ing of justification is, in my terms, that (1) the epistemologist has to choose between (a) mind-internalist foundationalism (e.g., evidentialism), (b) mind-externalist foundationalism (e.g., process reliabilism), and (c) mind-internalist coherentism (e.g., simple coherentism), and (2) objections such as the Alternative-Systems Objection and the Isolation Objection dictate against choosing (c) and, therefore, in favor of choosing either (a) or (b). I have challenged this orthodox line on two fronts. I have argued, first, that the epistemologist has a fourth option: (d) mind-externalist coherentism. I have argued, second, that mind-externalist coherentism is immune to both the Alternative-Systems Objection and the Isolation Objection—so that even if these objections are decisive against mind-internalist coherentism, it in no way follows that the epistemologist has to choose between mind-internalist foundationalism and mind-externalist foundationalism.[16]

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Fusions of Modal Logics and Fitch's Paradox[1]

ALEXANDRE COSTA-LEITE
Institute of Logic,
University of Neuchâtel

This article shows that although Fitch's paradox has been extremely widely studied, up to now no correct formalization of the problem has been proposed. The purpose of this article is to present the paradox from the viewpoint of combining logics. It is argued that the correct minimal logic to state the paradox is composed by a fusion of modal frames, and a fusion of modal languages and logics.

1. *Introduction*

What is nowadays known as Fitch's paradox appeared in 1963 in the famous *Journal of Symbolic Logic* (Fitch [1963]). However, F. Fitch states that the argument was discovered rather by an anonymous referee (*ibid.*). J. Salerno recently launched an investigation to uncover this anonymous referee by examining some correspondences between E. Nagel and A. Church (Salerno [2006]). He suggests that Church was the referee:

> In 1945 Church refereed a paper written by Fitch; the author of the report was anonymous to Fitch; and Fitch's paper was (at least, at this stage) not being accepted for publication. If this was the paper in question and there were no other referees on the job, then it would seem that Church was the anonymous referee who conveyed the knowability result to Fitch in 1945. (Salerno [2006])

Despite the problem examined by J. Salerno, showing that Church was indeed the author of the paradox, Fitch's name is used to identify the problem which shows that if we accept that "All truths are knowable" then we should also accept that "All truths are known".

The purpose of this article is to examine the nature of Fitch's paradox of knowability from the viewpoint of combining logics. In order to introduce the paradox, the verification principle and the collapse principle

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are investigated showing how Fitch's paradox connects both. The language of the paradox is not that of simple normal modal logics, but a language generated by fusion of two modal languages: that of normal modal logic with ◊ and that of epistemic logic with modality K. Also, it is shown what is the logic of the paradox (i.e. what is the logic used within Fitch's argument) by examining in detail Fitch's theorems. A counter-model is proposed in order to avoid Fitch's paradox.

2. *The verification principle*

There are different ways to state the verification principle, for example:

- All true propositions can be known (i.e. are knowable);
- If a proposition is true, then it can be known (i.e. it is knowable);

The "it can be known" and "knowable" have different interpretations. Long time ago the verification principle has been stated by David Hume:

> When we entertain, therefore, any suspicion that a philosophical term is employed without any meaning or idea (as is but too frequent), we need but enquire, from what impression is that supposed idea derived? (Hume [1748])

Of course, Hume's investigation of what impression corresponds to a given philosophical concept (or idea) is a discrete manifestation of the principle of verification. Afterwards, The Vienna Circle also defended the verification principle to determine when propositions are meaningless. This principle has also been called by some authors "knowability principle" and it is certainly a central step towards an understand of the knowability paradox. H. Putnam [1982] criticized the principle of verification arguing that it cannot itself be verified, and is thus meaningless. T. Williamson [2000] calls this principle weak verificationism and argues that it deals with the limits of knowledge, given that it states exactly up to what point it is possible to know. Kant, in his *Critique of Pure Reason*, investigated how/what human beings can know and what are the limits of knowledge. The principle of verification is also an answer to Kant's problems and, obviously, to the antinomies of pure reason.

Formally, we can drop quantifiers and announce this principle by the following statement in a fusion of the languages of modal logic **K** and the epistemic version of **KT**:

(VP) $\varphi \rightarrow \Diamond K\varphi$

B. Brogaard and J. Salerno [2006] argued that knowability is factive because it implies truth ($\Diamond K\varphi \rightarrow \varphi$). If knowability is factive, and if the verification principle holds, then knowability is equivalent to truth, what is clearly incorrect. R. Cook [2006] also has an interesting and intuitive argument showing why knowability cannot be factive.

The verification principle is the main statement of Fitch's paradox, because from it Fitch deduces the collapse principle.

