chose the apple. Then the first of the following statements seems true and the second false:

(1) Adam *ate* the apple because he was hungry.

(2) Adam ate the *apple* because he was hungry.

To be in this way semantically sensitive to nonsemantic factors is an unusual feature which would make the development of a full semantic account of ‘because’ difficult.[4]

But nevertheless, ‘because’ and other explanatory expressions (such as ‘because of’, ‘in virtue of’, ‘due to’, etc.) play a highly important role both in ordinary discourse and in philosophical arguments. Most importantly, ‘because’ is frequently used to formulate questions of *priority*. In particular, contributions to the recent debate about grounding and fundamentality are often framed by the aid of ‘because’; basically the idea of grounding is that some facts (the grounded ones) obtain because some other facts obtain (the more fundamental ones).[5] The same holds for the debate about truth-making; many truthmaker theorists think that truth-making has explanatory implications: if an object x makes a proposition y true, then y is true because of x.[6] But questions of priority and their formulation in terms of ‘because’ are by no means limited to debates in metaphysics; instead, they appear across the board in philosophical reasoning. Thus, one of the earliest and most influential cases in which ‘because’ carries the weight of a philosophical argument is concerned with practical virtues. In his attack on Euthyphro’s analysis of piety as god-belovedness,[7] Socrates makes use of a priority consideration phrased in terms of ‘because’ (hoti): Euthyphro admits that whatever is pious is pious *because* it is loved by the gods, but not vice versa; this admission then becomes the cornerstone of Socrates’ argument.

So, a rigorous account of the semantics and pragmatics of ‘because’ is wanting. This paper focuses on purely *logical* properties of ‘because’. It will be shown how those properties of ‘because’ can be captured in a deductive system.[8] Other semantic and pragmatic

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2 For a characterization of cognitive equivalence, see Künne (2003, p. 42).

3 See Dretske (1972) and van Fraassen (1980, chap. 5).

4 Notice, however, that the apparent sensitivity to contrastive stress is not unique to ‘because’ but also occurs, for example, with ‘only’. For an overview of the phenomenon see Glanzberg (2005).

5 See, for example, Fine (2001, especially 15f.), Cameron (2008), and Schaffer (2009).

6 See, for example, Rodriguez-Pereyra (2005), Schnieder (2006), and Schaffer (2010).

7 Stephanus pages 10a–11a.

8 Although the logic of ‘because’ has not received much attention so far, some noteworthy inspirations for the current paper are Bolzano (1837), Tatzel (2002), Correia (2005, chap. 3), and Schnieder (2008). It should be pointed out that the semantics of ‘because’ seem to be tightly connected to the notion of grounding, which has recently received much attention; see particularly Audi (manuscript), Batchelor (2010), Correia (2010), Fine (forthcoming), and Rosen (2010). Some of these authors have in fact developed accounts of the logic of grounding which resemble the currently proposed logic for ‘because’ in many respects. Their approaches and the current one

aspects of 'because' will be set aside. In particular, the paper will not present full truth-conditions of 'because'-sentences. Yet, the logic for 'because' helps to make aspects of our pretheoretic understanding of 'because' explicit and precise, thereby *constraining* accounts of the truth conditions of 'because'-sentences.

The paper is structured as follows: Section 2 presents a calculus for a propositional logic with truth-functional connectives and the connective 'because', which is then examined in Section 3. Section 4 discusses how the proposal bears on the grounding of logical truths. In Section 5, it is briefly shown how to extend the calculus in various respects.

1.2. The scope of the presented logic. Some preliminary remarks on the connective 'because' will help to understand the scope of the project. 'Because' seems to have quite distinct uses. A first distinction is that between a purely *evidential* or *inferential* use and *genuinely explanatory* uses. The purely evidential use of 'because' is exemplified by utterances such as:

(3) She must like Ann a lot, because she typed Ann's script for her.

Here, the 'because'-clause does not provide an explanation or ground of why the main clause is true; rather, it states a reason for why it is (or should be) believed. If any genuinely explanatory relation holds between the two clauses in (3), it will run in the opposite direction: presumably, she typed the script for Ann because she likes Ann.

There are some typical though fallible marks of purely evidential 'because'-statements: first, they often involve epistemic modals in their main clauses (without such phrases, the statements tend to have a lower degree of acceptability).[9] Second, according to English grammar their two clauses should ideally be separated with a comma.[10] Third, such statements do not accept ordinary negation which rather triggers a nonevidential reading.[11] Yet, one can deny them with a special construction; in the case of (3):

(3*) No, *just because* she typed Ann's script *doesn't mean* that she likes her a lot.

The logic presented in this paper is not meant to apply to evidential uses of 'because' but only to genuinely explanatory uses.

However, the proposed logic is not claimed to apply to *every* explanatory occurrence of 'because'. 'Because'-sentences can be used to give different *sorts* of explanation. A major division is that between causal and noncausal explanations (all mathematical explanations are noncausal, and many explanations in, e.g., linguistics, philosophy, or literary studies are noncausal too), and there are several potential subdivisions (e.g., mechanical versus rationalizing causal explanations, or conceptual versus constitutive noncausal ones). The explanations for which the logic is designed are of a noncausal character, and it is left open whether it applies to every kind of explanation.[12]

Hence, applications of the rules constituting the proposed logic may be in need of certain restrictions. What kind of restrictions depends on how the distinction between different sorts of explanation bears on the semantics of 'because'. There are three possibilities. First,

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differ in focus, however: while theirs are primarily metaphysical in nature, the current one takes as its starting point reflections on the use of 'because' and thus contributes to the philosophy of language. A detailed comparison has to wait for another occasion.

9 Cp. Morreal (1979, p. 236).

10 Cp. Kac (1972).

11 Cp. Bender & Kathol (2001).

12 The minimal claim is that the logic covers at least those explanations which correspond to a metaphysical notion of ground; cp. Fine (2001, p. 16).

'because' could be *semantically ambiguous* between, for example, causal and noncausal readings. Second, 'because' might be univocal but *context-dependent*, picking out different relations of explanatory relevance in different contexts (compare indexicals such as 'I'). Linguistic contexts in which causally related objects are involved might, for example, normally make 'because' pick out causality as the salient relation of explanatory relevance. Third, 'because' might be univocal and context-invariant (with respect to explanatory relations) but exhibit what linguists call a *lack of specification*. On this view, 'because' is univocally and across all contexts used to give explanations, but *explanation* is a genus with different species (compare: 'mammal' applies univocally and across all contexts to instances of any species of the genus *mammal*). While a decision between those alternatives would require a paper on its own,[13] the possible consequences of the decision can be outlined. Since it is left open whether the proposed logic applies to every kind of explanation expressible by 'because'-statements, it may be that the logical rules only apply to a certain meaning of 'because' (if 'because' is ambiguous), or to 'because' as used in a distinguished class of contexts (if 'because' is context-dependent), or finally to 'because' as used to give certain kinds of explanation (if 'because' lacks specification). This cautionary remark should suffice for now.

