Simple or Simplistic? Scientists' Views on Occam's Razor*

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ABSTRACT: This paper presents a discourse analysis of 40 semi-structured interviews with scientists on their views of Occam's razor and simplicity. It finds that there are many different interpretations and thoughts about the precise meaning of the principle as well as many scientists who reject it outright, or only a very limited version. In light of the variation of scientists' opinions, the paper looks at the discursive uses of simplicity in scientists' thinking and how scientists' interpretations of Occam's razor impact on philosophy's representation of the principle and affects the communication between philosophy and science.

Keywords: scientists' philosophies of science, Occam's razor, sociology of philosophy of science

1. Introduction

The need to understand the way scientists understand principles from the philosophy of science is generally overlooked, but potentially vital in helping dialogue between science and philosophy progress beyond accusations of naivety on the philosophers' side, or accusations of irrelevance from scientists. This study presents a sociological look at how scientists talk about one frequently raised philosophical principle, Occam's razor. In analysing scientists' discourse around Occam's razor, it aims to provide the scientists' perspectives as well as exploring when and how Occam's razor is being represented as a fundamental principal in science, and thus has a use for scientists beyond its philosophical message. It also indicates a subtle difference in the interpretation of the principle between scientists and philosophers.

This study is not intended to demonstrate that scientists disagree on philosophical ideas, which would probably not come as a surprise to many. But neither is it intended to show that scientists are philosophically naïve, or that they are in need of more rigorous philosophical education. Instead it takes scientists ideas of Occam's razor on face value and classifies the different categories in which the talk about it, and the rhetorical uses to which it is put.

While there is a rich tradition of philosophical and historical studies examining scientists' work in practice and comparing that work with philosophical theorising (Donovan et al., 1992; Brush, 1989), there is little work that examines scientists' own conceptions of the philosophical foundations of science. Researchers in science education and public understanding of science (PUS) often argue that it is important to know

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about how science is "*really* done" (in Durant's 1993 phrase, see also Gregory and Miller 1998). A lot of research in science education in particular has focussed on assessing topics from the philosophy of science for the purposes of teaching about science (Matthews, 1994; Osborne et al,. 2003; Koponen, 2006). For this reason several studies in these disciplines have looked at scientists' philosophical opinions (Wong & Hodson 2009 on scientists, Osborne et al., 2003 on experts in general, though that includes some scientists; Nieman, 2000 and Turney, 2001 for philosophies in popular science books), either to ground science teaching on philosophies as they are held by scientists, or as an interesting question in its own right. Other sociological and philosophical studies on scientists' opinions on philosophy (Mulkay and Gilbert, 1981 on Popper; Bailer-Jones, 2003 on models) have sought to draw philosophical conclusions, by using scientists' insights to inform philosophical theorising. Direct comparison of these studies is difficult as they focus on different philosophical themes and were performed with different aims in mind.

This paper will add to these studies by looking at a philosophical concept not yet covered, as well as presenting a more general argument on how the social study of scientists' opinions of philosophy can help inform philosophical thinking and inform communication between scientists and philosophers. Occam's razor is often seen and justified by philosophers as an intuitive rule. The argument that appeal to the philosophers' own intuition is often inadequate as a foundation for philosophical discussion is also advanced by the recent school of "experimental philosophy", which aims to use the empirical methods to investigate how people think about philosophical issues and use the results to inform philosophical debate (Nadelhoffer and Nahmias 2007). In a similar vein, I intend this study to investigate how the intuitions over simplicity are held by scientists, and how they can open up new directions in the philosophical discussion on Occam's razor.

I will start by giving a quick introduction to some of the philosophical debate surrounding Occam's razor. I will then present the results from 40 qualitative interviews with purposively selected university-based scientists in the UK and France[1]. The scientists have been selected to provide a roughly even split of physics/astronomy, chemistry and life sciences. I have chosen scientists that are research active, and that represent a roughly even split of career stages from postdocs and PhD students to lecturers to full professors. I have also tried to achieve a roughly representative split between male and female scientists. Bearing in mind that female scientists are still very underrepresented in science, slightly above quarter of respondents were female.