3. *The collapse principle*

There are different ways to state the collapse principle:

- All true propositions are known;
- If a proposition is true, then it is known;

Formally, we can eliminate quantifiers and announce this principle by the following statement in the epistemic version of the modal logic **KT**:

(CP) $\varphi \rightarrow K\varphi$

The collapse principle, also called strong verificationism by T. Williamson, is a problematic statement because if it is true, then it implies that:

- There are omniscient agents who are able to know all true propositions. The collapse principle is obviously equivalent to the following: $\neg(\varphi \,\&\, \neg K \varphi)$.
- The concept of knowledge collapses with the concept of truth.

From the intuitive viewpoint, the collapse principle states that true propositions are always known, which is not reasonable, given that there are a lot of propositions which are true and that we do not know. From the logical viewpoint, the collapse principle states that the concept of knowledge and the concept of truth are the same, and then there is no need for epistemic logics, because they collapse with classical propositional logic, given the verification principle.

4. *The nature of Fitch's paradox*

There is a very famous problem related to the verification principle and, consequently, to the concept of knowability. It has been treated recently by a great variety of philosophers and logicians. Fitch's paradox (or the Church-Fitch paradox, as J. Salerno suggested) shows that the verification principle entails the collapse principle.

There is a substantial amount of articles presenting the knowability paradox (Benthem [2004], Melia [1991], Wansing [2002], Williamson [2000], Edgington [1985], Brogaard and Salerno [2006]). In this article, I examine Fitch's text itself and explore what is the exact language of the paradox as well its right logic, the minimal logic used to generate the problem.

4.1. *The language of the paradox*

In order to understand Fitch's paradox, let us assume that there is a set PROP of propositional variables $\{\varphi, \psi, ...\}$ and full classical propositional constructors $\{\neg, \&, \vee, \rightarrow\}$ expanded by two modal operators ◊ and *K*. The main argument is the following:

> (Fitch [1963], theorem 5) "If there is some true proposition which nobody knows (or has known or will know) to be true, then there is a true proposition which nobody can know to be true."

The problem begins with the formalization of the argument. The full formal language of Fitch's theorem 5 should be second-order modal epistemic temporal logic, but this would make our work much too complicated, considering quantification over propositions, a temporal dimension and multi-agent systems. Fitch even states that "For the purposes of simplification, the element of time will be ignored..." and "we will often ignore the agent". Choosing another kind of language to express the problem, we can concentrate on the language defined as a fusion of a modal language and an epistemic language without quantifiers.

Fitch's argument can be decomposed in the following way:

1. "There is some true proposition which nobody knows to be true."
2. "There is a true proposition which nobody can know to be true."

Consider two modal languages, one alethic L1=<¬, &, ∨, →, ◊> and the other epistemic L2 =<¬, &, ∨, →, *K* >. The language of their fusion is defined as the union of all constructors L1⊕ L2=<¬, &, ∨ , →, ◊, *K*>; (see Gabbay [1999] for a study on fusion of modal languages). Only in a fusion of the languages it is possible to state and formalize the verification principle and, therefore, Fitch's paradox for epistemic modalities.

The first clause states that there is at least one true proposition which is unknown.

$$\varphi \,\&\neg K\,\varphi$$

Indeed, the above formula, which can be formalized without a fusion of modal languages, is equivalent to the negation of the collapse principle, and it states that epistemic agents are not omniscient. The second clause states that there is at least one true proposition which is unknowable (i.e. which can not be known). Its formalization is the following:

$$\varphi \,\&\neg\Diamond K\varphi$$

Surely, if we have two non-interdefinable modal operators, a simple modal logic does not work while we are formalizing Fitch's paradox. The above formula is equivalent to the negation of the verification principle. Fitch's theorem 5, then, can be reduced to the following inference, assuming that there is always a consequence relation ├ associated with an → (and also assuming that the metatheorem of deduction holds):

$$\vdash (\varphi \,\&\neg K\,\varphi) \rightarrow (\varphi \,\&\neg\Diamond K\,\varphi)$$

By contraposition, it follows that:

$$\vdash \neg\,(\varphi \,\&\neg\Diamond K\,\varphi) \rightarrow \neg(\varphi \,\&\neg K\,\varphi)$$

And by the De Morgan rules together with the definition of classical →, it follows that:

$$\vdash (\varphi \rightarrow\Diamond K\varphi) \rightarrow (\varphi \rightarrow K\varphi)$$

So, Fitch's paradox deduces from the verification principle the thesis that all truths are known. This fact is clearly a problem at the intuitive level and at the logical level, because inside the logic of Fitch's reasoning there is the knowledge's axiom which states that:

$$\vdash K\varphi \rightarrow \varphi$$

Therefore, theorem 5 implies the collapse of knowledge with truth:

$$\vdash \quad K\varphi \leftrightarrow \varphi$$

The minimal language to generate the paradox has to be a language powerful enough to express the combined modality ◊K. Therefore, the first conclusion of this paper is that we need a fusion of two modal languages in order to model the verification principle. Hence, the language of Fitch's paradox is a fusion of two modal languages: one alethic and other epistemic.