Finally, a terminological note: being interested in *explanatory* uses of 'because', I sometimes simply call a 'because'-sentence an *explanation*, its main clause its *explanandum*, and its 'because'-clause its *explanans*. But some explanations (e.g., those of how something is done, or how it is possible) require other linguistic forms than 'because'-sentences, for example, 'by'-locutions,[14] and many aspects of explanation (e.g., features of the speech act of explaining) are independent of the semantics of 'because'. Even though a general account of explanation and a semantic account of 'because' may overlap, they should not be conflated.[15]

§2. A propositional calculus. This section presents the calculus BC, an extension of a classical propositional natural deduction calculus. Its object-language L_{BC} is a standard language containing the connectives '$\vee$', '$\neg$', '&', '$\rightarrow$', which are treated by the usual deduction rules. Additionally, L_{BC} contains the binary connective 'because', whose rules are developed in what follows.

First, the calculus needs *introduction rules* for 'because', allowing derivations of 'because'-statements from statements whose main connective is not 'because'. The rules exploit a systematic interplay between 'because' and the classical truth-functional connectives. The basic idea is that those connectives have a distinctive feature:

Core Intuition A sentence governed by a classical truth-functional connective has its truth-value *because of* the truth-values of the embedded sentences.[16]

The *Core Intuition* straightforwardly yields introduction rules for 'because'. Consider disjunctions. The usual rule of $\vee$-introduction captures the fact that a sentence S entails any disjunction D in which it occurs as a disjunct. But the truth-value of a disjunction is not only *entailed* by, but moreover *explainable* in terms of the truth-values of its disjuncts: if a disjunct d of a disjunction D is true, then D is true *because* d is true. (Note that in this

13 See Nickel (2010) for an argument against context-dependency.

14 On 'how'-explanations, see for example, Cross (1991).

15 As was stressed by Bromberger (1962).

16 On this idea cp. Schnieder (2008).

formulation, other than in schema **Truth**, the truth predicate is only used as an expressive device of stating generalizations about explanations; it is not *part* of the explanation aimed at.) Hence, a true sentence entails explanations of disjunctions in which it occurs as a disjunct. Accordingly, inference rules are stateable allowing us to derive an explanation of a disjunction from any premise:

$$\frac{\varphi}{(\varphi \vee \psi) \text{ because } \varphi}\ \ \textbf{$\vee$-bec} \qquad \frac{\psi}{(\varphi \vee \psi) \text{ because } \psi}\ \ \textbf{$\vee$-bec}$$

(The schematic letters in the rules can be substituted with arbitrary wffs of the language.)

The rules for the other truth-functional connectives can be formulated analogously:

$$\frac{\varphi}{\neg\neg\varphi \text{ because } \varphi}\ \ \textbf{DN-bec}$$

$$\frac{\psi}{(\varphi \rightarrow \psi) \text{ because } \psi}\ \ \textbf{$\rightarrow$-bec} \qquad \frac{\neg\varphi}{(\varphi \rightarrow \psi) \text{ because } \neg\varphi}\ \ \textbf{$\rightarrow$-bec}$$

$$\frac{\varphi \qquad \psi}{(\varphi \,\&\, \psi) \text{ because } \varphi}\ \ \textbf{\&-bec} \qquad \frac{\varphi \qquad \psi}{(\varphi \,\&\, \psi) \text{ because } \psi}\ \ \textbf{\&-bec}$$

The above rules yield explanations of disjunctions, conjunctions, and conditionals, but not explanations of their negations. However, such explanations also follow from the *Core Intuition*. Assume, for example, the negation of a conjunction is true. This will be so either because the first conjunct is false or because the second is false. So, we can state rules allowing us to derive explanations of negations of truth-functional compounds:

$$\frac{\neg\varphi \qquad \neg\psi}{\neg(\varphi \vee \psi) \text{ because } \neg\varphi}\ \ \textbf{$\neg\vee$-bec} \qquad \frac{\neg\varphi \qquad \neg\psi}{\neg(\varphi \vee \psi) \text{ because } \neg\psi}\ \ \textbf{$\neg\vee$-bec}$$

$$\frac{\varphi \qquad \neg\psi}{\neg(\varphi \rightarrow \psi) \text{ because } \varphi}\ \ \textbf{$\neg\rightarrow$-bec} \qquad \frac{\varphi \qquad \neg\psi}{\neg(\varphi \rightarrow \psi) \text{ because } \neg\psi}\ \ \textbf{$\neg\rightarrow$-bec}$$

$$\frac{\neg\varphi}{\neg(\varphi \,\&\, \psi) \text{ because } \neg\varphi}\ \ \textbf{$\neg$\&-bec} \qquad \frac{\neg\psi}{\neg(\varphi \,\&\, \psi) \text{ because } \neg\psi}\ \ \textbf{$\neg$\&-bec}$$

Some comments on the rules are in order. First, these rules are peculiar in that they always involve the introduction of a truth-functional connective within the scope of 'because'.[17] Thereby, they capture the interaction of 'because' and the other connectives, exploiting the *Core Intuition*. Second, consider the introduction rule **&-bec**. Is a statement of the form '(p & q) because p' really true? A source for worries is that the explanation given is *incomplete*: the truth of the explanans 'p' is insufficient for the truth of the explanandum 'p & q' (the same doubt applies to the $\neg\vee$**-bec** and the $\neg\rightarrow$**-bec** rule).[18]

However, that 'because'-statements are often true but incomplete is a well-known fact.[19] Just think of causal explanations. The explanans of a causal explanation, taken by itself, seldom suffices to ensure the truth of the explanandum. A roof can crash because it is hit by a falling tree, even though the falling of the tree, taken by itself, does not ensure that the roof crashes. A *complete* explanation of the crash whose explanans is sufficient for the explanandum would have to cite information on the conditions of both the tree and the roof, and on numerous circumstantial facts as well (such as the force of gravity). But not only causal explanations are typically incomplete. To use a famous example of a noncausal explanation: Xanthippe became a widow because Socrates died.[20] This is a correct explanation corresponding to some noncausal dependency relation. Yet, the death of Socrates, taken by itself, does not ensure that Xanthippe became a widow since this also requires that Xanthippe was married to Socrates at the time of his death.

