Applying Logic
Some Remarks on the Reciprocal Influence of Experimental and Formal Investigations of Identification

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1. Logic and Science

In recent years, logic has played a relatively minimal role in main-stream philosophy of science. According to popular wisdom, logic does the philosopher more harm than good, abstracting us from the important subtleties of scientific investigation and mistakenly forcing a frozen universal structure on the dynamic and highly particular processes of scientific inquiry. This near consensus view has meant that advances in logic over the past twenty years have gone virtually unnoticed in the broader philosophical community. In collaboration with Shahid Rahman, I have argued elsewhere that recent work in logic, for instance in the plethora of non-classical logics, such as game theoretical semantics and independence-friendly logic can serve as a rich source of conceptual insight for contemporary philosophy of science. (See Rahman & Symons 2004.)

One obstacle to recognizing the relevance of logical investigations to broader scientific inquiry is the lack of any clear account of what it means to apply insights from logic to problems in natural science. Not only do we lack any convincing account of how logic might apply, we also lack an account of how one modifies one's formalism in response to empirical or other criteria. While there is relatively little philo-sophical discussion of these questions, there is a great deal of work in computer science and elsewhere, that deals with issues at the interface of theory and practical application in an ad hoc manner. As Scheutz and others have noted, solutions to practical engineering problems related to, for example, the question of implementation, are likely to have some philosophical significance in this regard. (Scheutz 2002.)

The lack of a developed philosophical account of the interplay between logical and other scientific investigation admits, at least partially, of an historical explanation. Traditional anti-psychologistic arguments from the late 19th and early 20th centuries encouraged the notion that logic exists in splendid, self-justified isolation. The intention of these arguments was to insulate logic from what were understood to be the insidious effects of psychology. Of course, Frege, Husserl and other opponents of the encroachment of psychology on logical questions certainly did not intend to make logic irrelevant to the sciences. Instead, they hoped to guard its fundamentality. However, when combined with the increasing influence of sociological and historical concerns in general philosophy of science since the early 1970's, the principal effect of logic's quarantine was a gradual diminishment of its role in philosophy. Recent decades have seen the virtual disappearance of logic from the philosophy of science. Logicians are increasingly sequestered in mathematics and computer science departments while few philosophers of science actively attempt to apply logical techniques to questions in philosophy of science.

This short paper cannot engage with past debates over the role of logic and other kinds of formalism in scientific inquiry. However, it is worth considering briefly whether the reasons for the anti-logical turn in philosophy of science are compelling. After all, no philosopher of science would deny that in addition to its empirical function, natural science is a conceptual or theoretical enterprise. Given the conceptual component of natural science it is difficult to argue that developments in logic should have no bearing on its problems. This is especially true for sciences like neuroscience or cognitive science where abstract notions like information, representation and the like, play a central role. It can be shown that such notions behave in a fashion that is amenable to formal treatment. The logic of notions like knowledge and belief has been developed by logicians and computer scientists, (since its original articulation by von Wright in the 1950's and Hintikka in the 1960's) and holds direct implications for the scientific study of real-life knowledge seekers. It is regrettable that this work has received such meager attention in the wider philosophical community. It is likely that as the traditional arguments against psychologism come under greater scrutiny, (see for example Kusch (1995), Jacquette (2003) and others) there will be more interest in understanding the interaction of logical and scientific investigations.

In order to specify some of the problems that emerge out of reflection on the notion of application, I will focus, for the remainder of

the paper on a topic that has both a highly conceptual and highly practical component, namely the notion of identification. I have argued elsewhere that identification can serve as an example of a topic where logical insights can play a role in the development of scientific understanding. As we showed in Hintikka & Symons (2003) for example, developments in epistemic logic are directly applicable to conceptual problems in the neuroscientific study of perception. In the pages that follow this project will serve as an example of the kind of application that can directly contribute to progress on specific scientific problems.

While one can be rightfully enthusiastic regarding the application of formal insights to scientific questions, it would be a mistake to believe that successful applications encourage some kind of logical fundamentalism. For example, reflecting on the notion of identification has also served to illuminate the influence of non-logical criteria on our understanding of logic. As we shall see, analysis of the nature of identification can provide grounds for changing the way we understand logic. Specifically, reflection on the nature of cross-identification can support the view that deciding on the interpretation of the quantifier may require us to turn to non-logical criteria for answers. Obviously, the interplay of logical and empirical factors raises far more questions than I can address in this short paper. However, since this is a volume devoted to charting some of the open problems in epistemology, I will take the liberty of leaving some loose ends.