There was some unavoidable vagueness about who to count as a scientist, and I settled on the doctorate as a criterion for being a scientist, although I also interviewed three people who were studying towards one. I have chosen to limit myself to the disciplines outlined above as, unlike say psychology or economics, they are unquestiona-

[1]As this paper is part of a larger project on scientists' opinions of philosophical topics (Riesch 2008), the rationale for including French scientists as well as UK based ones was to investigate if the French tradition of philosophy of science following Bachelard and Canguilhem had any marked influence on scientists' views, this however turned out not to be a major factor. Some of interviews were held in French, in which case I have presented my own translation below, with the original in a footnote.

bly regarded as scientific. The interviews show a much more varied and nuanced array of opinions and convictions towards the simplicity principle than is usually supposed, both in philosophical and popular science accounts of Occam's razor. There may be a slightly different way in which Occam's razor is discussed to the way the simplicity principle is discussed, suggesting possibly that Occam's razor has specific connotations for scientists that the mere discussion of simplicity has not. I will finish by pointing towards some of the implications of this study that I see concerning the philosophical discussions of Occam's razor.

The interviews have all been analysed as part of a larger project on scientists' views of philosophical topics, and I have therefore looked out for a variety of philosophical themes discussed by a corpus of popular science books which were then followed up in interviews. Of the various topics, Occam's razor, and/or a version of the simplicity principle was one of the most prominent in the books (Riesch 2008).

The interviews coded with qualitative data analysis software Atlas.ti. My decision to perform a qualitative study, rather than polling scientists' opinions on philosophy or Occam's razor quantitatively was made because philosophical concepts are interpreted and thought about in such a variety and subtlety that simply counting the numbers of scientists who agreed or disagreed with Occam's razor will not give any worthwhile insight into the thinking of scientists. Instead, this study is meant to be charting the variety and diversity of opinions on the topic rather than their representativeness, and by talking in depth to a much smaller group of scientists I have been able to assess and interpret the diverse opinions.

2. Occam's razor

In the interviews Occam's razor was introduced usually like this: "When you are faced with two theories (hypotheses, statements etc) that, other things being equal, both describe the available evidence equally well, is it sensible to choose the simpler one"? This rather vague formulation captures the essence of what the principle is generally held to say, and through its vagueness gave plenty of room to the respondents to interpret the principle as they like it best. It also possibly echoes the vagueness in most philosophical introductions to Occam's razor. In the question I have put to the interviewees I have explicitly formulated Occam's razor as a question of theory choice. This is the way the razor is usually introduced by contemporary philosophers (Baker, 2004). Kuhn (1977) for example has argued for simplicity as a value to consider when choosing a theory. Philosophical introduction often emphasise the intuitive character of Occam's razor especially to scientists, and proceed to find a justification for that intuition.

2.1 What is simplicity?

One of the central questions in philosophical discussion on Occam's razor is the question of what exactly we mean by simplicity. Historically there has been a rather confusing array of definitions which even include the contradictory opinions of simplicity as high probability and simplicity as low probability (Sober, 1975 p.vii). In technical

applications of the razor, like ones in decision theory and artificial intelligence, the principle can achieve rather complicated ideas of simplicity that fulfil the formal criteria set by the philosopher so that the principle performs the desired task.

Suppose we have the choice of two lines that both fit the data, a straight line and a circle. Aesthetically, both seem equally simple. Mathematically, the straight line is easier to describe, unless we switch to polar coordinates. It appears therefore that what is simpler is often dependent on background assumptions of the scientist mulling over it. Philosophical discussions such as that of Popper (who attached simplicity to the concept of testability), and Sober (who defines simplicity as informativeness) have provided formalised solutions to such problems, but it is ironically precisely the most sophisticated philosophical definitions of simplicity that are in danger of being ignored by scientists, because they are too complicated to be useful in routine scientific practice. This does not matter in specialised contexts such as finding epistemological justifications or for designing rules for reasoning in artificial intelligence, where most recent discussion of Occam's razor has taken place. It does however affect its usefulness to actual scientists whose intuition has started the whole question in the first place. Therefore, even if we find an epistemologically satisfactory answer to the problem of simplicity, it may well fail as a methodological, normative principle for scientific practice, even if it is satisfactory for the philosophical discussion. Also of course, being ignored by scientists because it is too complicated does not mean that these rules are irrelevant.

The formulation which I have given above is open to interpretation on other points as well: what do we mean by "other things being equal"? Can we really imagine a case where *all* other things really are equal? In the absence of a clear definition of what we really mean by simplicity, the phrase "all other things" has no clear meaning either. And even so, how do we decide what the other things are that matter, and which ones do not? This clause is itself a topic of serious philosophical discussion which often goes beyond its scientific practicality (Schiffer 1991, Pietroski and Rey 1995), and therefore not directly relevant to the interviewed scientists.

