

RESEARCH PAPER



Managing the transition to open access publishing: a psychological perspective

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ABSTRACT

To manage the transition to the open access (OA) model of scholarly publishing, we need to understand better what enables, encourages and inhibits the adoption of OA publishing among scientists, and to appreciate individual differences within disciplines. The study adopts a psychological perspective to elucidate motivations, capabilities and opportunities for OA publishing among bioscientists in the UK. To identify differences within the discipline, bioscientists with starkly different past practices for disclosing research data and technologies were interviewed. The sampled bioscientists face similar obstacles and enablers in their physical environment, but that their motivations and experience of their social environments differ. One group is strongly motivated by their moral convictions and beliefs in benefits of OA and feels peer pressure related to OA. The other group expresses fewer pro-OA beliefs, holds beliefs demotivating OA publishing, but feels pressure from research funders to adopt it. The former group makes more frequent use of OA publishing, which suggests that only those with strong motivations will work to overcome the social and physical obstacles. The individual differences within the discipline suggest that bioscientists are unlikely to respond to OA policies in the same way and, thus, the appropriateness of one-size-fits-all OA policies is questioned.

Introduction

The knowledge transfer channels among universities, industry and other users have been the topic of much investigation in recent decades (Perkmann *et al.*, 2013; Azagra-Caro *et al.*, 2017). Studies have examined closed disclosure practices related to the commercialisation of academic inventions (e.g. Gao and Haworth, 2016), open disclosure practices such as publications (Kapeller and Steinerberger, 2016) and, more recently, production of open data

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(Perkmann and Schildt, 2015). As the academic publishing industry undergoes significant changes driven by the open access (OA) mandates of public research funders (Harvie *et al.*, 2013; Beverungen *et al.*, 2013), OA publishing is emerging as a new knowledge disclosure practice (Houghton and Oppenheim, 2010; Suber, 2012). This new practice makes research outputs openly and freely accessible and, it is believed, makes it easier to evaluate, replicate and build upon knowledge produced by others and, thus, to facilitate scientific and technological advancements and the mobilisation of knowledge for social and economic benefits (Gaulé and Maystre, 2011; McKiernan *et al.*, 2016; European Commission, 2016). Academics in the science, technology and innovation (STI) field have begun to investigate OA in this context; however, the amount of research remains small and the findings shed little light on how the transition from the traditional to the OA model of academic publishing can be managed. For instance, what kind of policies and other interventions are appropriate for governments, research funders, universities and publishers to encourage the adoption of OA publishing in academia? This paper aims to shed some light on how this transition should be managed.

We argue that changing the publishing behaviour of academics is a major challenge in the transition to the OA model of academic publishing. Traditionally, scientists have had little control over readers' abilities to access or re-use their published research papers. However, OA publishing is making it possible to ensure that readers have free access. OA in the context of published research requires behavioural change. To provide repository-mediated OA, researchers need to provide an appropriate version of their manuscript for the relevant repository (e.g. PubMed Central, arXiv, bioRxiv) without violating the publisher's rules. In some disciplines, the publisher/journal is responsible for depositing the published papers in the relevant discipline-specific repository (e.g. many biomedical and life sciences journals use PubMed Central); however, it is more common for this responsibility to lie with the author. According to SHERPA/RoMEO¹ (2017), 80% of journals allow authors to archive a pre-print (i.e. a pre-refereed draft) and/or a post-print (i.e. a final draft post-referee review); in 2014, only 1.3% of papers worldwide were made accessible through this route (Jubb *et al.*, 2015). Another option is to provide journal-mediated OA in fully OA or hybrid journals. Authors may have to pay a publisher's article processing charge (APC) to make their paper openly accessible from the journal's website. Jubb *et al.* (2015) estimate that, in 2014, 16.6% of peer-reviewed research papers worldwide were immediately accessible from a journal website, including 9.6% in APC-charging fully OA journals, 4.6% in fully OA journals with no APC, and 2.4% in APC-charging hybrid journals. In the UK, some universities have developed centralised processes for paying the APC to selected publishers, but academics are required to check with their employing university whether their paper is eligible for institutional funds. Thus, providing APC-based journal-mediated OA remains slightly more onerous for academics than non-OA publishing. Publishers enabling OA have tested alternative user-pays and author-pays business models, such as: (a) OpenEdition's freemium model (where some content in HTML format is available free of charge while users have to pay a premium for other formats and some exclusive content), (b) PeerJ's membership model (until 2016) (where authors pay a one-time membership fee for the right to publish in PeerJ OA journals), and (c) BMJ's mixed model (where advertising revenues are combined with an APC paid by the authors or their institutions). While alternative models are emerging, enabling OA to published research via a repository or APC-charging journal requires individual behavioural change.