So, the ordinary use of 'because' does not require a 'because'-statement to express a complete explanation. It is a difficult question to what extent an explanation can be incomplete and yet be correct (is there a *measure* for incompleteness?). For the present purposes, the question need not be settled. A minimal condition for the truth of 'p because q' is that the truth of 'q' is explanatorily relevant for the truth of 'p', and explanations derivable by the **&-bec** rule meet this condition. Whether the rules stated above deviate to some extent from those governing the natural language connective 'because' is a question for future inquiries into the semantics of 'because'. Even if the rules and ordinary language did not perfectly match, they would still do a job of approximating the logic of 'because'. (Compare: even if the rules for the truth-functional conditional do not perfectly match the logic of the English 'if ... then ...', they are useful in illuminating important aspects of it.)

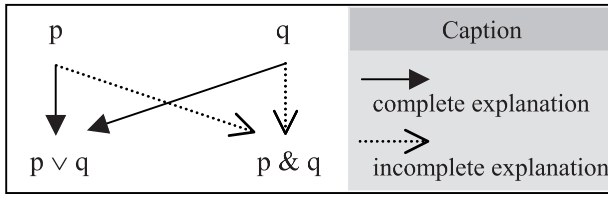
A final worry: assume that ϕ and ψ are true. Then $\ulcorner\phi \,\&\, \psi\urcorner$ is assigned exactly the same explanantia by **&-bec** that $\ulcorner\phi \vee \psi\urcorner$ is assigned by $\vee$**-bec**. So, one may fear that the rules do not sufficiently discriminate between conjunctions and disjunctions here. However, while there is a relevant difference between the conjunction and the disjunction, it is not that they have different explanantia. They have the same. What differs is the *status* of those explanantia. While the explanantia of the conjunction only provide *incomplete* explanations, the same explanantia serve as *complete* explanations for the disjunction:

[17] Due to the mentioned peculiarity, the rules for 'because' do not live up to Gentzen's original ideal of natural deduction calculi (neither does any calculus containing a rule for double negation; on the history of natural deduction, see Pelletier, 1999). So, one may quarrel about whether to call BC a natural deduction calculus; here, nothing hangs on that.

[18] There are other senses in which an explanation may be called 'incomplete' or 'partial'—see Hempel (1965, p. 415f.)—but present purposes do not require a discussion.

[19] Cp. Railton (1981, p. 239ff.) for a similar point.

[20] Cp. Kim (1974).



This difference, however, does not affect the truth of the relevant ‘because’-statements, since ‘because’ does not discriminate between complete and incomplete explanations; instead, it used to give either of them.

Having introduced the introduction rules for ‘because’, let us come to an elimination rule. ‘Because’ is a *factive* connective: any instance of ‘p because q’ implies the corresponding instances of ‘p’ and ‘q’. This gives us the following elimination rule:

$$\frac{\varphi \text{ because } \psi}{\varphi} \qquad \textbf{FB} \text{ Factivity of ‘because’}$$

$$\frac{\varphi \text{ because } \psi}{\psi} \qquad \textbf{FB} \text{ Factivity of ‘because’}$$

Moreover, ‘because’ (or, more generally, explanation) has two important structural properties which warrant the derivation of ‘because’-statements from other ‘because’-statements. Firstly, explanation is asymmetrical. As Dowe (2000, p. 167) puts it: if x explains y, it is not the case that y explains x.[21] If the asymmetry of explanation is accepted and ‘because’-statements provide explanations, ‘because’ should be a noncommutative connective and obey the following inference rule:

$$\frac{\varphi \text{ because } \psi}{\neg\,(\psi \text{ because } \varphi)} \qquad \textbf{AB} \text{ Asymmetry of ‘because’}$$

Secondly, explanation may seem to be transitive:[22] if an explanans ψ of an *explanandum* ϕ is explained by an explanans ξ, then ξ also counts as an explanans of ϕ (although a less direct explanans than ψ). If the transitivity of explanation is accepted and ‘because’-sentences provide explanations then ‘because’ should be a chainable connective and obey the following inference rule:

$$\frac{\varphi \text{ because } \psi \qquad \psi \text{ because } \xi}{\varphi \text{ because } \xi} \qquad \textbf{T-bec} \text{ Transitivity of ‘because’}$$

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21 The asymmetry of explanation is widely acknowledged. To cite but some examples: it already features in Plato’s dialogues—see Sharvy (1986, p. 513f.)—and it is defended by Bolzano (1837, sec. 209), who attributes the view to Aristotle. More recently, it played a prominent role in the debate about explanation; see, for example, Kitcher (1981, p. 522ff.). Note, however, that while most authors in that debate agree that explanations are *usually* irreversible, some leave it open whether this is an exceptionless rule; Woodward (1984) even explicitly denies it.

22 That explanation is transitive is, however, controversial. It is denied, for example, by Hesslow (1981) and Owens (1992, p. 15ff.).

While it is debatable whether 'because' has the described features of asymmetry and transitivity, a thorough discussion would go beyond the scope of this paper. Let me, for the nonce, just call to attention that the participants in the debate usually agree that *most* typical cases of explanation are irreversible, and also that at least small chains of explanations typically preserve explanatory value. So, it should in any case be instructive to see what the properties of universal asymmetry and transitivity would mean for a logic of 'because'.

§3. An examination of the calculus.

3.1. Consistency and conservativeness. This section examines the deductive system BC in some detail. After showing that BC is a consistent and moreover conservative extension of classic propositional logic (for short: CC), features of BC will be discussed that can shed light on our understanding of 'because'.

B.1 BC is consistent, that is, for every formula ϕ: If $\vdash_{BC} \phi$ then not $\vdash_{BC} \neg\phi$.[23]

Proof. BC is consistent if there is an interpretation i mapping the formulas of BC to the truth-values T and F under which (i) every inference rule is truth-preserving,[24] and which (ii) interprets '¬' classically, such that $\forall\phi : i(\ulcorner\neg\phi\urcorner)$=T iff $i(\phi)$=F. For, assume that $\Im$ is an interpretation on which the rules of BC are truth-preserving. If we now assume that there is a formula ϕ with $\vdash_{BC} \phi$ and $\vdash_{BC} \neg\phi$, it follows that $\Im(\phi)$=T and $\Im(\ulcorner\neg\phi\urcorner)$=T. But then $\Im$ does not interpret '¬' classically.

Now let us define an interpretation $\Im$. Sentential letters receive an arbitrary interpretation. The truth-functional connectives are interpreted classically, with $\Im(\neg\phi)$= T iff $\Im(\phi)$=F, etc. Let $\ulcorner C(\phi)\urcorner$ denote the complexity of ϕ, in the sense of the number of token symbols in ϕ; for example, C('p')=1, C('¬p')=2, C('¬¬p')=3. Now $\Im$ treats 'because' as follows:

BEC $\Im$ ($\ulcorner\phi$ because $\psi\urcorner$)=T iff (i) $\Im$ ($\ulcorner\phi$ & $\psi\urcorner$)=T and (ii) $C(\phi) > C(\psi)$.