2.2 Three types of Occam's razor?

For the purposes of interpreting the scientists' perceptions of the razor, I propose to classify it into three categories. These three categories are meant to chart the possible usefulnesses of Occam's razor, they are not meant to be mutually exclusive, as it is perfectly possible that Occam's razor has several uses or justifications. Baker (2004) distinguishes between epistemic principles of simplicity (it is rational to believe the simpler theory) and methodological justifications (it is rational to adopt the simpler theory "as one's working theory for scientific purposes") of Occam's razor. To this I will add a third type of principle, a variation of Baker's epistemological one, which I have come across on several occasions: It is rational to believe in the simpler theory because that is what the world is like.

It should be stressed that these categories have arisen out of the analysis of the interviews and were not preconceived ideas into which I then tried to force the scientists' opinions. This is the reason I judged it best to introduce three main divisions

rather than the two that Baker talks about (because the ontological razor forms a large part of the scientists' own conversations of simplicity), and for this reason they are slightly vague and do not correspond exactly to the way philosophers such as Baker have discussed them. This is especially true of what I call the methodological razor, which equates simple with whatever the scientist mulling over a theory choice problem finds easier (personal preference) or socially more convenient (social norm).

a) The methodological razor

Under this application of Occam's razor, it is more a practical matter that we should choose the simpler option. I call it "methodological", with Baker, because it prescribes Occam's razor as a *method* for doing science. If there really is no other reason to choose one way or the other, why should the scientist make her already stressful life harder by choosing the complicated option?

While nobody suggests that the scientist should go for the more complicated option, this justification of the value of simplicity for science is speedily dismissed by some philosophical commentators such as Popper: As Popper is generally looking to find a logic of science, purely practical considerations are "extra-logical" (Popper 2002 [1934] p.122), and therefore not quite what he is looking for when he tries to define simplicity and why or whether it is a good idea. The injunction that the scientist should go for what is easier often depends on the personal preferences of the individual scientist (or, again, on social norms), and can in these circumstances not serve as a normative and logical philosophical principle. However, there are also occasions when there is an objective basis on what is simpler in this sense; for example some equations really are harder to solve than others.

b) The epistemological razor

Instead, it is frequently argued that the scientists' intuition to prefer the simpler hypothesis must rest on an understanding that it is the best way to proceed for reaching an understanding of the world. This for example is Popper's position, as he argues that simplicity is an intrinsic value of a good scientific hypothesis. In fact, because Popper defines simplicity to be nothing other than the degree of a hypothesis' testability, it is one of the cornerstones of Popper's methodology, getting a whole chapter to itself. Note that this does not depend on an understanding that the world will eventually turn out actually to be simple — it merely supposes that by consistently choosing the simpler hypothesis, we will gradually get a better understanding of the world whether it is simple or not.

The same goes if we suppose simplicity to be an approximation. It can be argued that a hypothesis is simpler because it is only an approximation, much in the same way that "3" is a simpler value for pi than "3.141". In this sense of simplicity, we have the almost counterintuitive result that the simpler a hypothesis, the further away it is from a faithful description of the world, but the more likely it is to be true.

These two contrary ways of identifying simplicity also lead to the quite incredible fact noted by Sober above, that the simplicity in Occam's razor has both been identified with being probable (the simplicity-as-an-approximation idea), and with being im-

probable (Popper's idea of simplicity-as-testability rests on the idea that the more likely something is to be true, the less falsifiable it actually is).

c) The ontological razor

Here we assume that fundamentally the world is simple, and because it is simple any successful scientific theory must mirror that fact. This idea has a considerable intuitive appeal for some people, and has been justified through the argument of the uniformity of nature, which underlies the principle of induction. If we try to find generalisable laws of science from induction, then we will have to assume at least some sort of uniformity of nature. If we observe a pen to fall ten thousand times, then the simplest assumption is that it will fall the ten thousand and first time as well.

Going further than mere inductive reasoning, however, the ontological idea of simplicity is one that pervades such fundamental quests as the search for the "theory of everything", as it is in essence trying to explain the world with as few forces and particles as possible. In a similar way often the ideas of beauty, elegance or aesthetics of a scientific theory betray a conviction that the world is in some way easily understandable.

The phrase "choosing a theory" is usually ambiguous because it can mean accepting a theory or merely using it to pursue your science. In the methodological and the epistemological razor, theory-choice is therefore of the second type. It is a practical thing to do either because it is easier or because it systematically leads us to progress in science. In the ontological razor however, theory choice should usually imply acceptance as the truer theory.