Bernius *et al.* (2009, p.108) note that ‘despite the high number of scholars who support the new paradigm when asked, the realization of OA in most disciplines is rather low’ and ‘little is known about the reason of this discrepancy’. While the varying OA adoption rates across disciplines have received some attention (Jamali and Nabavi, 2015), the differences within disciplines and the reasons for them are less well known (Park, 2009). This is problematic, since, without understanding what enables, encourages and inhibits adoption of OA publishing it is difficult to develop effective policy instruments to facilitate transition to the OA model of academic publishing. Previous studies shed little light on researchers’ reasons for adopting OA publishing since they tend to take bibliometric, economic or socio-political perspectives (Houghton and Oppenheim, 2010; Gaulé and Maystre, 2011; Harvie *et al.*, 2013). Our study adopts a psychological perspective, namely the COM-B behaviour model (Michie *et al.*, 2011), to reveal the individual characteristics (researchers’ motivations and capabilities) and the aspects of their physical and social environments that influence adoption of OA publishing. We discuss how insights into what drives, enables and inhibits OA adoption can be used to manage the transition to OA publishing.

Our exploratory study is based on 22 in-depth interviews with scientists working in the biosciences field in the United Kingdom (UK) following the launch of the UK Research Councils’ OA policy (RCUK, 2012), which allowed us to capture how researchers respond to funders’ OA mandates. In the UK, uptake of OA in the biosciences is higher than in other disciplines (Jubb *et al.*, 2015) and the UK is among those countries that are pioneering OA policies. We anticipated that this situation would allow a good understanding of the psychological disincentives and barriers in conditions that, generally, are very conducive to choosing OA. Any difficulties identified in biosciences are likely to be more pronounced in other settings. Guided by the COM-B model, we combine quantitative analysis of OA publications with qualitative content analysis of interview data to gain insights into the psychological and environmental factors that affect adoption of OA publishing among bioscientists, including researchers in the fields of systems biology, metabolomics, genomics, proteomics, synthetic biology, microbiology, molecular biology, biomedicine, biochemistry and bioinformatics. To advance our understanding of differences within disciplines, we examined how past knowledge-disclosure practices affect adoption of OA publishing. Specifically, we explored two aspects. First, whether researchers who, in the past, provided open access to their intellectual property (IP) (specifically data and technologies) resulting from their research more frequently provide OA to their publications. Second, whether they have different motivations, capabilities and opportunities for doing so than researchers who previously used more restrictive channels, such as exclusive/for-profit IP licensing, contract research or sharing data within exclusive multilateral collaborations with industry.

Our study contributes to the academic literature in two ways. First, we generate new empirical insights into what enables, encourages and inhibits adoption of OA among academic researchers by providing a better understanding of the motivations, capabilities and opportunities for OA publishing. We show that the realisation of OA varies within a discipline, depending on past knowledge-disclosure practices. Specifically, we find that bioscientists with a past record of sharing IP openly are more strongly motivated to adopt OA publishing, driven mainly by their moral convictions and beliefs that OA benefits themselves, other scientists and society. These motivations encourage them to overcome the obstacles in their social and physical environments. In contrast, scientists with a previous history of proprietary approaches to sharing IP have less strong motivations and hold beliefs

that are de-motivating towards OA publishing. Despite feeling subject to the OA mandates of research funders, they are less motivated to overcome the external obstacles and tend to embrace OA less frequently than the other group. Our second contribution is conceptual. We introduce the COM-B model of behaviour to the field of STI studies and show that it can be a useful guide to analyses of scientists' behaviour, and can generate findings that may inform the design of science policy interventions. Our paper is the first to apply the COM-B model to study OA.

The paper briefly summarises the key works on OA academic publishing in the STI field and highlights a gap, which our study aims to address. It then introduces our analytical framework and explains the discipline differences likely to be observed among bioscientists. Following presentation of our methodology and findings, the paper summarises and discusses the latter in light of the literature. The last section discusses implications for managing the transition to the OA model of publishing.