On $\Im$, every inference rule of BC is truth-preserving, as can easily be checked. Hence, BC is consistent. (Note that BEC is merely used for proving the consistency of BC; for that purpose, it need not be a faithful interpretation of the semantics of 'because' in English.)

B.2 BC is a conservative extension of CC. In other words:
For every formula ϕ of CC, $\vdash_{BC} \phi$ iff $\vdash_{CC} \phi$.

Proof. Since BC contains all rules of CC, the problematic part is only: $\forall\phi$ of CC, if $\vdash_{BC} \phi$ then $\vdash_{CC} \phi$. So, assume ϕ is a CC-formula with $\vdash_{BC} \phi$ but not $\vdash_{CC} \phi$. Now consider again interpretation $\Im$ as defined above. Since $\nvdash_{CC} \phi$, there is an interpretation $\Im^*$ with $\Im^*(\phi)$=F, whose definition differs from $\Im$ at most with respect to the sentential letters in ϕ (for, $\Im$ interprets the connectives classically and CC is complete with respect to classical consequence). Under $\Im$, all rules of BC are truth-preserving, and $\Im^*$ treats the connectives as $\Im$ does; hence, the rules of BC are also truth-preserving under $\Im^*$. But then, $\vdash_{BC} \phi$ implies that $\Im^*(\phi)$=T, which contradicts the assumption that $\Im^*(\phi)$=F. So, if $\vdash_{BC} \phi$ then $\vdash_{CC} \phi$.

[23] Corner quotes are omitted in the scope of '⊢'.

[24] Roughly, a rule is truth-preserving under an interpretation i iff whenever it is applied to n formulas $\varphi_1 \ldots \varphi_n$ with $i(\varphi_1)$=T … $i(\varphi_n)$=T, the derived formula is also true under i. This characterization suffices for the present purposes.

(B.2 is stronger than B.1 since any conservative extension of a consistent theory ϑ which allows *ex falso quodlibet* is consistent. So, one could prove B.1 by proving B.2. The above procedure was chosen for its greater accessibility.)

3.2. Some features of ‘because’ and BC. BC allows the derivation of theorems essentially involving ‘because’, as for example:

T₁ p → (¬¬p because p)

T₂ ¬¬q → (¬¬q because q)

The proofs are trivial, for example:

1	(1)	¬¬q	A
1	(2)	q	1 DNE
1	(3)	¬¬q because q	2 DN-bec
	(4)	¬¬q → (¬¬q because q)	1,3 →I

Now in as much as the rules of BC are also adequate for the English connective ‘because’, the system can be used to illuminate some important features of that expression. Let us begin by noting that

B.3 BC is not congruential.

(A calculus *D* is *congruential* iff all formulas which are logically equivalent in *D* can be substituted for each other *salva derivatione*; in other words, iff for all formulas ϕ, ψ: if $\phi \dashv\vdash \psi$ then for any context C: C $(\phi) \dashv\vdash$ C(ψ))

B.3 is a welcome result. For, consider Theorem T_1:

T₁ p → (¬¬p because p).

If BC were congruential we would, by accepting Theorem T_1, also be committed to accepting numerous formulas as theorems that are intuitively invalid, as for instance

(i) p → (p because ¬¬p)

(ii) p → (p because p)

(iii) p → (p because (p & (q ∨ (q → ¬p)))).

For, the formulas ‘¬¬p’, ‘p’, and ‘p & (q ∨ (q → ¬p))’ are interderivable in BC.

Fortunately though, B.3 holds. By the asymmetry of ‘because’, one can easily establish that instead of (i) and (ii) their negations are theorems of BC. Hence, since BC is consistent, the examples establish B.3. (The negation of (iii) is also derivable in BC.)

The examples that demonstrate B.3 also yield the more specific result that formulas which are equivalent in classical truth-functional logic are not always substitutable for each other in the context of ‘because’. Since formulas that are interderivable in CC are also modally equivalent, this confirms that

B.4 ‘because’ is a hyperintensional connective.

So, the noncongruentiality of BC is a desirable feature because it reflects the hyperintensionality of ‘because’. In fact, the interaction between ‘because’ and double negation in BC models the interaction between ‘because’ and the truth predicate, expressed in schema **Truth** (see Section 1). With these results, one of the main goals of the paper has been achieved. The hyperintensionality of ‘because’ seemed a disturbing feature, potentially preventing ‘because’ from receiving a systematic treatment. But BC shows how the strong opacity of ‘because’ is tameable in a well-behaved calculus.

There are some further noteworthy features of BC. The following is a theorem:

T_3 $\neg$ (p because p).

Hence:

B.5 ‘because’ is an irreflexive connective.

Another observation is that explanation is not *exclusive*; an explanandum can have different nonequivalent but nonconflicting explanantia:

B.6 For some formula ϕ, there are nonequivalent formulas ψ and ξ for which both $\ulcorner\phi$ because $\psi\urcorner$ and $\ulcorner\phi$ because $\xi\urcorner$ are derivable under the same consistent assumptions.

This can easily be seen from the following theorems:

T_4 p $\rightarrow$ ((p $\vee$ q) because p)

T_5 q $\rightarrow$ ((p $\vee$ q) because q)

Even though BC is not a modal system, it can be used do draw some consequences on the modal properties of explanation:

B.7 Explanation can be contingent, in the sense that one explanandum can have different explanantia with respect to different possible worlds.

That B.7 is an informal consequence of the logic of BC can be seen from disjunctions of contingent truths. Assume it is contingently the case that p and that $\neg$q BC yields that (i) (p $\vee$ q) because p, and (ii) $\neg$ ((p $\vee$ q) because q). However, had it been true that q and false that p, we would have had: (iii) (p $\vee$ q) because q, and (iv) $\neg$ ((p $\vee$ q) because p). Hence, the explanans of ‘p $\vee$ q’ varies across possible worlds.

B.8 Not every explanandum is necessitated by every explanans of it.

Recall the discussion of the **&-bec** rule. A conjunction always has its two conjuncts as two explanantia. Now if one of the conjuncts could have been true without the other being true, then one of the explanantia could have been true without the explanandum, that is, the conjunction, being true. But the phenomenon is not limited to the proposed explanations of conjunctions; it was already pointed out that many (if not most) ordinary ‘because’-statements have an explanans which does not necessitate its explanandum. That Oswald fired his gun does not necessitate JFK’s death, even though JFK died because Oswald fired his gun. And the marriage of Paul does not necessitate the fulfilment of his mother’s dream, even if his mother’s dream was fulfilled because he married.