3. Occam's razor in the interviews

In approaching the scientists for interviews I have aimed to achieve a roughly even split between the biological and the physical sciences, where I considered the physical sciences to be physics/astronomy and chemistry. Since of course not everyone who is approached agrees to be interviewed, a precise split was impossible to achieve. Disregarding the pilot interviews (marked numbers 1 to 4 in the quotes below, which were based on a convenience sample of a UK physics and astronomy department), the eventual numbers were 16 biologists, 16 physicists and 4 chemists. The fact that chemists were the least likely to respond to my approach is interesting, and — as one of the chemists noted in the interview — may suggest that chemists are much less likely to worry about philosophical issues. There were however also issues of career structures, as the movement between chemistry and physics — and sometimes between physics and biology — was quite fluent. Several interviewees started with a chemistry background and moved to work in physics departments, or started in physics and moved to biology (in which case I've noted the interviewee's background discipline as well in the quotes below). The eventual numbers mean that, including the pilot interviews, there were slightly more physical scientists in the corpus than biologists, and this is reflected in the spread of quotes below. Considering the whole of our conversations on other philosophical topics and general attitudes towards philosophy,

I have not found that there is much difference in philosophical interest and opinions between the disciplines.

A third of the interviews were held in Paris, and three interviewees had experience of working in both Anglophone and Francophone countries. 28 respondents were male, 12 were female, which is probably a fair reflection of the gender proportions in science generally. 13 respondents were early career, which were mainly postdoctoral researchers and on three occasions PhD students. 13 respondents were mid career, meaning lecturers, senior lecturers or readers or their French equivalents. 14 were senior researchers, i.e. full professors and equivalent.

In terms of general attitude and interest in philosophy, and Occam's razor in particular, I did not detect any striking differences between genders or career stage. French scientists were more likely to be aware of the French philosophy of science traditions following Bachelard and Canguilhem, though they did not generally influence the scientists' ideas on science. In fact though most French scientists were aware of Bachelard as a general philosopher, many did not know of his work on philosophy of science.

The interviews were fully transcribed and coded using qualitative data analysis software. Every interviewee was asked about their opinions on the value of simplicity for science, as well as selected other topics. Though the interview schedule was not fixed for the pilot interviews, the discussions there all touched on simplicity as well, and therefore they are included here as part of the main analysis. Comments on the value of simplicity were coded (see the appendix for the coding frame), and the primary codes were then organised into broader categories. Comments on what Occam's razor or simplicity is or should be fell into three broad groups: Comments about the razor being a practical maxim designed to make the scientist's life easier, comments that were giving a specific epistemological justification for why a simple theory or hypothesis is valuable and lastly comments that speculated about the nature of the world being simple. The first two categories I found mapped well onto Baker's division between methodological and epistemological interpretations of Occam's razor, while the third type of comment seemed somewhat apart as it talks about the nature of the world, rather than the nature of science. I have therefore divided the scientist's comments into three sections that represent the three types of razor I have outlined above.

During the interviews, I tried to assess whether the scientists were in favour of Occam's razor or not. While I have received a few unambiguous answers, usually delving deeper into the question revealed a more nuanced view that differentiated between different interpretations of simplicity. Seven interviewees even regarded Occam's razor or simplicity as important enough to mention it during the initial stages of the interview when we discussed their general opinions on scientific method. Regardless of their opinions of what simplicity really is, interviewees also often stressed that Occam's razor is very intuitive, but that it is also very difficult to judge in practical situations when a hypothesis really is simpler than the alternative.

Although a few scientists rejected Occam's razor outright, there was general agreement that simplicity is important in science. This however mostly took the form of the methodological razor. When the interviewees tried to go beyond practical considera-

tions, there was little agreement over what simplicity really is, and why it should help in science.

3.1 The ontological razor and intuitive evaluations of simplicity

As the interviews were part of a larger project aimed at identifying scientists' attitudes towards scientific method, sometimes Occam's razor or more rarely some mention of the importance of simplicity have frequently come up spontaneously in the conversation without being directly prompted by me. That alone indicates that at least for some people, Occam's razor is centrally important to their view of science. In several cases the principle formed an integral part of scientific method for the respondents.

