Logical probability as traditionally defined is a movement that is generally considered to be dead. Some, such as J. Franklin, have attempted to resurrect this position, though not without problems.[1] Qualitative probability has emerged as an important concept for fields as varied as medicine and artificial intelligence. In technical fields such as these, it is often not possible to assign an actual or accurate degree of belief to a particular proposition, yet decisions relying on the epistemic warrant of the statement must be made, despite the fact that certainty does not exist. It is argued that logical probability should be resurrected, updated and understood as a method of epistemic warrant based on qualitative probability in order to formalize the system of reasoning to be used in situations where certainty is not possible.

This suggestion is *prima facie* strange for a few reasons. First, the term probability typically connotes a quantitative measurement; second, theories of knowledge have traditionally sought certainty, which would clearly not involve merely probable assertions. In explaining this new conception for logical probability, both of these potential problems need to be addressed. In as far as they both deal with uncertain knowledge, a seeming oxymoron, logical probability and Bayesianism both face the same criticism: how can there be an epistemology based on uncertainty? Hajek and Hartmann trace this epistemological split back to the 17th century differences between Descartes' push for epistemic certainty on one hand, and Pascal's and Fermat's explorations of uncertainty represented by probability on the other (2009). Although certainty is a worthy goal for which to aim, it is often not possible to achieve this certainty at the time that some decision or other needs to be made; further, it may simply not be possible to attain

[1] See Sylvia IV, John. "A Critical Assessment of the Resurrection of Logical Probability" (Abstract), *Journal of the Mississippi Academy of Sciences*, vol. 53(1), 2008.

certainty regarding certain issues such as the existence of God. A probabilistic epistemology is beneficial because it offers decision making power.

Hajek and Hartmann consider other benefits of the Bayesian epistemology, most of which can be applied to any probabilistic epistemology. Along with the decision making power, they note that "observations rarely deliver certainties – rather their effect is typically to raise our probabilities for certain propositions… Traditional epistemology apparently has no way of accommodating such less-than-conclusive experiential inputs," (2009). Although this is observation is accurate, it should be noted that probabilistic epistemological systems, including Bayesianism, actually have a difficult time showing exactly how this updating of probability occurs. The rest of the benefits suggested can be summarized as follows: a probabilistic epistemology more accurately reflects the way people actually think – both *how* they think when they are making decisions, which is reflected in fields such as engineering, and artificial intelligence, as well as the *ways* in which they think about knowledge beliefs; for instance, one may have more confidence in some beliefs than others (Hajek and Hartmann). Despite the seeming strangeness of a probabilistic epistemology, it has many advantages over traditional epistemology and can address issues and complexities of thought and decision making which traditional epistemology cannot.

The second strangeness is how a probability theory could consist of something which is not qualitative, and this is where logical probability would diverge from Bayesian probability. The answer to this question of strangeness is actually quite simple: this actually *is* how we think. Foley (1992) and Hawthorne (2009) develop a Lockean Thesis which I interpret as being compatible with what I am proposing for logical

probability. Foley originally deems it Lockean because of Locke's discussion of probability and degrees of belief in *An Essay Concerning Human Understanding*. In Book IV, Chapter XV, Locke writes:

> *It is to supply our want of knowledge.* Our knowledge, as has been shown, being very narrow, and we not happy enough to find certain truth in everything which we have occasion to consider; most of the propositions we think, reason, discourse- nay, act upon, are such as we cannot have undoubted knowledge of their truth… Probability is likeliness to be true, the very notation of the word signifying such a proposition, for which there be arguments or proofs to make it pass, or be received for true. (1994).

My reading of Locke suggests that there are strong elements of a probability notion of knowledge, but I see nothing that speaks to whether this probability is quantitative or qualitative. His commentary could just as likely apply to a Bayesian epistemology as to logical probability. For that reason, I continue to suggest the use of the term logical probability rather than Lockean Thesis, although I do interpret the Lockean Thesis as friendly.

Why then suggest a qualitative method over the quantitative method? Most simply stated, that is precisely how humans do think:

> The problem [with quantitative systems] is that this kind of account of how probabilistic coherence should function as a normative guide seems pretty far-fetched as a guide for real human agents. It would have them try to emulate the normative standard by actually constructing numerical probability measures of their belief strengths as a matter of course. Real agents seldom do anything like this, (Hawthorn).