3.3. Truth-making. ‘Because’ does not distribute over either conjunctions or disjunctions:

B.9 (p & q) because r $\nvdash$ (p because r) & (q because r)

B.10 (p $\vee$ q) because r $\nvdash$ (p because r) $\vee$ (q because r)

The nondistributivity over conjunction, that is, B.9, becomes clear from a reflection on the introduction rule **&-bec**. This rule generates incomplete explanations of conjunctions: a conjunct ϕ of a conjunction $\ulcorner\phi$ & $\psi\urcorner$ can be cited in a partial explanation of the conjunction. But ϕ need not be an explanans of a conjunct of $\ulcorner\phi$ & $\psi\urcorner$: neither of itself (due to irreflexivity), nor of ψ, which can be a wholly independent matter.

The nondistributivity over disjunction, that is, B.10, is shown by the following derivation:

1	(1)	$(p \vee p)$ because p	A
	(2)	$\neg$ (p because p)	T_3
1	(3)	$((p \vee p)$ because p) & $\neg$ (p because p)	1,2 &I

Let me briefly relate those results to the debate about truth-making. As pointed out earlier, talk about truth-making is often regarded as connected to ‘because’-explanations. Recently, Horwich (2008, p. 273) even argued that the only acceptable part of truth-maker theories consists in implicated claims about ‘because’:

> The grains of truth in a truthmaker theory are (i) schematic constitutive theses of the form, “p because q_1, q_2, ... and q_n”—where “p” ranges over the propositions of a given logical type (e.g. disjunctions, counterfactuals, etc.); and (ii) conclusions to the effect that only certain types of proposition can ever appear in any of the q-positions [...].

Of course, one may acknowledge the positive part of Horwich’s claim—one important output of truth-maker theories are principles on explanation—without sharing his scepticism about truth-making. Now, *if* truth-making has explanatory implications, it can be instructive for the evaluation of allegedly constitutive principles on truth-making to compare them with analogues that are formulated explicitly in terms of ‘because’. Take, for example, the following two theses which have recently been the subject of a controversial debate:[25]

Con_{TM} If x is a truth-maker of a conjunction C, x is a truth-maker of both conjuncts of C.

Dis_{TM} If x is a truth-maker of a disjunction D, x is a truth-maker of one of D’s disjuncts.

One motivation for holding those theses can be the intuition that explanation (‘because’) distributes over conjunction and disjunction. But, as was argued above, this motivation would be a failure. So, further investigation into the connections between the proposed logic of ‘because’ and truth-making promises to be a fruitful project.

§4. Logical truths.

4.1. Explanations of logical truths. Some of the ‘because’-formulas derivable in BC have an explanandum which is a logical truth of classic propositional logic. Here is an example:

T_6 $((p \rightarrow p) \vee q)$ because $(p \rightarrow p)$

So, an important result which can be established by the aid of BC is that

B.11 Not every logical truth is explanatorily basic (i.e., unexplainable).

[25] See, for example, Read (2000) and Rodriguez-Pereyra (2006).

For the following results, we should first sharpen the concept of a *basic* (unexplainable) formula for the calculus BC. Given a set of assumptions Γ and a formula ϕ, ϕ can be called grounded with respect to Γ if there is a ψ for which ⌜ϕ because ψ⌝ is derivable from Γ. But even if there is no such formula ψ, there is an important sense in which ϕ need not be unexplainable with respect to Γ. For, it may still be the case that a *disjunction of explanations* of ϕ is derivable from Γ. For instance, 'p' should not be counted as unexplainable with respect to the assumption '(p because q) ∨ (p because r)'. After all, given the assumption, we know that 'p' has an explanation, even if we cannot decide how 'p' is to be explained (there is no formula ψ such that ⌜p because ψ⌝ is derivable from the assumption). So, let us say:

Basic-Γ A formula ϕ is basic with respect to a set of assumptions $\Gamma \leftrightarrow_{df.}$ ϕ is derivable from Γ, and there are no formulas ψ_i such that ⌜(ϕ because ψ_1) ∨ … ∨ (ϕ because ψ_n)⌝ is derivable from Γ.

A formula ϕ is *grounded* with respect to Γ iff ϕ is derivable from Γ but not basic with respect to Γ. A formula can be called *basic* (grounded) without qualification iff it is basic (grounded) with respect to the empty set of assumptions.[26]

Now let us return to Theorem T_6. While this theorem provides a particular explanation of a logical truth, there are other theorems which show that a given logical truth ϕ is not basic while not yielding any particular explanans of ϕ. Take, for instance, the following theorem:

T₇ ((p ∨¬p) because p) ∨ ((p ∨¬p) because ¬p)

According to Theorem T_7, 'p∨¬p' is either explained by 'p' or by '¬p'. Since this exhausts the space of possibilities, Theorem T_7 shows that 'p∨¬p' is grounded. However, neither 'p' nor '¬p' are derivable in BC; hence, it cannot be decided without further assumptions which of the explanations holds for 'p∨¬p'.

Theorem T_7 illustrates an important feature of BC: not only are some logical truths grounded, but some of them are true because of a nonlogical truth. In fact, the result carries over to any truth-functional tautology (and hence, to any theorem of CC):

B.12 Any theorem of CC is explainable in terms of nonlogical truths.

More precisely: If ϕ is a theorem of CC then an explanation ⌜ϕ because ψ_1⌝ or a disjunctive explanation ⌜(ϕ because ψ_1) ∨ … ∨ (ϕ because ψ_n)⌝ is derivable in which every ψ_i is a formula, but not a theorem of CC.

The proof of B.12 makes use of the following metatheorem:

B.13 If ϕ is not a literal of CC, there are formulas ψ_i each of which is less complex than ϕ such that ⌜$\phi \rightarrow$ ((ϕ because ψ_1)∨ … ∨ (ϕ because ψ_n))⌝ is derivable.

(A *literal* is a sentential letter or its negation.)

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26 The grounded/basic (with respect to Γ) distinction is not exhaustive, because it only applies to formulas that are derivable (with respect to Γ). This is indeed intended because the distinction corresponds to that of grounded and basic *truths* or *fact*. Think of the formulas derivable from Γ as those which are true given the assumptions in Γ.