> Scientific method is that within some system you make hypotheses, you make testable hypotheses, you test them, and you keep the ones that are verified, and you throw out the ones that are falsified. If you have two hypotheses which are verified, which explain the same phenomenon, you use Occam's razor and take the simplest. (32 Senior, Physics, Male, France/En)

However, further discussion often revealed that people are only confident that at best they have merely a "gut-feeling" that this is the best way to do science, and that they don't really see any particular reasons why a simple hypothesis should be better. One difficulty about determining what role Occam's razor should play in science is that it is bound with the scientist's attitude towards truth itself, as with the ontological razor presented above. We cannot believe that Occam's razor helps us in uncovering the truth if we don't believe science is in the business of getting the truth. When I asked the scientist quoted above whether he thinks that a simpler hypothesis is more likely to be true he remarked that

> I don't really think anything is true, that's the problem I've got, because I mean I get a bit, I get a bit allergic to absolutes, so… the… there's no doubt that it's a practical thing, *at least*, but is it only this, is the question I guess. (32 Senior, Physics, Male, France/En)

If nothing else, Occam's razor here seems a practical consideration. Its epistemic worth is not really being questioned, but it is at least sidelined.

Another scientist who thought that Occam's razor was "absolutely critical" remarked in the subsequent discussion that he would not be able to explain why Occam's razor should apply, even though he was sure it did. When I asked whether a simple hypothesis is more likely to be true, he hesitated before ultimately responding that it is, but that this opinion rested merely on a "gut feeling".

> *Respondent*: …simplicity is more likely to be true… but don't quote me on that [laughter].
>
> *Interviewer*: Well, if you ask me not to…
>
> *Respondent*: No, you can say what you like, I mean that facetiously. Just I couldn't stand up in front of, you know, various philosophers and defend that remark. (7 Senior, Biology, Male, UK)

There was also a sense among some respondents that we know that simple is more likely to be true, but we just don't know why. The following remark also came up in an unprompted discussion of Occam's razor: "I wish we could work out why mathematical beauty is a good guide to the universe". (2 Early Career, Physics, Male, UK). Note here also that mathematical beauty is being seen as the simplicity that Occam's razor is about.

What I call the ontological razor therefore seems to have at least had some followers among the interviewees. While there was a general consensus that we can't really prove it, some people had a very strong feeling that it somehow is right. This argument was sometimes backed up by the argument that for us to be able to do science at all, the universe *has* to be understandable. If nature was not uniform and therefore in some sense simple, science would be impossible. Similar to the popular expositions of the search for a Grand Unified Theory (Greene 2000), there were also some comments that explained the quest for that theory of everything with the search for simplicity.

> That is, we search for a theory of everything because it's a theory that explains everything, and that [*inaudible*] simple. (33 Senior, Physics, Male, France)[2]

In the same vein, people also very often spoke about the beauty, aesthetics or elegance of theories.

3.2 Explanations for simplicity and the epistemological factor

Some respondents have ventured to find an explanation of what useful simplicity should be other than an intuition or a gut feeling, while others have provided arguments why they think it can't be done. One respondent had a rather negative initial reaction to Occam's razor, but provided an explanation of how simplicity could be defined, which he sees as useful in science:

> And actually my PhD supervisor always used to say, on this aspect of agreeing with data, he's only interested in the first factor of two. Get within the factor of two, and then the interesting physics ends, and somebody else can work out the details. So what I think he means by that is that you want an idea that explains broadly lots of things to a reasonable degree of accuracy, rather than one idea that explains one thing to a billionth of a percent. (23 Early Career, Physics, Male, UK)

This is a variation of the idea that simplicity is defined as an approximation. Therefore, even though Occam's razor is recognised by the respondent as being valuable for science, it does not in fact entail that the underlying world is simple. A similar idea of simplicity as an approximation was also made by other respondents.

One identification of the meaning of simplicity was that of testability. One respondent who initially reacted very guardedly towards Occam's razor, admitted that how you define simplicity is difficult. Nevertheless on reflection he gave this idea of what simplicity could mean, and why it's useful in science:

> I like the simplicity for that matter, I like the Darwinian natural selection principle, it's very beautiful you start with one idea and it explains many things. (9 Senior, Physics, Male, UK)

Another related idea was to identify simplicity with the number of "degrees of freedom", or parameters.

> There, I want to say that… I myself see it like, I think it's, maybe a, there is an analogy with the number of degrees of freedom. […] It's the number of independent parameters that you have for explaining a dataset. (35 Senior, Biology/Physics, Female, France)[3]

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2 " C'est, on cherche la théorie de tout parce que c'est une théorie qui explique tout, et ça [*inaudible*] simple".

Quite often though, people reacted spontaneously questioning the whole principle of Occam's razor, precisely because it's hard to define what simplicity actually is. Others have pointed out that it's the background knowledge you have that determines what you find is simpler.