Rather than arguing for the usefulness of applied logic, I believe that a more fruitful and interesting set of questions arise when we assume some level of applicability and then focus on the new problems and possibilities that arise out of the application. It strikes me that such an assumption entails a non-fundamentalist stance towards both our logic and our science. If we reject the reduction of logic to empirical data and vice versa, we make room for a fruitful study of their interaction. The general thesis of this paper is that applications of logic are a matter of reciprocal influence between the logic and the scientific subject matter in question.

2. Identification and Identity

As an example of this kind of study, at least in outline, let's turn to the question of identity or identification. When one makes an identity

claim, one asserts that two objects, though picked out in different ways, are one and the same. Choosing the problem of identification as an example of the application of logic to natural science, might strike readers as a little odd. Surely, identity and identification are perennially metaphysical or at least purely logical matters. In one of the founding moments of analytic philosophy, Frege was led by the fact that we learn something from identity claims to introduce the sense/reference distinction. In recent decades as a result of Kripke's work, reflection on the nature of identity led to a revival in analytic metaphysics. Both Fregean and Kripkean lines of thought were inspired by reflection on the basic character of identity claims.

Why should such abstract seeming lines of investigation have any bearing on concrete scientific questions? Stated quite simply, while 'identity' can be understood to be an ineluctably metaphysical term, 'to identify' is to engage in an activity that depends in large part on epistemological and scientific, rather than purely metaphysical considerations. Identity, as we shall see, is invariably tangled up with identification and identification is an activity that we can study behaviorally, psychologically and neurally.

Over the past three decades, philosophical discussions of identification have followed the metaphysical path mapped out by Kripke in his *Naming and Necessity*. Kripke's starting-point is familiar. Any object is identical with itself and itself alone. No two objects can be identical. True identity statements are true necessarily. According to Kripke, true identity statements holding between names, for example, "Cicero is Tully" are markers of *de re* necessity. If it is true that Cicero is Tully then it is necessarily true, and this necessity stands apart from how anyone happens to come to know the true proposition. Kripkeans contend that arguments presented in *Naming and Necessity* have somehow overcome traditional objections to non-epistemic treatments of identity and have cleared the way for a revival of metaphysical inquiry free from the critical constraints of epistemology. The necessity of identity is, after all, a straightforward theorem of modal logic and would be, according to Kripke, no matter what the state or sources of our knowledge. Such a view implies that the necessity of identity precedes any particular identification and, more significantly perhaps, that it is possible to examine the implications of some metaphysical propositions apart from all epistemological considerations. Kripke's argument is powerful and its basic premises seem incontrovertible. However, in order to understand how to build upon this metaphysical

insight in order to actually conduct an investigation or application of the notion of identity or identification, one has to turn to other sources.

Hintikka and Sandu (1995) understand Kripke's basic insight in *Naming and Necessity* as the claim that quantification in a modal or intensional context presupposes identity conditions that do not reduce to descriptive conditions. They acknowledge that this insight is undeniable. The theory of rigid designation that follows from the necessity of identity is criticized by Hintikka and Sandu not on metaphysical grounds, but because, by characterizing rigid designation as a relationship between names and objects, Kripke has arbitrarily restricted the sense of what it is to identify an individual. The criticism is intended to show that questions of reference are orthogonal to questions of identification. Essentially, what they criticize is Kripke's restriction on the behavior of quantifiers and the theory of rigid designation that follows from it.

Kripke understands quantifiers as ranging over a fixed set of values and he therefore excludes the difference between identifying that, and identifying what or who, between saying for example 'it is known that someone paid Ann'

(1.) $K(\exists x)P(x,a)$

where x ranges over individuals of some one possible world, and 'it is known who paid Ann'

(2.) $(\exists x) KP(x,a)$

where the x will pick out only such individuals as can be identified in all the relevant or accessible knowledge worlds. In the second case, the individual being spoken of is identifiable in all possible worlds that are compatible with the agent's knowledge.

Once we turn to the question of understanding an agent's knowledge one must decide on whether, for example, a Kripkean account of the quantifier is appropriate. One is basically asking whether a distinction of the kind presented above, is worth retaining in one's formal apparatus. This is a separate matter from our view of the metaphysical necessity of identity. One's criteria for deciding between different treatments of the quantifier will inevitably be drawn from some source other than our reflections on the *de re* necessity of identity. While Hintikka and Sandu argue that the necessity of identity is not enough to enforce the treatment of quantifiers underlying Kripke's theory of rigid designation, Kripke may be able to defend it on other grounds. The

point here is that when we consider how one might go about quantifying-in in epistemic and other modal contexts, it is clear, even in the relatively straightforward example mentioned above, that logical connectives, quantifiers and all the rest are not sufficient for giving an account of the cross-identification for individuals.