Proof of B.13. If ϕ of CC is not a literal, there are formulas ψ and ξ such that ϕ is identical to $\ulcorner\neg\neg\psi\urcorner$, $\ulcorner\psi\vee\xi\urcorner$, $\ulcorner\psi\&\xi\urcorner$, $\ulcorner\psi\rightarrow\xi\urcorner$, $\ulcorner\neg(\psi\&\xi)\urcorner$, $\ulcorner\neg(\psi\vee\xi)\urcorner$, or $\ulcorner\neg(\psi\rightarrow\xi)\urcorner$. In each case, the introduction rules for ‘because’ yield a theorem partly verifying B.13; together, the theorems prove B.13. Two cases should suffice for illustration:

T₈ ¬¬p → (¬¬p because p)

T₉ (p ∨q) → (((p ∨q) because p) ∨ ((p ∨q) because q))

Proof B.12. Let ϕ be a theorem of CC. By B.13 and the fact that ϕ is a theorem, a disjunctive explanation of ϕ in terms of ψ_1 to ψ_n is derivable with each ψ_i being less complex than ϕ. Take the first disjunct, $\ulcorner\phi$ because $\psi_1\urcorner$, as an assumption. If ψ_1 is not a literal, it is (by factivity and B.13) explainable in terms of less complex formulas ψ^*_1 to ψ^*_m. By the transitivity of ‘because’, the same holds for ϕ. Now each ψ^*_i which is not a literal again has a disjunctive explanation in terms of less complex formulas; by transitivity, the explanation also applies to ϕ. Since formulas of CC are finite, repeating the procedure for each disjunct in each of the disjunctive explanations finally yields a disjunctive explanation of ϕ in terms of literals, which holds under the assumption of $\ulcorner\phi$ because $\psi_1\urcorner$. The same reasoning applies to each of the original ψ_i. Hence, in a finite number of steps, a disjunctive explanation of ϕ in terms of literals can be derived, which proves B.12. (Indeed, a slightly stronger result than B.12 has been reached, namely that every tautology is explainable in terms of literals.)

4.2. Discussion. For every tautology ϕ, it can be shown in BC that ϕ is disjunctively explainable in terms of nonlogical truths (even if it cannot be decided what the explanation is). This result may be surprising and/or look awkward. One could be worried about it because one holds that (i) logical truths are independent of how the world is, or that (ii) they are true because of some noncontingent factors, as for example, the laws of logic or the nature of the logical concepts. Finally, one could have the epistemological worry that (iii) possession of contingent grounds threatens the *a priori* knowability of logical truths. Such worries are unnecessary; but discussing them will help to clarify the relation between the concepts involved.

Re (i). There is a sense in which logical truths are independent of how the world is, even if they can be explained in terms of contingent facts: they are necessary truths and thereby *modally* independent of actual facts.[27]

Admittedly, some philosophers will also hold that

Nec No necessary truth can be true on contingent grounds.

But why should this be so? Ambrose (1956, p. 247) argues for **Nec** by stating: ‘Part of what is meant by saying that a proposition is necessary is that matter of fact is no ground for its truth.’ However, this seems plainly wrong: that a proposition is necessary means that it could not have been false, or that it is true in every possible world. There is nothing in the concept of necessity which would be concerned with the *grounds* of *why* a truth is true.[28]

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27 On modal notions of dependence, see Simons (1987, p. 293f.).

28 Cp. Fine’s (1994, p. 9) account of essence, which is partly motivated by the observation that ‘[t]he concept of metaphysical necessity, [. . .], is insensitive to source’.

Another reason for endorsing **Nec** could be the thought that if a necessary truth has a contingent ground, it could have lacked that ground and therefore could have failed to be true. The thought is mistaken, though. That a truth T has a contingent explanans E entails that T could have lacked *that* explanans (in worlds in which E is false, E cannot explain T). But this is not to say that T could have failed to have *any* explanans: while the explanation of a logical truth may vary from world to world, it necessarily has an explanation.

Re (ii). That a logical truth can be explained in terms of contingent facts does not imply that it cannot *also* be explained in some other way. There is no need to choose between these two options because it was already pointed out that explanation is not exclusive (see B.6). The mere possibility to explain logical truths in terms of noncontingent factors does not exclude its explainability in terms of contingent truths. It is, for instance, a venerable idea that genuine *laws* are explanatory; this may then equally be true for laws of nature and for laws of, for example, logic and mathematics. Whether this idea is correct cannot be decided here (it depends, among other things, on the right conception of laws); but *if* it is correct, then logical truths may have explanations in terms of logical laws while at the same time having the explanations in terms of contingent truths that are derivable in BC. If it is, for example, a law of logic that any proposition or its negation is true, this law may give rise to an alternative explanation of why a particular instance of '$p \vee \neg p$' is true. (Note that such a case would provide another counterexample against the distributivity of 'because' over disjunctions; see Section 3.3)

Of course, once a specific account is developed of how logical truths are explained by noncontingent factors, it may turn out that this particular account after all conflicts with the explanations derivable in BC. But this will be due to the specific makeup of the account, not due to any general feature of explanation. In such a case there is a good reason to view the conflict as a vice of the account rather than a vice of the proposed logic of explanation. For, the current proposal is built on the intuitively valid idea that a truth-functional compound has its truth-value because of the truth-values of its components. This idea is perfectly general and it is directly built into the inference rules. If the idea reflects an important aspect of the semantics of 'because' and the truth-functional connectives, it is hard to see any reason why it should not be applied to those truth-functional compounds which are necessary and moreover logical truths.

Re (iii). Now for the epistemological worry. Does the approach imply that logical truths are not knowable a priori? One reason to think so would be the idea that in order to know a truth, you have to know its grounds or explanation. But that idea is wrong. We know all kinds of things without knowing why they are true. Indeed, the search for an explanation typically starts because we are puzzled about something we know.[29] But even if a truth can be *known* without knowledge of its grounds, it may seem puzzling how a truth should be knowable *a priori* if it has contingent grounds. Here is how: we can know about a logical truth T that it necessarily has an explanation, and we can know this without recourse to contingent facts (including any contingent grounds of T, even if there are such grounds). This enables us to know a priori that T is true. Moreover, if logical truths are, as suggested above, explanatorily overdetermined and can also be explained by logical laws then there is a further account of how we can know them a priori: via our a priori knowledge of logical laws.

[29] Cp. Bromberger (1962).

A remaining worry may be that even if the proposal does not exclude a priori knowledge of logical truths, it at least opens the possibility of a posteriori knowledge of them; but there cannot be such knowledge, since there cannot even be evidence for logical truths.[30] However, the latter assumption is false.[31] If I know that Socrates is wise, I may correctly conclude that he is wise or he is not wise, and this inference preserves knowledge. Perhaps, in this case it is likely that I had the knowledge before, but this is only because the example is extremely simple. In cases of more complex logical truths, an analogous reasoning can certainly produce knowledge. In drawing complicated inferences from a nonlogical truth, one can even come to know a logical truth without realizing that it is a logical truth.