3.3 Criticisms of Occam's razor: the merely methodological razor and outright rejections

One of the most common responses was that Occam's razor is useful, but mostly for practical reasons. This practical choice argument was also often made by people who thought there was something more to simplicity but couldn't say exactly what. Even those who argued that simplicity was easily definable and gave such a definition argued that at the very least that's why we go for it. Curiously however, people who completely disagreed with Occam's razor often also made the same argument: While Occam's razor has misled us in the past, and may even be harmful to our understanding of the world, it still makes no practical sense to go for the more complicated option.

For many people just the practical aspect of the razor was enough to agree with Occam's razor, but then some also argued that that isn't always the case, either.

> [Occam's razor] tends to make good biological sense, because it is less resource wasting to use a simpler way of doing something than a complex way of doing something. Although that isn't always true, and in certain circumstances you find multiple pathways that actually achieve the same thing, because it's so important that if that didn't happen, then life would cease, or whatever. But… on, you know, on sort of a day to day basis it usually holds true, I would have thought. (8 Senior, Biology, Female, UK)

Not everybody reacted positively towards Occam's razor, even in the limited sense of the methodological razor. One respondent was talking about the difficulty he had with general definitions of scientific method, as they didn't give him any practical, useful hints on how to proceed when faced with radically different worldviews. Here he is talking about the difficulty he faced when explaining to a friend why he shouldn't believe in creationism:

> I mean, I don't buy Occam's razor, either, particularly, I mean it's something you use, but it's not very useful when you're comparing various, different paradigms. (21 Mid Career, Physics, Male, UK)

Another possible reaction was to question not whether it is sensible to choose the simpler one, but whether we should choose at all. This actually tied into the respondent's beliefs about the value of scientific realism, and therefore led her to reject the razor as a practical guide on what to believe, if not on what to work with. If all things really are equal, why do we *have* to chose at all?

> [W]ell if there is sufficient evidence for both, then I believe both happily. And then wait for more… I mean if the experimental data doesn't favour one of them, why should I believe the simpler one? […] I probably would because it's easier to understand, easier for my brain to work on, but if they both show sufficient data, then either of them might be right or neither of them

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3 "La, je veux dire que… je le vois moi comme un, je crois un, peut être, il y a une analogie avec nombre de degrés de liberté. […] C'est le nombre de paramètres indépendants que vous avez pour expliquer un système de données".

> might be right, so I'm happy to believe both until one is disproven. (25 Early Career, Biology, Female, UK)

Another argument was that Occam's razor only gets us to the next best solution for a problem, and possibly harmful as it leads us up blind alleys. Following the simpler theory would lead us only to the local, rather than the global minimum:

> So all you do is you take small steps in the right direction. And to me that's what Occam's razor is like, is that you say, this is the, this is... I'll go in this direction… doesn't mean you end up at a, what's called a global minima, you end up in a, most likely, local minima. […] So you would have thought maybe Occam's razor would keep you trapped in that little corner (21 Mid Career, Physics, Male, UK)

An even more extreme reaction is to argue that not even is Occam's razor not giving us any practical help in deciding which theory to go for, it may even be harmful to our understanding of the world, as it is maybe more wishful thinking.

> But at the end of the day, if you want to understand that phenomenon or something completely, probably going a little complex would help (22 Early Career, Physics, Female, UK)

Finally, it is perfectly possible to actually argue inversely and hold to an epistemological razor which does not correspond to a methodological one: While simplicity is a good guide to the universe, it doesn't mean it's the easiest or most practical option — or even the most elegant.

4. Discussion

4.1 Occam's razor vs. the principle of simplicity and the social representation of simplicity

Although Occam's razor is frequently held to be a critical part of science that is intuitively held by scientists, in the interviews a slightly different story about Occam's razor unfolds. While for some interviewees, Occam's razor indeed forms an integral part of scientific method, this view was not held very often, and was quickly qualified in the discussion as either meaning that it doesn't really have any real implications for getting at the truth as such, because that concept is itself highly problematic, or that its intuitiveness, the "gut feeling" it conveys, is all we really have to justify it.