It therefore makes sense to attempt to formalize this method of thinking. The benefit is that a qualitative system would eliminate the Bayesian necessity of constantly assigning numerical weights to propositions. There are very few day-to-day circumstances in which a person actually does assign weights to propositions, and these situations are well

accounted by frequency probability. Rather, it seems there are many circumstances in which assigning a numerical weight cannot but help being entirely arbitrary. Consider an historical example. The French poet Alphonse de Lamartine said that one of his famous poems came to him fully in a single flash of inspiration. If someone living during the same time period as Lamartine is trying to determine if the poem was a flash of inspiration or was worked out meticulously, the only obvious evidence at the time is the word of Lamartine. Assuming that there is no evidence that his word should not be believed, it seems to be a rational belief that the poem was conceived in a flash. However, upon Lamartine's death, many drafts and versions of the poem in question are discovered, and the evidence now points to the notion that this poem was very carefully worked out. It seems obvious with this updated evidence that it is rational to believe the poem was worked out rather than conceived in a flash. Is it necessary to quantify this claim, or is there rather some statement of quality being made? More importantly, in the process of deciding on this issue, does anyone actually assign a numeric probability to the choices? No; this is not the way we reason and decide. Therefore, a systematization and axiomatization of logic probability would be beneficial.

A complete axiomatization is presented by Ognjanović, Perović, and Rašković,[2] however, for my purposes I will focus on the rudimentary confidence relations. We will take '$A \geq_\alpha B$' to mean 'α is at least as confident that A as that B'. Further '$Cert_\alpha[A]$' is read as 'α is certain that A'. Hawthorne elaborates the confidence relations:

> Definition 1: Rudimentary Confidence Relations: Given a language L for predicate logic with identity, the rudimentary confidence relations on L are just those relations $\geq_\alpha$ that satisfy the following rules (where '|= A' say that A is a logical truth of L):

[2] An Axiomatizatin of Qualitative Probability. Acta Polytechnica Hungarica. 5,1(2008).

> First, define 'Cert $_\alpha$ [A]' (read 'α is (warranted in being) certain that A') as $A \geq_\alpha (A \vee \neg A)$;
>
> For all sentences A, B, C, D, of L,
> 1. it's never the case that $\neg(A \vee \neg A) \geq_\alpha (A \vee \neg A)$ (nontriviality);
> 2. $B \geq_\alpha \neg(A \vee \neg A)$ (minimality);
> 3. $A \geq_\alpha A$ (reflexivity);
> 4. if $A \geq_\alpha B$ and $B \geq_\alpha C$, then $A \geq_\alpha C$ (transitivity);
> 5.1 if $Cert_\alpha [C \equiv D]$ and $A \geq_\alpha C$, then $A \geq_\alpha D$ (right equivalence);
> 5.2 if $Cert_\alpha [C \equiv D]$ and $C \geq_\alpha B$, then $D \geq_\alpha B$ (left equivalence);
> 6.1 if for some E, $Cert_\alpha [\neg(A \cdot E)]$, $Cert_\alpha [\neg(B \cdot E)]$, and $(A \vee E) \geq_\alpha (B \vee E)$, then $A \geq_\alpha B$ (subtractivity);
> 6.2 if $A \geq_\alpha B$, then for all G such that $Cert_\alpha [\neg(A \cdot G)]$ and $Cert_\alpha [\neg(B \cdot G)]$, $(A \vee G) \geq_\alpha (B \vee G)$ (additivity);
> 7. if $\models A$, then $Cert_\alpha[A]$ (tautological certainty).
>
> Also, define '$A \approx_\alpha B$' (read "α is equally confident in A and B") as '$A \geq_\alpha B$ and $B \geq_\alpha A$'; define '$A >_\alpha B$' (read "α is more confident in A than in B"), as '$A \geq_\alpha B$ and not $B \geq_\alpha A$'; and define $A \sim_\alpha B$ (read "α's comparative confidence that A as compared to B is indeterminate"), as 'not $A \geq_\alpha B$ and not $B \geq_\alpha A$' (2009).

Finally, a belief operator may be added, such that '$Bel_\alpha[A]$' is read as 'α believes that A'. Hawthorne ties all of these together with the following rules:

> 8. If $Cert_\alpha[A]$ then $Bel_\alpha[A]$ (certainty-implies-belief)
> 9. If $A \geq_\alpha B$ and $Bel_\alpha[B]$, then $Bel_\alpha[A]$ (basic confidence-belief relation) (2009).