Literature review: what is known about the transition to OA publishing

Our review of the papers on OA academic publishing in STI journals reveals that scholarly debate has been dominated by bibliometric, economic and socio-political perspectives. The spike in publications on this topic around 2012–2013 coincides with the introduction in the UK of more stringent OA mandates. While the existing work provides many valuable insights, which are discussed below, it sheds little light on how the transition from the traditional to the OA model of academic publishing can be managed.

Most studies of OA published in STI journals use bibliometric methods and fall into three main categories. The first stream of work includes descriptive studies focused on one or more scientific disciplines, characterising the uptake of publishing in fully OA journals (Mukherjee, 2009; Cheng *et al.*, 2012), the characteristics of these journals (Gumpenberger *et al.*, 2012; Graziotin *et al.*, 2014), and the demographic characteristics of the academics publishing in them (Mukherjee, 2009). The second stream of work examines whether existing metrics for evaluating journals accurately characterise OA journals with a two-stage publication process (Bornmann *et al.*, 2010). The third, and largest, stream of work examines the advantages of OA (Dong *et al.*, 2006; Davis and Fromerth, 2007; Sotudeh and Horri, 2008; Sotudeh and Horri, 2009; Gentil-Beccot *et al.*, 2010; Gaulé and Maystre, 2011; Koler-Povh *et al.*, 2014; Wang *et al.*, 2015) with the main focus on the scientific impacts of OA publishing. Papers deposited in open repositories receive higher numbers of citations (Davis and Fromerth, 2007; Gentil-Beccot *et al.*, 2010; Koler-Povh *et al.*, 2014), but there is no agreement on whether this effect is attributable to the open and early accessibility of deposited papers (Gentil-Beccot *et al.*, 2010) or to their quality (Davis and Fromerth, 2007; Koler-Povh *et al.*, 2014). Papers published under OA licences also have a citations advantage (Gaulé and Maystre, 2011; Wang *et al.*, 2015) and receive more page views (Wang *et al.*, 2013), downloads and mentions on social media (Wang *et al.*, 2015). Work in the third stream of bibliometric studies enhances our understanding of the benefits of the OA model of academic publishing, in some cases strengthening and in others weakening the rationale for the transition to the new model of publishing. But it tells us nothing about how this transition should be managed.

There is a fourth stream of work that focuses on the economics of OA publishing and examines whether new models for scholarly publishing constitute more cost-effective ways

than subscription-based models for the communication and dissemination of research findings. The study by Houghton and Oppenheim (2010) shows that the benefits and cost saving related to journal-mediated and repository-mediated OA models exceed their costs, and that the repository-mediated model is more cost-effective than the journal-mediated OA model. This cost-benefit analysis is highly controversial.² Some considered Houghton and Oppenheim's assumptions and figures to be 'for the most part reasonable and even conservative' (Harnad, 2010, p. 55): others criticised their work for underestimating the true cost of publishing, overestimating the cost savings, and making unreasonable assumptions; for example, about worldwide uptake of OA (Hall, 2010). This body of work on assessing the cost-effectiveness of different publishing models could inform the focus of policy instruments (e.g. on the repository-mediated OA model). However, it says relatively little about the range of interventions needed to stimulate adoption of a specific OA publishing model.

The transition to OA publishing has also been analysed from a socio-political angle. This stream of work points to the ethical and political unacceptability of the traditional academic publishing system and considers the role of the OA model for bringing about changes to the system (Harvie *et al.*, 2013, Beverungen *et al.*, 2013). These works examine the socio-political dynamics of change, focusing on the bottom-up strategies adopted by academics to resist what they see as the profiteering practices of commercial academic publishers (Harvie *et al.*, 2013) and the top-down policies of national governments and research funders aimed at improved dissemination and utilisation of scholarly knowledge (Harvie *et al.*, 2013, Beverungen *et al.*, 2013). For example, UK funders' policies promoting journal-mediated OA model have been scrutinised and their potential consequences discussed. These include universities (weighed down by financial pressures) making decisions about which publications are openly accessible the responsibility of university committees in charge of allocating funds for APCs (Beverungen *et al.*, 2013), and also the potential of editorial boards to leave a publisher and set up replacement journals in order to bring down charges.