In the case of cross-identification, what Hintikka and Sandu have suggested is that once criteria for cross-identification are specified, quantification into modal or intensional contexts becomes manageable via the specification of the relevant set of worlds and the fate of their members. This is precisely the reverse of what Kripke understood his work to have demonstrated. For Kripke, the basic insight that a thing is identical with itself and itself alone, that Nixon is Nixon, (even if he had been named something other than Nixon) is evidence that something like rigid designation is called for. While Hintikka and Sandu would certainly agree with the necessity of self-identity, they do not see this as grounds for the introduction of rigid designators. Instead, they argue that true identifications of the kind that hold any real interest for us are drawn between different ways of specifying the same thing. How one determines the appropriate criteria for such cross-identifications is not a matter for logic alone to accomplish, however, once these criteria are in place, then the ordinary quantificational infrastructure can do all the necessary work. In order to engage in any modal or intensional reasoning whatsoever, one must be able to cross-identify. Since cross-identification is conceptually prior to quantification in a modal context, it cannot be explained without moving beyond the resources of our logic *per se*.

Given its importance, Hintikka has had strikingly little to say about the non-logical principles governing cross-identification. The closest he comes is an hypothesis concerning continuity in a joint paper with Merrill Hintikka (1989) where they outline an account of how one might use the stability theory of differential equations as the mathematical framework for cross- identifications. Such a view contrasts sharply with Kripke's claim that our having stipulated the possible worlds eliminates the problem of trans-world identification. It also contrasts sharply with other attempts to understand what is involved in cross-identification. David Lewis, for example, famously suggested that we cross-identify or more accurately that we pick out counterparts across possible worlds via subjective similarity measures. Of course, Lewis was keen to point out that counterparts are never actually identical with one another. Plantinga too, in a very different way, and in a way opposed to Lewis, is also eager to point out that the

denizens of possible worlds are fundamentally different (this time in kind) from those of the actual world.

While the way one understands identity may well be influenced by one's attitude towards metaphysical questions in general, the metaphysical difference between Hintikka and Kripke over the existence of rigid designators as I have indicated above stems from differences concerning the nature of logic and specifically concerning the nature of quantification. Logical, metaphysical and, as we shall see even empirical considerations of identity are thoroughly entangled. This entanglement is the site of a range of open-problems for philosophers.

3. Epistemic Logic and the Neuroscience of Identification

To get a sense for the details of these problems, the remainder of this paper will discuss an application of the logic of identification to the neuroscience of identification. A complete account of the details of the neuroscience is provided in Hintikka & Symons (2003). For the purposes of this paper it will suffice to outline some of the central points in the epistemic logic, in order to highlight the range of problems that remain unaddressed. The logical insights in question are not new, nor are they especially complicated. They date from Hintikka's (1969) paper 'On the Logic of Perception' where he systematically distinguished physical from perceptual methods of cross-identification. The same distinction can be characterized as a contrast between subject-centered and object-centered modes of identification. As discussed in Hintikka & Symons (2003) the logic of this distinction is directly relevant to the neuroscience and psychology of identification.

Such applicability is striking, given that epistemic logic treats of idealized knowledge seekers and seems to operate far above the messy empirical details of the natural sciences. Because they must be restricted to a defined class of rational agents epistemic logics deal in idealizations. These classes are defined in terms of a set of specified postulates. These rationality postulates vary from researcher to researcher and in recent years there have been efforts to shape them so as to make the agents a little more realistic. Limits on the kinds of resources available to the knowledge seeker, as well as dynamical and social considerations have all been introduced to logics of knowledge in order to make the idealized agents under consideration more relevant to

realistic episteric contexts (see for example, Fagin et al. 2004). Even with such additions, epistemic logic must begin from a specification and will be restricted to the characteristics of some idealized knowers.

In spite of its idealized character, specification of the nature of the knower is the first point where epistemic logic and empirical factors must intersect. The initial choice of rationality postulates is likely to be made in light of empirical adequacy. Epistemic logic functions as a means of modeling the natural phenomenon of knowledge seeking. These models are organized around some basic beliefs concerning knowledge seekers as we find them in nature. Likewise, the merits of a particular set of rationality postulates can be judged, in part, by their implications. Consequently, the construction and the evaluation of an epistemic logic will be difficult to separate from empirical considerations.