This is a logical system which more accurately reflects the way one actually thinks about the world and is used to make decisions.

In addition to these benefits, a further aspect of this logical probability is that it requires ones to act as if there were certainty in propositions that are believed. Wellman elaborates on the significance of this aspect of logical probability: "To accept a proposition is essentially to act as though it were certainly the case. Although a strict Bayesian would deny that it is ever reasonable to accept uncertain propositions, some

have advocated it on grounds that it simplifies reasoning," (1995). A Bayesian can broadly be classified as either objective or subjective. An objective Bayesian would argue that there is a limit on the acceptable range of the numeric prior, whereas a subjective Bayesian would allow that any numeric prior is acceptable (Talbott). Again, both of these positions are problematic in actual reasoning and decision making. Some cases do not lend themselves to a particular numeric prior – or even a range of priors – as an objective Bayesian would like, and in these cases the assignment of any prior by a subjective Bayesian is entirely arbitrary. The argument is that with updated evidence, these arbitrary priors tend to fall within an acceptable range, but my objection is that this method of reasoning does not reflect the nature of actual reasoning by a human agent.

In addition to this objection, there is further reason to object to the Bayesian claim that it is not reasonable to accept uncertain propositions – it creates the preface paradox (Hawthorne). Consider an author working on a book: during the final stages of editing, the author carefully goes through each page of the manuscript, making sure she can find no errors. Thus, it is rational for her to believe that every page is error free. However, in the preface she makes note that because the subject matter is quite difficult, there is likely to be an error on at least one page. According to traditional epistemology as well as Bayesian epistemology, this would be a contradictory belief state. The author both believes that every page is error free and that at least one page has an error at the same time – a fairly simple contradiction.

On the other hand, these contradictory beliefs do appear to be rational at least in some sense – everyone can acknowledge that despite the author's best efforts it is entirely possible that some mistake remains somewhere. One simply needs to pick up any

introduction to logic textbook if he doubts this likelihood. This being the case, the author would actually be more epistemically justified in her seemingly contradictory belief – she is probably correct in assuming that there is at least one error somewhere in the book, despite her best efforts. Here, logical probability shines by being able to account for this contradiction:

> It allows that the agent may well believe two statements without believing their conjunction, just as happens with probabilities, where it may well be that $P_\alpha[A] \geq q$ and $P_\alpha[B] \geq q$ while $P_\alpha[A \cdot B] < q$. Similarly, according to the confidence-belief logic, the agent is not required to believe the conjunction of individual beliefs. So the kind of doxastic state associated with the preface "paradox" is permissible, (Hawthorne).

The solution offered by logical probability matches exactly how a human agent would think about this situation. The author thinks page A, B, C, etc. are each error free, but not that A and B and C and etc. are error free together.

In addition to the rules discussed here, Hawthorne has done work showing more can be derived and thus an aximomatized and complete system for a qualitative logic has been shown to be both desirable and possible. Consider the central claim being made by this system of logic:

> **Contextual Qualitative Lockean Thesis [logical probability]:** An agent is epistemically warranted in believing a statement in a context Ψ *just in case* she is epistemically warranted in having a sufficiently high *grade of confidence* in the statement – sufficiently high to make her attitude towards it one of *belief* in context Ψ, (Hawthorne).

Once the warranted beliefs are derived, this system is developed well enough to be able to handle confidence relations. Undoubtedly that is an admirable achievement, but one question that has not been asked is exactly why or how an agent should be considered epistemically warranted in believing a statement. This is a problem similar to that faced

by the subjective Bayesian. I have argued that the random assignment of a logical prior is not an acceptable answer, so the solution for logical probability must be found elsewhere. Virtuoso epistemology[3] can fill this gap in logical probability.

Virtuoso epistemology is a neo-Aristotelian conception which eliminates the appearance/reality distinction in favor of arguing that the expert in any particular field is the agent to go to as the authority for truth in that field. An expert will demonstrate excellence in the epistemic intellectual virtues, including understanding, wisdom, practical wisdom, perception, and imagination. Understanding is the ability to grasp concepts individually. Seeing how first principles and what follows from them hang together is the virtue of wisdom. Perception is seeing a particular thing as an instance of some universal, while imagination is seeing how things might be in service of an overarching good. Each of these is a disposition to "see" things one way rather than another, and this disposition is developed through practice and education in the same manner as Aristotle's moral virtues, and indeed relyies on the moral virtues.