Socio-political studies highlight a wide range of consequences of promoting the journal-mediated or repository-mediated route to OA, but tell us little about the range of interventions that could stimulate adoption of a specific OA publishing model. Thus, our understanding of how to manage the transition to OA academic publishing remains limited. It is believed the transition is largely dependent on researchers' adoption of the new publishing model. However, the analytical perspectives adopted in existing studies are not well suited to revealing what drives or inhibits adoption of OA publishing among academic researchers. In the next section, we introduce a psychological perspective that allows a better understanding of researchers' publishing behaviours and provides new insights into managing the transition to OA publishing.

Psychological framework for analysing researchers' publishing behaviour

To examine what drives, enables and inhibits researchers' OA publishing behaviour, we use the COM-B model proposed by Michie *et al.* (2011) as a comprehensive and parsimonious framework to model a 'behavioural system', applicable to all volitional and non-volitional behaviours. The COM-B model draws on insights from past theories and empirical studies and suggests that capability, opportunity and motivation interact to generate behaviour. In other words, for any behaviour to occur, an individual must be motivated, capable and have the opportunity (meaning a conducive social and physical environment) to perform the

behaviour. The model hypothesises that each component affects the behaviour directly and, in addition, that changes to opportunities and capabilities can alter the level of motivation and thus have an indirect effect on behaviour (Michie *et al.*, 2011). The COM-B framework has significant analytical strengths, allowing more comprehensive and fine-grained analysis of behaviours than older psychological frameworks, such as the theory of planned behaviour (Ajzen, 1985) and social cognitive theory (Bandura, 1977, 1986).

First, unlike these earlier models, the conceptualisation of motivational forces in the COM-B framework includes both reflective and automatic sources of motivation. The framework also endogenises environmental factors (opportunities) and explains their relation to internal factors (motivations and capabilities) for generating behaviour. Analysing OA publishing through the lens of a COM-B model allows us to generate more fine-grained insights into motivations and to understand the interdependencies between individual/internal factors and environmental/external factors, which, so far, have been studied separately. Second, unlike its predecessors, the COM-B model assumes that engagement in a behaviour alters the factors predisposing the individual to adopt that behaviour (Michie *et al.*, 2011). This draws attention to scientists' past knowledge-disclosure practices, which might affect their pre-disposition to OA publishing, and help reveal within-discipline differences. We argue that those accustomed to producing open datasets, open-source materials or open-source software may have different motivations, capabilities and opportunities for OA publishing from scientists who work extensively with industry to commercialise their research outputs. The latter may well have a record of proprietary approaches to sharing IP; for example, through exclusive licensing or contract research.

Third, and still important, these earlier behaviour frameworks explain the factors affecting the behaviour, but do not readily suggest how to change it. In the COM-B framework, a behaviour change is thought to involve a change in one or more components in the behavioural system in order to reconfigure it. The COM-B model is integrated in the behaviour change wheel (Michie *et al.*, 2011) – a conceptually sound framework for behaviour change interventions that identifies nine intervention functions which can be deployed to address deficits in one or more of the three components of the behavioural system, and seven policy categories that can be used to enable the relevant interventions. Therefore, the COM-B model is able to inform policy and practice outside academia. It has been used in the design of health-policy interventions in areas as diverse as eating disorders (Robinson *et al.*, 2013), risk of Alzheimer's disease (Anstey *et al.*, 2013) and condom use (Newby *et al.*, 2013). We show that the framework is also useful for obtaining an in-depth understanding of the OA publishing behaviour of academic researchers and for understanding how to manage the transition to the OA model of publishing. In the succeeding sections we review some studies that are outside the STI field, but which provide insights into the psychological and environmental factors affecting the adoption of OA publishing among academics, and posit why the rate of adoption of OA publishing is likely to depend on past IP sharing practices within a discipline.

Motivation for OA publishing

People have the capabilities and opportunities to do many things, but it is frequently their motivation that determines what they actually do. In the COM-B framework, motivation is defined broadly as 'brain processes that energize and direct behaviour' (Michie *et al.*, 2011,

p.4) and comprises automatic and reflective motivation. The former includes factors that drive behaviour without involving intentional decision-making, such as emotions, impulses, desires, inhibitions, reflexes and habits. Reflective motivation is associated with analytical intentional decision-making and includes evaluations and plans (conscious intentions) (West and Michie, 2010; Michie and West, 2013).