4.2 *The logic of the paradox*

How do we prove Fitch's theorem 5? How do we prove that the verification principle entails the collapse principle? In Fitch [1963], he intends to "provide a partial logical analysis of a few concepts that may be classified as value concepts, or as concepts that are closely related to value concepts". Such concepts, according to Fitch, have some basic properties:

1.They are closed with respect to conjunction elimination;
2.They are closed with respect to conjunction introduction;
3.They are truth-classes.

The first clause states that if * is a value concept, then it respects:

(1)$* (\varphi \,\&\, \psi) \rightarrow (*\varphi \,\&\, *\psi)$;

Such a principle holds in all extensions of the normal modal logic **K**. The second clause states that if * is a value concept, then it respects:

(2) $(*\varphi \,\&\, *\psi) \rightarrow *\, (\varphi \,\&\, \psi)$;

And the third clause means that "A class of propositions will be said to be a truth class if (necessarily) every member of it is true". Indeed, what Fitch wants to say is that the following law holds:

(3) $(*\varphi \rightarrow \varphi)$

What is the minimal modal epistemic logic which respects (1)–(3)? B. Brogaard and J. Salerno in [2006] state that "[t]he logic of Fitch's result is modest: a minimal, normal, modal logic and two very intuitive epistemic principles". This is partially correct, because there is no normal modal logic with epistemic principles, but only a combined and complex modal logic with alethic and epistemic modalities. We cannot simply add epistemic principle to a modal logic. If we do this, it would not be possible to semantically judge formulas with K, given that our models would not be able to recognize a complex modality as ◊K; (see the fibring problem in Gabbay [1999], and see Gabbay *et al.* [2003] for a detailed study on fusions of modal logics).

H. Wansing [2002] states that the logic of the paradox is modal epistemic logic based on classical propositional logic. This is correct, but H. Wansing does not show exactly how to generate this combined logic.

The same happens with J. van Benthem [2004].

Before presenting the right logic of the reasoning, let us observe that Fitch proves a very important theorem that is used to demonstrate the knowability paradox (see also Brogaard and Salerno [2006], and Salerno [2006] for some remarks on Fitch's theorems and its history):

> (Fitch [1963], Theorem 1 of [7]) "If * is a truth class which is closed with respect to conjunction elimination, then the proposition (φ & $\neg{*}\varphi$), which asserts that φ is true but not a member of * (where φ is any proposition), is itself necessarily not a member of *."

It means, formally, that it is the case:

$\Box\neg * (\varphi \,\&\, \neg{*}\varphi)$

Or:

$\neg\Diamond * (\varphi \,\&\, \neg{*}\varphi)$

The concept of knowledge is not only a truth class but also a notion which satisfies conjunction elimination. Therefore, as a result of Fitch's theorem 1, we have the same for the knowledge operator:

$\neg\Diamond\, K(\varphi \,\&\, \neg K\varphi)$

There is a non-constructive proof of theorem 1 (see Fitch [1963]): Suppose, for *reductio ad absurdum*, that (φ & $\neg{*}\varphi$) is a member of *: $*(\varphi \,\&\, \neg{*}\varphi)$. Given clause (1), we know that * distributes over φ and ($\neg{*}\varphi$), therefore $*\varphi$ and $*(\neg{*}\varphi)$. Given that * is a truth class, it follows ($\neg{*}\varphi$), which is a contradiction. Fitch uses theorem 1 to prove a very similar result, but now in a constructive way:

> (Fitch [1963], Theorem) "If * is a truth class which is closed with respect to conjunction elimination, and if φ is any true proposition which is not a member of *, then the proposition, (φ & $\neg{*}\varphi$), is a true proposition which is necessarily not a member of *."

Fitch's paradox is generated by putting together the instantiation of theorem 1 and, as said J. van Benthem in [2004], "a clever substitution instance" of the verification principle:

(VP) $(p \,\&\, \neg Kp) \rightarrow \Diamond K\, (p \,\&\, \neg Kp)$

Using an instance of Fitch's theorem 1:

$\neg\Diamond\, K(p \,\&\, \neg Kp)$

which leads to:

$\neg(p \,\&\, \neg Kp)$.

or, equivalently:

$p \rightarrow Kp$.