Originally, epistemic logic simply involved the addition of an epistemic operator K to ordinary first-order logic. (Hintikka 1962). The semantics of this supplemented first-order logic are modal in nature. To talk about what a person knows is to specify a set of possible scenarios. This space of possible scenarios is divided between those that are compatible with what an agent knows, and those that are not. This is a relation between a knower a in the scenario $w1$ and those scenarios that are compatible with everything the knower knows in $w1$. a knows S in $w1$ if it is true that S in all scenarios w^* accessible to a from $w1$. w^* is the set of epistemic alternatives to $w1$ for a, they are what Hintikka calls a's knowledge worlds in $w1$. The epistemic operator Ka therefore functions as a universal quantifier ranging over all a's knowledge worlds. The behavior and nature of quantifiers becomes one of the most critical topics in the development of epistemic logic.

Applying this formal approach to the study of actual empirical cases of knowledge acquisition and identification is surprisingly straightforward. Consider, for example, the set of visual stimuli an agent receives at a certain moment of time. Inevitably, this stimulus will not specify a unique scenario as to the nature of the agent's visual space. Given some prior knowledge, new visual stimuli leave a number of alternatives open as to what is the case. This space of possible visual scenarios are those that are compatible with what an agent knows. Following our account of epistemic logic above, this relation can be understood as obtaining between a knower a in the visual scenario $w1$ and those scenarios that are compatible with everything the knower knows in $w1$. Thus the identification that is being considered here concerns the identity of an object in the different scenarios that the

perceiver's visual information leaves open. These alternatives, we will simply call them the perceiver's visual alternatives at some given moment, are the scenarios between which identification is to take place.

As we saw in the discussion of Kripke's interpretation of the quantifier above, the identification of objects between various visual alternatives can happen in at least two different ways. As we discussed in Hintikka & Symons (2003), to identify a person or an object can be understood by analogy with locating him, her or it in some framework or "map". In perspectival visual identification this framework is provided by the subject's visual space. While the perspectival or subject centered mode of identification employs something like a coordinate system defined by reference to a particular perceiver or knower it is not subjective in the sense of being inaccessible to others. Instead, it relies on objective general principles and on the possible situations between which the world lines of identification are drawn. To illustrate this, consider what a person, Jane, sees at a particular moment of time. Let's assume that she sees a man standing in front of her, but that she does not see who the man is. The man standing next to Jane occupies a particular slot in Jane's visual space and can be individuated in such a way as to allow Jane to track him through various visual alternatives. In this case, we can call him one of Jane's perspectival visual objects, even though this locution has to be used with caution[1].

Of course, this man happens also to have a name, a social security number and many other features of his public persona by means of which he can be identified. Persons and other objects so identified can be called public objects. Public identification constitutes another way to track a person through possible scenarios, namely by reference to who that person is. Let's imagine that this man standing in front of Jane happens to be the Mayor of El Paso. Jane may have numerous beliefs and opinions about the Mayor without being able to identify the man standing in front of her with the dignitary. She cannot identify, solely by means of the visual information, the perspectivally individuated object standing before her as the publicly individuated celebrity whose name regularly appears in the newspaper and for whom she voted. This means that in some of the scenarios that are compatible with Jane's visual information the mayor is elsewhere in her visual space or even outside it. This does not exclude the possibility that she knows who the man in front of her is on the basis of other kinds of information, for

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[1] Much of the following follows closely on the analysis provided in Hintikka & Symons (2003). I am grateful to Hintikka for permitting me to include it here.

instance by having been told who he is. It is also compatible with Jane's knowing who Mr. Wardy is outside the particular visual situation, for example, with being able to identify Mr. Wardy as a public object which in this case comes close to knowing which public official he is. She can track him through political history, she holds opinions about his policies, etc.

Stimuli contribute to reducing the set of alternative scenarios ; the more information one has, the more narrowly is one's set of alternatives is restricted. For instance, when the set of alternative scenarios is so narrow that in all of them a term picks out the same person, it becomes true to say that the perceiver sees 'who this person is' or 'sees this person' depending on the mode of identification. By contrast, the identificatory relations between two different scenarios are independent of the factual information an agent happens to possess.

In more general terms, one can say that in public identification one takes a visual object and places him, her, or it on one's map of public figures in a wide sense of the expression. When this happens by means of one's momentary visual information, we can say that the perceiver sees who or what the visual object is. In contrast, in perspectival visual identification the perceiver takes a public object and places him, her or it among one's visual objects. The colloquial expression for this kind of feat of identification is to say that the perceiver sees the (public) object in question, thus illustrating the semantical import of the direct object construction with perceptual verbs.