Curiously, most of the people who did venture an explanation of what could be meant by simplicity, are those that did not specifically react with mentioning Occam's razor to my initial question. It was also the case that people who did offer an explanation of what simplicity could mean, did not really like talking about "simplicity" because it is such a vague concept. In this they actually echo the discussion by Popper (2002, p.131, addendum to the 1972 edition), who gives his definition of simplicity as testability, but then argues that he does not want to get bogged down on whether this really is the definition that best captures our intuitions of simplicity, and instead wants us to concentrate on the epistemic benefits of testability. That is reflected by the number of people in the interviews who initially reacted positively towards Occam's razor but then offered an explanation of what could be meant by simplicity for the principle to become valid, an opinion which is not that much different in fact to some of the people who disagreed with Occam's razor or the simplicity principle, but then also offered an explanation of what simplicity could be for the principle to be valid.

There was also a group of interviewees who arrived at a negative conclusion, rejecting Occam's razor altogether. This can either take the form of people disagreeing that simplicity is definable at all, to people who argue that simplicity can even be harmful to science.

What this suggests is that there is a difference about how people talk about *Occam's razor* and how they talk about *simplicity*. While Occam's razor in the interviews found a lot of agreement as a critical principle in science, it usually got qualified when the discussion turned to simplicity itself. Simplicity on the other hand, received a good amount of critical discussion which reflects a surprising amount of variation of opinions.

The theory of social representations (Moscovici 2000, Bauer and Gaskell 1999 and 2008) may help here in analysing the scientists' perception of the razor. When a group of people is confronted with new concepts, they seek to *anchor* them to concepts or ideas they are already familiar with. Through this different social groups can converse and communicate on certain topics without necessarily seeing eye-to-eye on the precise interpretation. This process also insures however that interpretations of concepts can easily shift in subtle ways as they travel to new communities. In this case there is the added factor that scientists are continuously told, by philosophers, popular science communicators such as Hawking (1988 p.61) and other authority figures, that Occam's razor is an integral and well accepted part of science. Moscovici had in fact explicitly intended his theory of social representations to be a social psychology of knowledge, and even saw it as a social psychological explanation for Kuhn's idea of paradigms (2000 p.151): through the mechanism of anchoring, new representations always have an aspect of things already familiar, which leads to a certain conservatism when groups are confronted with new concepts. As a theory of public representation of scientific concepts, it has been applied by Bauer and Gaskell (1999) and Farr (1992), particularly within research on science communication.

Nieman (2000) has interpreted philosophical remarks in popular science books as boundary building in the sense of Gieryn (1999), which sets up a simple demarcation criterion for authors to show that they are conforming to proper scientific practice by showing that they adhere to well accepted philosophical principles. Occam's razor, as I have analysed in a separate study of popular science books (Riesch 2008), fulfils much the same function as a boundary marker. The concept of social and epistemic boundaries elaborated by Gieryn I have argued is linked with social representations, because the boundary separates disparate groups which assimilate boundary-spanning concepts and develop their own representations of them. Through this, communication between groups is eased because even without agreeing on details the groups can still use the same vocabulary. However, this also means that there are bound to be conceptual differences in the interpretation of these concepts. When faced with the imperative to comply with what is usually presented as accepted scientific practice, scientists *anchor* their interpretations of Occam's razor to what they are familiar with, in this case their own experience of scientific work. If epistemic or ontological interpretations of simplicity don't much feature in their own work, Occam's razor acquires a methodological interpretation, because that corresponds most closely to the scientists' own experi-

ence. The scientists' own representations of Occam's razor has thus acquired a different meaning from how philosophers discuss it, without necessarily being seen as a different concept by either group. This, as I will argue below, has some consequences for how philosophy of science itself uses the concept, particularly since, as Mosccvici argues (p.150), the original representation is changed as much in the process as the new one acquires its meaning. Philosophers can themselves be influenced by how scientists interpret Occam's razor (for example through the insistence of its intuitiveness to scientists).

4.2 Implications for the philosophy of science

In contrast to how it is often portrayed in philosophy, simplicity as a criterion for theory choice is not held intuitively by all scientists. As outlined above, while a few questioned Occam's razor outright, many others believed Occam's razor to be a pragmatic choice that is only relevant to make the scientist's life easier, rather than either an integral part of scientific method or even a pointer to the theory that is more likely to be true. This "lowest common denominator" option for Occam's razor however has already been dismissed by Popper and other philosophers as not really embodying the real importance of simplicity. Therefore one immediate lesson for philosophy is that referring to scientists' intuitions is a poor justification for starting to look at why we should need simplicity in discussions of scientific method. That is of course not to say that simplicity is not a useful principle, but it conceivably lessens the importance we think we should attach to it.