So, by theorem 1 and contraposition, Fitch's theorem 5 can be proved. Therefore, propositions of the form p & ¬Kp are counterexamples to the verification principle because they cannot be known. As an instantiation of the verification principle, if the proposition p & ¬Kp is true, then it can be known. But there is a proof that this kind of proposition cannot be known. So, the proposition p & ¬Kp is false. Therefore, there are omniscient agents able to know every true proposition. Indeed, Fitch states in his real anonymous theorem 4 that "For each agent who is not omniscient, there is a true proposition which that agent cannot know". This is probably the foundation of the "clever substitution instance" mentioned by J. van Benthem. Note that in above argument, φ has been replaced by p because we are not dealing with propositional variables, but atomic propositions.

What is the right logic of the paradox? We know that to formulate (VP) we need two modalities. and therefore a fusion of modal languages. Hence, no simple modal logic can be used. But how do we discover what is the exact logic of the paradox? The answer is this: evaluating formulas containing ◊K, we need at least fusions of Kripke frames or fibred models with fibring functions, (otherwise those fibring problems mentioned in Gabbay [1999] would appear).

Thus, the axiomatic system of the logic of Fitch's paradox is the following:

Take the propositional classical modal logic *K* and the propositional epistemic modal logic $\mathbf{KT_m}$, for m = 1 (single-agent). The fusion of the axiomatic systems **K** and $\mathbf{KT_m}$ is composed by the following set of axioms (for a complete study on fusions of modal logics check Gabbay et al [2003]):

1. $\Box(\varphi\rightarrow\psi) \rightarrow (\Box\varphi\rightarrow\Box\psi)$;
2. $(K(\varphi\rightarrow\psi) \,\&\, K\varphi)\rightarrow K\psi)$;
3. $K\varphi\rightarrow\varphi$;

In order to obtain the logic of Fitch's paradox, we have to add the verification principle:

4. $\varphi \rightarrow \Diamond K\varphi$

And two inference rules which came from each axiomatic system:

4. $\vdash \varphi$ then $\vdash \Box\varphi$
5. $\vdash \varphi$ then $\vdash K\varphi$

And the rule of modus ponens.

Indeed, the right, minimal logic of Fitch's paradox is composed by the fusion of a modal and an epistemic languages and logics, and by the fusion of two Kripke models (one alethic and the other epistemic) plus the verification principle. In particular, for Fitch's paradox, the fusion is $\mathbf{K} \oplus \mathbf{KTm} \oplus \varphi\rightarrow\Diamond \mathbf{K\varphi}$.

One can check that those principles which are considered as the basic rules for generating Fitch's paradox are just consequences of the above axiomatic system.

From the semantical viewpoint, the frames that should be used to model Fitch's reasoning are obtained by fusions of Kripke frames:

$F_1 \oplus F_2 = \langle W, R, P \rangle$ where:

1. *W* is a set of possible worlds;

2. R is an accessibility relation for ◊;
3. P is a reflexive accessibility relation for K.

F1 = <W,R> is a frame for the alethic modal logic K and F2=<W,P> is a frame for the epistemic modal logic **KTm**. The resulting logic **K⊕KTm** has a complete and sound axiomatization because the fused logic preserves completeness (Check the results contained in [9]). But what about the logic $\mathbf{K \oplus KT_m \oplus \varphi \rightarrow \Diamond K\varphi}$? Is it also complete?

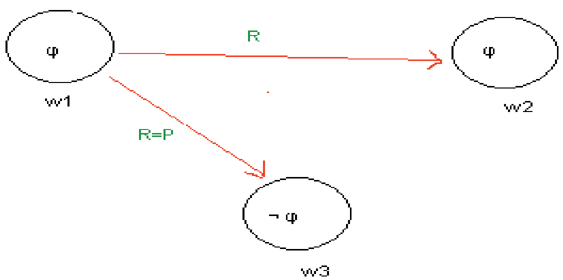
4.3 *A countermodel to Fitch's paradox*

If frames are fusions of the form F1⊕F2 = <W,R, P>, then there is a countermodel based on the fused frame where Fitch's paradox does not hold. It is the following:

M1⊕M2 = <W,R,P,V>, where:

0. *W*={w1, w2, w3};
1. w1Rw2, w1Rw3;
2. w1Pw3 and P is reflexive;
3. $P \subseteq R$;
4. V(φ)={w1, w2}

In a picture, the above model is the following:



Th: The formula $\vdash (\varphi \rightarrow \Diamond K\varphi) \rightarrow (\varphi \rightarrow K\varphi)$ is not valid in the model M1⊕ M2.