To sum up, the distinction between public, or object centered and perspectival or subject centered modes of identification is thus clear in the case of visual perception. There one can use as one's identificatory framework the perceiver's visual space. Persons and bodies occupying the same slot in this visual space (in the different situations compatible with what the person sees) can be considered identical, even if that person does not see who they are. This results in a perspectival, or subject-centered, identification system. Please note that by identity, two different (but interrelated) things can be meant, either identity within a scenario ("possible world") or identity across the boundaries of scenarios. What is being referred to here is the latter, which might more explicitly be called cross-identity.

Conceptually speaking the most significant feature of the analysis of the two modes of identification is that only one notion of knowledge is involved in the two. This is true in more than one sense. As was shown in Hintikka & Symons (2003), all the different constructions in terms of knowledge can be analyzed without evoking more than one sense of

knowing, viz. knowing that. This can be considered a major accomplishment of epistemic logic, in combination with the two-modes-of-identification principle. Moreover, the distinction between the two kinds of identification does not turn on any distinction between different sentences S in the construction $K_a S$, of course except for the presence of different kinds of quantifiers. Here, an important interpretational point is seen directly from the use of appropriate notation. The distinction we have here is a distinction between two principles of identification, not between two kinds of knowledge or information. It is a distinction between two kinds of identificatory frameworks to which one's visual knowledge can be related.

Applying this analysis of the two modes of identification to the context of scientific research on visual cognition proves quite striking. To identify b in the perspectival sense means finding a slot for b among our visual objects, in other words, locating b visually. This means in effect being able to answer a 'where' question. In contrast, identifying b in the sense of public cross-identification means being able to put b on the map of abstract impersonal knowledge. It means being able to answer a 'who' or 'what' question. This suggests strongly a parallel the distinction between the two cognitive systems and the distinction between perspectival and public identification. This is shown vividly by subjects suffering from disturbances in the one or the other system. This identity of the semantical distinction between the semantical distinction between the two methods of identification and the two cognitive systems is so strong that such disturbances can be used to teach and to internalize the logical distinction between the two kinds of quantifiers. The most common type of disturbance is a failure to identify objects of a certain kind, for instance faces (prosopagnosia) or colors (color agnosia).

As we showed in Hintikka & Symons (2003) this analysis of the two modes of visual identification has important implications for the way neuroscientists treat the flow of information in the brain. We showed there, that the assumption that there are two kinds of information and two sets of visual pathways is unwarranted. The information provided by different neuronal pathways to different cortical areas need not be differentiated in order for two modes of identification to be applied. What the univocity of knowledge suggests is that knowledge "where" and knowledge "what" are both extracted from the same, or at least overlapping information. If we accept that the same kind of knowledge or information are involved in the two distinct identificatory frame-

works, then research programs in neuroscience will have to be reconsidered. One would expect, for example, the identificatory systems to draw on any available clues, rather than being restricted to one particular source or kind of information. One would also abandon the idea that different aspects of the stimulus to the visual array should be such that they can be traced through distinct neural pathways in the brain. As we have seen, the two streams should probably not be construed as two largely separate informational routes running all the way through the visual system. Instead, different areas will call on different components of input processing most useful for the kinds of action being initiated. Later areas in the system are dedicated to solving specific sorts of problems (e.g., coordinating limb movements) and extract from relevant earlier processes information relevant to those respective tasks.

The analysis in Hintikka and Symons showed that logical investigations can play a nontrivial role in neuroscience. In the case of the visual system, we have argued that the striking correspondence between two modes of identification, as distinguished in the semantical context, and two cognitive systems distinguished by neuroscientific investigation of the visual system (the "where" and "what" systems) is unlikely to be a mere coincidence. Instead, this correspondence has the potential to play a clarificatory role in the neuroscience of perceptual identification.

Conclusion

If one accepts that there is any interplay between logical and other scientific investigations, then a range of deep and interesting questions arise. Understanding the nature of the fit between logical and empirical research will require far more detailed investigation than I can accomplish in this short paper. However, I hope at the very least that the foregoing has shown how analyses like those presented in Hintikka & Symons (2003) can provoke some interesting questions concerning the very idea of applying logical insights to scientific problems. In any event, there can be little doubt that the project of understanding this reciprocal influence between logical and scientific investigation opens a vast range of new and potentially fruitful areas of philosophical research.

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