There is little research to shed light on researchers' reflective motivations for OA publishing. Specifically, Collins and Milloy (2012) find that scholars in the humanities and social sciences expect OA monographs to be more highly cited and used, but to attract lower print sales – an evaluation that might motivate or demotivate adoption of OA publishing, depending on individual preferences. Bernius *et al.* (2009) propose a computational simulation of the scientific publishing market showing that early adopters of OA publishing benefit from more citations, but their advantage will disappear if all authors adopt the new publishing model. The study shows the incentives that could motivate scholars to adopt OA publishing, but does not examine these motivations in an empirical way. Finally, a study by Park (2009), analysing the reasons for publishing in fully OA journals through the lens of the theory of planned behaviour (Ajzen, 1985) and innovation diffusion theory (Rogers, 2003), reveals the importance of past behavioural experience and five attitudinal factors.

While these studies advance our understanding of reflective motivation, albeit in a somewhat limited way, they ignore non-rational motivational forces such as habits and emotions. We expect that automatic motivations may play a role in driving OA publishing in that many fully OA publishers have been in operation since the early 2000s (from 2000 the Public Library of Science (PLOS) in the US and BioMedCentral in the UK, and PeerJ from 2012) and habits and other automatic motivations may have become established. We also expect there is a wider range of considerations affecting scholars' decisions to provide OA to their publications than those revealed by past studies. These might include evaluation of the benefits of OA publishing, funders' OA policies, quality of OA journals and the costs of APCs.

Most studies of the motivation for OA publishing provide only limited insights into within-discipline differences. One exception is the study by Park (2009), which shows that researchers' attitudes towards OA differ depending on tenure status. Publication rates are affected also by levels of scientists' collaboration with industry (Banal-Estañol *et al.*, 2015), which suggest that publication practices are shaped by other knowledge disclosure practices. Researchers' motivations for OA publishing may vary with their past knowledge-disclosure practices. Those with a track record of open approaches to sharing IP will likely make more positive evaluations of OA publishing than researchers with experience of somewhat restrictive approaches to disclosing knowledge. Since the latter group has first-hand experience of the difficulties associated with bringing scientific knowledge into commercial settings and is aware of the importance to commercial organisations of IP protection and temporary secrecy, it may be more sceptical of the potential positive impacts of OA publications on innovation. On the other hand, those who have invested time and energy in making their data or research materials openly accessible may have a more positive attitude to OA publishing and see OA publications as complementing other openly accessible research outputs.

In summary, using the COM-B framework as a conceptual lens, our study will provide a deeper understanding of the reflective and automatic motivations energising researchers to make their publications openly accessible and reveal how differences in the motivations of researchers relate to their previous knowledge disclosure practices.

OA publishing capabilities

A capability is the component of a behavioural system that enables a behaviour. The COM-B framework defines capability as the ‘individual’s psychological and physical capacity to engage in the activity concerned’ (Michie *et al.*, 2011, p.4). To capture important distinctions in the research literature, Michie *et al.* subdivide capability into psychological capability (having the knowledge, psychological skills, strength and stamina to engage in the necessary mental processes), and physical capability (having the physical skills, strength and stamina). To our knowledge, the capabilities that enable researchers to provide OA to their research papers have not been studied. While it is safe to assume that most scientists will have the computer skills required to make online submissions to journals and express intent to provide OA, they may not have a full understanding of the complex legal issues related to OA, such as publishers’ copyright policies. For instance, a good understanding of copyright policies may promote repository-mediated OA since the researcher will be aware of how to make a deposit without violating publisher copyright. It may be that researchers who produce open-source software or open-source databases may have been involved in deciding the terms that define the extent of accessibility and re-usability of their research outputs and, hence, may be more familiar with copyright licences than researchers who have been used to proprietary approaches to IP sharing. Guided by the COM-B framework, our study aims to advance understanding of the capabilities that enable or inhibit adoption of OA publishing among researchers with track records of proprietary and open-source approaches to sharing IP.