Finally, some worries about the current proposal may stem from a confusion of two different objects of explanation. There is a crucial difference between explaining, of a given logical truth, why it is *true*, and why it is *logically* true. The proposed logic yields explanations of the former type, not of the latter. It does not allow to derive an explanation of why *it is logically true that snow is white or snow isn't*. And indeed, such an explanation cannot proceed in terms of contingent truths. But an explanation of why snow is white or isn't can.

§5. Extensions and variations. Some possible extensions and/or variations of BC will be outlined. Due to lack of space, the main purpose of the section must be to indicate directions for further research.

5.1. A quantificational extension of BC. First, let me introduce QBC, a quantificational extension of the propositional calculus BC. The language of QBC is L_{BC} enriched with the quantifiers '∃' and '∀', *n*-place predicate letters ('F', ...), the logical predicate '=', individual constants ('a', ...), and individual variables ('x', ...). QBC has the rules of BC plus standard introduction and elimination rules for the quantifiers.

QBC is a comparatively weak system, since explanations of quantified formulas cannot be derived in it. Nevertheless, it yields some useful results, for example, the theorem:

$$\mathbf{T_{10}}\ \ \forall x\,(Fx \rightarrow (Gx \text{ because } Fx)) \rightarrow \forall x\,(Fx \rightarrow \neg\,(Fx \text{ because } Gx))$$

This theorem is important for arguments such as Socrates' objection to Euthyphro, which involves a subargument trading on the asymmetry of explanation:

P Whatever is pious is loved by the gods because it is pious.[32]

C So, whatever is pious is not such that it is pious because it is loved by the gods.

The validity of this argument immediately follows from Theorem T_{10}.

QBC is also an interesting extension of BC with respect to the issue of fundamentality. Call a set Γ of assumptions explanatorily *founded* iff any formula ϕ is either basic with respect to Γ, or it is possible to derive disjunctions of explanations of ϕ with explanantia $\psi_1 \ldots \psi_n$ all of which are basic with respect to Γ. In BC, derivations start from finite

[30] Cp. Ambrose (1956).

[31] Cp. McQueen (1971).

[32] P is a faithful interpretation of Socrates' claim, whose literal translation is 'The pious is loved by the gods because it is pious'. For, the Greek phrase 'to hosion' ('the pious'), has different uses: it can denote an abstract property or idea (piety), or it can function as a quantifier phrase; cp. Allen (1970, p. 24) or Sharvy (1972, p. 212f.). Commentators agree that in premise P, 'the pious' must be understood in the latter way.

sets of assumptions, and all such sets are explanatorily founded. So, it may seem that BC dictates a positive answer to the question of whether there must be a fundamental layer of reality.[33]

However, that every set of assumptions is founded in BC is an accidental feature of the system which only operates with finite sets of assumptions; it is not an outcome of the principal ideas of the logic. This can be seen from QBC, in which there are unfounded but finite sets of assumptions. In standard predicate logic, assumptions can be formulated that are only satisfiable if the domain of interpretation contains infinitely many objects. Thus, the following formula characterizes an asymmetric, transitive, and right-universal relation; for it to be satisfied, the domain must contain infinitely many objects:

(1) $\forall x \exists y\,(Rxy)\ \&\ \forall x \forall y\,(Rxy \rightarrow \neg Ryx)\ \&\ \forall x \forall y \forall z\,((Rxy\ \&\ Ryz) \rightarrow Rxz)$

Now let us add the following assumption:

(2) $Fa\ \&\ \forall x\,(Fx \rightarrow \forall y\,(Rxy \rightarrow (Fx \text{ because } Fy)))$

These assumptions are consistent and together they ensure that there is an infinite chain of explanations, starting with 'Fa', in which every explanans is of the form 'Fx'. So, 'Fa' is grounded but does not have a fundamental explanation: any explanans ϕ of 'Fa' is itself of the form 'Fx'; so, by (1) and (2), ϕ itself has an explanans of the same form and is therefore grounded. Hence, the set of assumptions (1) and (2) is not founded and QBC is neutral with respect to the question of whether there must be a fundamental layer of reality.

Let me now turn to rules governing the interplay between quantified statements and 'because'. Existential quantifications correspond to infinite disjunctions and universal quantifications to infinite conjunctions. A plausible idea is that quantifications are true because of the true components of those corresponding infinite statements. Existential quantifications are then true because of their true instances.[34] We may thus formulate an introduction rule for explanations of existential quantifications:

$$\frac{\varphi(t)}{(\exists \nu\, \varphi(\nu)) \text{ because } \varphi(t)} \quad \textbf{∃-bec}$$

Restriction: variable ν does not occur in ϕ

Earlier, it was pointed out that in the case of disjunctions, explanatory overdetermination is possible: if both disjuncts of a disjunction D are true then there are two correct and sufficient explanations of D. Since existential statements correspond to disjunctions, there are cases of explanatory overdetermination for existential statements: if there are many Fs, there are many nonconflicting explanations of the truth that there are Fs.

The above account straightforwardly suggests an analogous treatment of universal statements. Just as existential statements, universal statements are true because of their instances. The difference is that whereas a single instance of an existential statement E provides a sufficient explanation of E, an instance of a universal statement U only provides an insufficient (a partial) explanation of T. This situation mirrors that of disjunctions and conjunctions: if ϕ and ψ are true, then both $\ulcorner \phi\ \&\ \psi \urcorner$ and $\ulcorner \phi \vee \psi \urcorner$ are true because of ϕ and because of ψ. However, the conjunction is only incompletely explained by its conjuncts, whereas the disjunction is completely explained by each of its conjuncts.

33 For a discussion, see for example, Schaffer (2003).
34 Cp. Lewis (1986, p. 223).

So, a rule for explanations of universal truths can be stated as follows:

$\dfrac{\forall \nu\ \varphi(\nu)}{(\forall \nu\ \varphi(\nu)) \text{ because } \varphi(t)}$	**∀-bec**

Admittedly, instances of the rule formulated in English are sometimes hard to swallow. ‘Every car in town weighs more than 100 kilos because this car weighs more than 100 kilos’ sounds odd, unless the said car is the only car in town. Otherwise, it would be natural to use phrases which make it explicit that only a partial explanation is given, as for example, ‘because, among other things’ or ‘partly because’. This may either be due to pragmatic or semantic factors (i.e., a limitation of the incompleteness tolerated by ‘because’). Since a decision of this matter depends on substantial considerations about the pragmatics/semantics interface, the question will be left open here. For now, two conditional claims can be made: if the observation reveals a semantic point then the developed logic should be taken as modeling the disjunction of the pure ‘because’ and the explicitly partial ‘because, among other things’. If the observation only reveals a pragmatic phenomenon—which seems more likely to me—then the logic is simply concerned with ‘because’.