Taking into account this conception of epistemology, the logical probability thesis could be updated as such:

> **Logical Probability Thesis:** An agent is epistemically warranted in believing a statement in context Ψ just in case her expertise of the statement in context Ψ prompts a high grade of confidence in the statement – sufficiently high to make her attitude towards it one of belief in context Ψ.

Epistemic warrant would be understood as requiring expertise in a specific context, Ψ. The context remains important because an agent may be sufficiently educated and trained

[3] The following discussion of virtuoso epistemology is taken from both classes and discussion with Dr. Lynn Holt. Similar arguments may be found in his *Apprehension: Reason in the Absence of Rules* (2002).

in some areas well enough to be considered an expert, but not in others. For example, most normal adults would have sufficient expertise in science to be epistemically warranted in believing the statement 'The sun will rise tomorrow.' On the other hand, most normal adults would not have sufficient expertise to be epistemically warranted in believing the statement that 'the electrons and quarks inside of atoms are one dimensional strings in the shape of closed loops which move and vibrate.'

Consider a more precise and practical example. A patient goes to the doctor with complaints of a sudden and severe headache. What is the cause? According to myelectronicmd.com:

> Possible medical conditions of Headache(Sudden severe) : - Sinusitis - Mucocele - Meningitis - Subarachnoid Hemorrhage - Subdural Empyema - Epidural Abscess - Brain Abscess - Hydrocephalus - Dural Venous Thrombosis - Intracerebral Hemorrhage - Brain Tumor - Pituitary Apoplexy - Aneurysm - Carcinomatous Meningitis - Glaucoma - Cluster Headache - Migraine Headache - Headache - Vasodilation From Medication - Allergic Reaction - Malignant Hypertension - Pheochromocytoma - Stroke - Transient Ischemic Attack - Subdural Hematoma - Intracerebral Hematoma.[4]

This is quite a varied list! Assuming the list is factually accurate in that all of these conditions are *possible* causes of a headache, how does one begin to attempt to determine which is the *actual* cause? The answer I'm suggesting is that an expert is required. This answer also seems to be supported by research. In November, Microsoft released a study about health related internet searches. The first comprehensive results for a study such as this are informative: "the study suggests that self-diagnosis by search engine frequently leads Web searchers to conclude the worst about what ails them," (Markoff). This tendency has even been nicknamed cyberchondria, alluding to the influence of self-diagnosis over the internet which leads one toward hypochondria. Why is this happening?

[4] http://www.myelectronicmd.com/symptom.php?ID=38&typ=1

"Horvitz, an artificial intelligence researcher at Microsoft Research, said many people treated search engines as if they could answer questions like a human expert. Horvitz is also a computer scientist and has a medical degree" (Markoff). Search engines, as well as those who use search engines, are lacking in the relevant expertise to be able to see how all of the symptoms and conditions hang together. Only an expert, such as a doctor, is able to use his expertise to determine more quickly and accurately what is the actual cause of a headache.

This application of virtuoso epistemology works better than other systems. Methodism would attempt to take the place of education, experience, and training. There is no methodological shortcut around this, though. Methodism attempts to democratize intellect by allowing everyone to get at it and denies the very conditions necessary for success. The failure can clearly be seen in the results of search engines and diagnosis applications such as myelectronicmd.com. Empiricism fails because it cannot draw a distinction between a novice and an expert, instead claiming that *any* person can make observations. While it is true that a person can use their senses to observe the things around them, expertise encompasses the ability to know what the relevant observations are. Without seeing how it all hangs together, observations are too numerous and unimportant. In trying to diagnosis a headache, for instance, does it matter if you observe your hair is going gray? This is certainly an empirical observation which everyone can make, but that observation alone is unimportant. Finally, intuitionism would not work because it says that ideas should be self-evident to anyone, but they simply are not self-evident for those lacking the intellectual virtues.

Logical probability should be resurrected as the Lockean Thesis bundled with virtuoso epistemology. A firm foundation is constructed in answering the question of *how* one can be epistemically warranted. From there, an full system of confidence relations logic allows for many extensions of this reasoning, which more fully mirrors the reasoning which is actually used by those working in technical fields.

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