Proof: To check that $\vdash \varphi \rightarrow \Diamond K\varphi$ holds, consider the world w1. In w1 $\vdash \varphi$ and w2 $\vdash \varphi$. Given that w2 is just accessible from itself, then w2 $\vdash K\varphi$. Therefore, w1 $\vdash \Diamond K\varphi$. To check that $\vdash (\varphi \rightarrow K\varphi)$ does not hold, consider that w1 $\vdash \varphi$. However, w3 does not prove φ. Therefore, w1 does not prove $(\varphi \rightarrow K\varphi)$. Hence, in w1 the implication $\vdash (\varphi \rightarrow \Diamond K\varphi) \rightarrow (\varphi \rightarrow K\varphi)$ is not true, and then the deduction $\vdash (\varphi \rightarrow \Diamond K\varphi) \rightarrow (\varphi \rightarrow K\varphi)$ is not valid in the model M1⊕M2.

5. *Conclusion*

Fitch's paradox shows that the verification principle leads to the collapse principle. J. van Benthem said that there are basically two approaches to the paradox:

> Some weaken the logic in the argument still further. This is like turning down the volume on your radio so as not to hear the bad news. You will not hear much good news either. Other remedies leave the logic untouched, but weaken the verification principle itself. This is like censoring the news: you hear things loud and clear, but they may not be so interesting. (J. van Benthem [2004])

We can mention as an example of those who are turning down the volume: the article of H. Wansing [2002], where he proposes a paraconsistent constructive relevant modal epistemic logic with strong negation to avoid some inferences of the argument. Strategies which go in the same direction are Costa-Leite [2003] and Carnielli *et al.* [2007], but the difference is that the later do not have all those ontological commitments of Wansing's solution. Other approaches use intuitionistic logic to avoid Fitch's argument (see Williamson [2000]). As examples of those who weaken the verification principle we can mention Restall [forthcoming] and Edgington [1985]. The last one adds one extra modal operator and applies it to reformulate the verification principle. Two similar approaches go in the same direction trying to reformulate the position defended by Edgington. The first one is that of Rabinowicz and Segerberg [1994]. The authors propose a way to combine actuality, possibility, and knowledge by using two-dimensional modal semantics. Another approach is that of Lindström [1997].

The conclusion of this article is the following: the logic to formulate Fitch's paradox is composed semantically by a fusion of Kripke frames and syntactically by a fusion of languages and logics plus the verification principle $\mathbf{K \oplus KTm \oplus \varphi \rightarrow \Diamond K\varphi}$. As an open problem, how to prove that the logic $\mathbf{K \oplus KTm \oplus \varphi \rightarrow \Diamond K\varphi}$ is complete? Or is it incomplete? Given that there is a countermodel able to falsify the deduction, probably the logic of Fitch's reasoning is not a complete logic (*soundness included*). If Fitch's paradox is formulated in the environment of fusion of modal logics, then there is a countermodel which validates the verification principle but falsify the collapse principle. Indeed, Fitch's paradox occurs when there is not a distinction between the accessibility relation for ◊ and the accessibility relation for *K*.[2]

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Skepticism About the Past and the Problem of the Criterion

BRYSON BROWN
Department of Philosophy,
University of Lethbridge

An argument for skepticism about the past exploits a circularity in the arguments connecting present observations to claims about past events. Arguments supporting claims about the past depend on current observations together with processes linking current observations to those claims. But knowledge of processes requires knowledge of the past: Knowledge of the present alone cannot provide evidence for claims about the past. A practical, coherentist response to this challenge rejects the assumption that we come to the problem with no information about the past. Beginning with partial and imperfect information about the past, a coherentist tests ideas about processes against the particular evidence of traces left by past processes, and particular claims about the past against ideas about the processes linking those events to present traces. However, this common-sense response is inadequate when faced with a radical skeptic prepared to insist on the problem of the criterion. *An answer to this radical skeptic can be drawn from Wilfrid Sellars 'bootstrap' argument in "Empiricism and the Philosophy of Mind." The result is a better response to the problem of the criterion than Chisholm's 'particularism.'*

1. *Skepticism about the past*

There are many things we claim to know about the past; to back them up, we need evidence that *justifies* the things we know. Here are just a few things I know about the past:

- I had scrambled eggs for breakfast this morning.
- John F. Kennedy was assassinated in 1963.
- Glaciers spread across northern Europe and North America within the last 20,000 years.
- Trilobites were arthropods that thrived during the Paleozoic era.

How do I justify these claims? The answers are obvious at first—I remember eating the eggs, and I remember JFK's assassination and that