While the current section presents the outline of a quantificational extension of BC, there is much more ground to be covered by further research. To name just some examples: QBC only yields adequate results if it is legitimate to quantify into an explanatory context; in a full treatment of a quantificational logic for ‘because’, this issue has to be carefully examined. Moreover, the rules for universal quantifications give rise to further questions, as for example: how do they bear on the issue of what grounds negative existential statements? How does the aforementioned idea of explanations by laws square with the proposal?

5.2. Variations of BC. Several modifications of system BC are worth exploring. Two interesting questions are (i) how the rules fare with a different underlying logic, and (ii) how the system fares with a weaker set of rules, or whether there are further attractive rules for ‘because’.

Re (i). While BC results from adding the rules for ‘because’ to a classical logic for the standard connectives, the rules for ‘because’ do not *presuppose* classical logic. One may, for example, use an underlying supervaluational framework. The intuitive motivation of the rules for ‘because’ would remain untouched, and since supervaluational logic yields all classical theorems as theorems, all results of the paper can be obtained within that framework. (An interesting question is how a determinateness operator would interact with ‘because’.)

Alternatively, one may combine the rules for ‘because’ with an intuitionist framework (i.e., with a set of standard rules for the connectives ‘&’, ‘∨’, and ‘→’, plus assumption introduction, *reductio* and *EFQ*). Call the resulting system BI. The rules for ‘because’ do not lose their plausibility in BI and the proofs of the main metatheoretic results (conservativeness, noncongruentiality, groundedness of tautologies in nonlogical truths) still go through. But because of the different underlying logics, BC and BI have different theorems containing ‘because’. For instance, the derivations of Theorems T_2 and T_7 fail in BI. The latter is desirable for an intuitionist since Theorem T_7 presupposes excluded middle; however, a weaker variant of Theorem T_7 is derivable in BI, namely:

$\mathbf{T_{7*}}$ $(p \vee \neg p) \rightarrow (((p \vee \neg p) \text{ because } p) \vee ((p \vee \neg p) \text{ because } \neg p))$

Theorem T_{7*} is an innocent theorem since intuitionists do not deny that the truth of a disjunction requires one of its disjuncts to be true. The derivation of Theorem T_2 fails in BI because it requires double negation elimination; indeed, Theorem T_2 is unacceptable if you think of truth in terms of provability: the double negation of ϕ may be provable while ϕ itself is not provable. $\ulcorner\neg\neg\phi\urcorner$ is true (provable) then, not because ϕ is true (provable) but only because you can derive a contradiction from $\ulcorner\neg\phi\urcorner$. (No analogous reasoning speaks against rule DN-bec, though: if a sentence is true (provable), its double negation can be regarded as true because of that. For, any proof of ϕ can indeed count as grounding a proof of $\ulcorner\neg\neg\phi\urcorner$.)

Re (ii). Are the rules for 'because' either too weak or too strong? The 'because'-introduction rules of BC are its essential ingredient; they all derive from the *Core Intuition* (see Section 2). But the structural rules of asymmetry and transitivity are not uncontroversial and one may explore weaker replacements of them. One might, for example, allow for certain exceptions to asymmetry, rendering 'because' merely nonsymmetric. The consequences of that move would depend on the sort of exceptions: obviously, some arguments become invalid if one allows for true instances of 'p because p'. (A traditional motivation for accepting at least one of them would be the theological idea of a *causa sui*.) Then, some results would have to make way for weaker variants, depending on how much of the asymmetry assumption is given up. Concerning transitivity, one could toy with a weaker version that allows only for limited chainings in canonical derivations. That would, for example, weaken the result about the nonlogical grounds of logical truths: only logical truths of a certain complexity would still be grounded in nonlogical truths, whereas more complex nonlogical truths would only be *indirectly* grounded in nonlogical truths (by being grounded in truths that are grounded in nonlogical truths, or in truths that are grounded in truths that are grounded in nonlogical truths, etc.).

However, as I accept both asymmetry and transitivity, the more pressing question for me is whether to enlarge the set of rules. What is tempting to add are rules of commutativity and associativity of conjunctions and disjunctions in the scope of 'because'. It may, for example, seem legitimate to move from 'p because (q & r)' to 'p because (r & q)', but the rules of BC are too weak to validate that inference. Similarly, it may seem legitimate to move from 'p because ((r & q) & s)' to 'p because (r & s)'. But again, the rules of BC do not warrant the move. So, it seems a good option to extend BC with rules of commutativity and associativity for '&' or '$\vee$'. First, however, one should reflect on the rationale of such rules.

Arguably, the intuition that such rules are plausible is not a basic datum. Instead, it is based on implicit assumptions on the semantics of the relevant connectives. A crucial question concerns the relation between the logical notation and the propositions expressed: does the order of conjuncts in a sentence reflect any aspect of its content, that is, the proposition expressed? While the question is not trivial, a positive answer would require an extremely fine-grained conception of propositions. On a more moderate view, the order of conjuncts is a merely linguistic phenomenon not indicative of any propositional difference.[35] Given such a view, the following principle can motivate rules of commutativity and associativity:

> If the difference between sentences φ and ψ is merely notational and does not reflect any aspect of the expressed propositions, then φ and

[35] The idea behind this principle seems comparable to Correia's (2010, particularly sec. 6) take on the relationship between views on factual equivalence and the logic of grounding.

ψ are explanatorily equivalent (i.e., φ and ψ are substitutable wherever they occur as clauses in a 'because'-sentence).[36]

Together with a not too fine-grained conception of propositions, on which the order of conjuncts and disjuncts is a merely notational matter, this principle warrants commutativity and associativity rules for '&' and '$\vee$' in the scope of 'because'.

Of course, there is much more to be said about the issues raised in this section than can be said in this paper. What the discussion is meant to show is how BC can serve as a fruitful starting point for the development of related systems that deserve to be examined.

§6. Conclusion. A deductive system for a propositional logic of 'because' has been presented. It can serve as a basis for further extensions which treat, for example, quantified and modal formulas. Also, while the current paper only provides a syntactic calculus, it is desirable that the system be supplemented with a formal semantics.[37] Such issues, however, require papers of their own.

But system BC already has philosophically important implications which have been addressed in the paper; it bears, for example, on the question of how logical truths can be explained, and on controversies from the debate about truth-makers. Future developments of the logic of 'because' promise to yield further results for those and related issues.

Most importantly, however, system BC should help to remove general doubts about whether the semantics of 'because' are tractable at all. Explanatory discourse may involve a great deal of pragmatic phenomena, but 'because' has a stable semantic core that deserves to be investigated.

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[36] Compare Williamson (1985) and Fine (2000) on whether the order of arguments in a relational predication reflects an aspect of the corresponding relation, or only of the relational notation.

[37] For accounts which seem to fit the needs see Correia (2010) and Fine (forthcoming).

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