Opportunities for OA publishing

Alongside internal factors, such as motivations and capabilities, the external environment also shapes individual behaviours. In the COM-B framework, the external environment is captured by the concept of ‘opportunity’, which refers to all the factors external to the individual that prompt or enable a behaviour (Michie *et al.*, 2011). Opportunity is of two types: (a) physical opportunity (referring to the environmental factors that allow and facilitate behaviour; for example, physical clues, resources, locations, physical barriers) and (b) social opportunity (defined as interpersonal influences, social clues and cultural norms that influence thinking and doing).

Past studies highlight the importance of financial resources as opportunity for the provision of OA cannot be seized if OA fees are unaffordable (Van Noorden, 2013). A study of 1,370 fee-charging OA journals active in 2010 finds that charges range from \$US8 to \$US3,900 (Solomon and Björk, 2012), with fees charged by hybrid journals tending to be at the higher end of this range (Van Noorden, 2013). If institutional funds are limited, papers resulting from projects supported by funders with OA mandates are prioritised by university committees allocating funds for OA fees, in an attempt to increase compliance with funders’ OA requirements. If this is the case, researchers funded by industry, who are more likely to adopt a proprietary approach to sharing IP, may have less access to institutional funds for OA fees and thus fewer opportunities to engage in journal-mediated OA publishing.

While it is clear that cost barriers can affect the uptake of OA publishing, our understanding of other environmental factors influencing researchers’ publishing behaviour, such as time and peer pressures, remains limited. Our study aims to enhance understanding of

the environmental forces that affect OA publishing by identifying the physical and social opportunities experienced by researchers with experience of proprietary and open-source approaches to sharing IP.

Methodology

Empirical context

Our research was conducted in the UK, a year after Research Councils UK (RCUK) – the strategic partnership of the UK’s seven research councils – urged OA publishing. Although RCUK has encouraged deposition of papers in open repositories, publishing in quality OA journals and the inclusion of APCs in grant applications since the mid-2000s (RCUK, 2005), these policies were not enforced evenly across research councils (BIS, 2011). In 2012, RCUK (2012) published an OA policy that superseded existing individual council policies and stated a clear preference for the journal-mediated route, immediate OA to papers from publication date and a Creative Commons Attribution licence (CC-BY). The repository-mediated option is allowed by RCUK policy if funds for APCs are not available. Subsequently, in 2014, the Higher Education Agency for England (HEFCE) encouraged repository-mediated OA by announcing that, for publications to be eligible for periodical research quality assessments, authors must deposit final peer-reviewed manuscripts in an institutional or subject repository on the date of their acceptance for publication (HEFCE, 2014). However, our research took place before the announcement of HEFCE’s policy.

RCUK’s OA policy takes a ‘one-size-fits-all’ approach and seems to assume that, if the financial barriers are removed and journals with appropriate OA licences are available, the proverbial ‘stick’ will be sufficient to motivate all researchers to provide OA for the published outputs of their research. The policy has been praised by the media for promoting free access to scholarly literature and maximising its re-usability (Neylon, 2012); however, it has also been heavily criticised for lack of clarity, inadequate consideration of implementation costs (Science Technology Select Committee, 2013) and promotion of ‘a model which will paradoxically intensify financial pressures on British universities – and thus is likely to make the environment for researchers even harsher’ (Harvie *et al.*, 2013, p.234). Our data collection took place as these debates were playing out in the media and in academic journals.

Methods

Since this is one of the first studies to take a psychological perspective on the adoption of OA publishing, we employ mainly qualitative methods, specifically semi-structured interviews. This approach is in line with other studies using the COM-B framework and allows us to be open to all factors that academic researchers consider relevant to their publishing behaviour, and to avoid limiting the study scope to only a few factors, decided in an ad hoc manner. Our qualitative analysis of motivations, opportunities and capabilities for OA publishing is complemented by a simple quantitative analysis of publishing behaviour.

The purpose of this paper is to illustrate within-discipline differences; thus, we decided to select scientists likely to differ in terms of their motivations, capabilities and opportunities for OA publishing. We chose to interview scientists with starkly different past practices of knowledge disclosure, assuming that they would orient themselves differently towards OA

publishing. We chose to focus on OA publishing in biosciences since, in this discipline, an open science ethos, exemplified by the open-data and open-source movements (e.g. BioBricks), has coexisted for some time with more proprietary approaches to sharing IP, and exclusive channels of knowledge transfer, such as exclusive IP licensing. We acknowledge that there may be many more complex ways in which scientists (including those studied here) orient themselves towards OA that are not captured by our approach. We do not claim that past practices of knowledge disclosure determine subsequent motivations, capabilities and opportunities for OA publishing, but rather assume that those with different past IP sharing practices may also display different orientations towards OA publishing.