I would also argue that there is a more positive message for philosophy to be had. As some previous philosophical studies such as Bailer-Jones (2003) have done, we can look to the scientists' views of philosophical concepts to open up new directions of research in philosophy of science, directions which can make a real claim of reaching practical relevance for science. The fact that there is a new strand in the philosophy of science that seeks to philosophise on actual scientific practice, evidenced by the establishment of the Society for the Philosophy of Science in Practice, shows that there is has recently developed an undercurrent of concern within philosophy about its relevance to scientific practice.

Given the importance of the methodological interpretation of simplicity within science, there are a host of new questions for philosophy to analyse, which have previously been largely dismissed. This is not to say that philosophy needs to come to more positive conclusions about the methodological razor, however by theorising on questions that are of actual importance to scientists, philosophical analysis can start offering value to scientists as well as philosophy itself, and thus transcend some of the barriers of language and interpretation that exist between philosophy of science and scientific practice.

This leads to the question of translation between philosophical and scientific language, and I think the most important lesson this study points to. Scientists, far from ignoring philosophical principles as they are often caricatured, have actually taken some principles on board, and attached their own meanings to them which reflect the way they themselves think about science. This as I pointed out through social repre-

sentation theory is in a way expected, as scientists hear about Occam's razor, from their own scientific education or popular science books that inspired them as kids where adherence to the principle is presented as a defining characteristic of science, yet not further explained. Subsequently, when they think about the science as they practice it, they can easily come to anchor their understanding of Occam's razor through their own experience of science. If a scientist has come to believe that Occam's razor is a defining norm of science, and since of course everybody thinks they are doing good science themselves, so their interpretation of Occam's razor will conform to their own way of practising science.

It is precisely through the iconic character that Occam's razor has acquired within the scientific community that it has lost most of its philosophical force: Because everybody thinks they need to adhere to it, it has become watered down for some scientists so much that it conforms to their science, but is uninteresting philosophically (as evidenced by Popper's swift dismissal of the methodological razor, or Baker's very cursory glance at it). This is not to say however that the scientists' understanding of philosophy in this case is naïve or unsophisticated. On the contrary, I have found plenty of intelligent introspection and thoughtful argumentation over the value of simplicity in the interviews, which demonstrates that philosophical musing is alive and well within science. But this also means that by acquiring this iconic status, the philosophical principal as understood by the scientists has changed meaning from its philosophical origins.

If meaningful dialogue between philosophy and science is to continue, we need to make sure that we and the scientists talk the same language. While it is tempting to rail against scientists that they misunderstand philosophy, we will have to be aware that scientists will always muse about their activity on their own terms and in their own language, and if philosophy wants to have any part in contributing to these musings and understanding the scientists' point of view, it must look at the way philosophical terms are used and understood in science, track the rhetorical and discursive uses they are put to, and work out the implications of that philosophical rhetoric. In this sense a sociological understanding of scientists' philosophical discourse can help philosophers re-establish a connection with scientific thought and practice.

Appendix: Coding Frame

1. General
Simplicity difficult to judge 13
Simplicity generally accepted by scientists 6
Simplicity is intuitive 10
simplicity: different for biology and physics 1
simplicity: no clear cases where OR applicable 2
Used to believe in simplicity 1

2. Initial reactions
Initial reaction to simplicity guarded 11
Initial reaction to simplicity negative 8

Initial reaction to simplicity positive 13
Initial reaction to simplicity, mentioning Occam 7
Spontaneous mention of Occam 6
Spontaneous mention of simplicity 1

3. Epistemological/what is simple
Epistemological razor 1
Simple valuable as approximation 7
Simplicity as explaining a lot with a little 2
What is simple depends on background knowledge 3
Simple possibly same as likely/probable 6
simplicity: No. of parameters 1
Simple not the same as likely 2

4. Ontological
Simple is more likely to be true 7
Simple is not more likely to be true 21
World actually quite complicated 1
World is unlikely to be simple 1
Beauty 15
Elegance 1

5. Methodological
Simple is more useful/practical 29
Simplicity not necessarily the easiest/most practical 1

6. Role of simplicity in science
simplicity useful for dealing with ad hoc theories 3
Simplicity has fooled us in the past 3
Simplicity helpful in science 8
Simplicity in everyday life 2
Simplicity in GUT ("Grand Unified Theory") 6
Simplicity may be harmful to science sometimes 6
Simplicity unhelpful in science 3
simplicity: No GUT possible 2
simplicity: not always applicable 1
Simplicity: OR invalid 2
We should not be afraid of complexity 1

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