We identified scientists with different past practices of knowledge disclosure, using information on the Internet and prior knowledge of the authors. We approached a number of principal investigators based in the UK and working in biosciences, 22 of whom agreed to be interviewed. The information gathered during the interviews confirmed that the scientists in our sample fall into two distinct groups: those with a track record of open-source approaches to sharing the IP resulting from their research, and those with more proprietary approaches. The first group includes 12 bioscientists who, in the past, shared IP with the wider academic and non-academic communities, predominantly through open channels; for example, through open datasets or open-source technologies. Their experience of working with industry was limited and consisted mainly of arms-length relationships with industry partners in publicly funded projects. The second group includes 10 bioscientists who, in the past, shared IP by publishing in academic journals or through more restrictive channels, exemplified by industry-sponsored collaborative research, contract research (i.e. fee for service), and exclusive/for-profit licensing of patented/non-patented technologies developed by the scientists and owned by a university. Table 1 presents the disciplinary backgrounds and IP-sharing profile of each interviewee.

The interviews with the 22 researchers were conducted between September 2013 and January 2014 and were part of a study examining different forms of openness in bioscience (see Levin and Leonelli, 2016; Levin *et al.*, 2016). The timing of our study allowed us to capture how researchers respond to the OA mandates of research funders, identify psychological and environmental factors that enable, stimulate and inhibit the adoption of OA publishing after the introduction of OA mandates, and make recommendations for further interventions needed to increase OA publishing. During the semi-structured interviews, the scientists were asked about: their awareness of OA policies and their impact on them; whether they provide journal-mediated or repository-mediated OA to their papers and, if so, since when; the reasons for making/not making their published papers openly accessible; and perceived benefits and challenges related to OA publishing. Issues related to open-data and open-source technologies were also discussed and are analysed elsewhere (Levin and Leonelli, 2016, Levin *et al.*, 2016). Interviews lasted between 90 and 120 min and were recorded and transcribed verbatim. The transcripts were anonymised and their accuracy was verified by the interviewees. To estimate the percentage of publications made OA by interviewees before and after RCUK's OA policy (2012), we retrieved their publications from SCOPUS for 2010–2011 and 2014–2015, and manually checked whether they were openly accessible from the publisher's website at the end of 2016.

We performed a content analysis of interview transcripts in order to identify the motivations, capabilities and opportunities experienced by each group of scientists. The analysis was assisted by NVivo® software (<https://www.qsrinternational.com/>). It started with a

Table 1. Sample characteristics

Knowledge disclosure practices	Group 1										Group 2											
	SN	M	P	G	SS	SS	BM	SN	SN	SM	BM	SN	SS	SS	SN	MO	MI	MO	BC	SN	BC	BC
Discipline	SS							SS														
Creating open databases																						
Sharing models openly (repositories, own websites, email)																						
Creating open-source software/other technology																						
Sharing software as executable files																						
No research collaborations with industry																						
Light touch relations with industry in publicly funded projects																						
Industry-linked PhD studentships																						
Industry-sponsored research/fee-for-service																						
Commercialisation of patented technologies																						
Restrictive licensing of know-how, materials																						
Commercialisation of proprietary software																						
Creating closed databases																						
Not sharing models																						

Note: BC = biochemistry, BI = bioinformatics, BM = biomedicine, G = genomics, M = metabolomics, MI = microbiology, MO = molecular biology, P = proteomics, SM = systems medicine, SN = synthetic biology, SS = systems biology.

deductive coding scheme corresponding to the components of the conceptual framework. The initial nodes included: 'OA publishing behaviour', 'automatic motivations', 'reflective motivations', 'psychological capabilities', 'social opportunities' and 'physical opportunities'. Next, the coding system was developed inductively as specific motivations, capabilities and opportunities for OA publishing were identified from the transcripts. For example, when a passage expressing the idea that OA publishing was morally right was identified, a new node ('OA is the right thing to do') was created under the node 'reflective motivations', and all text passages with the same meaning were coded onto this node. After the initial coding of the transcripts, several steps were taken to ensure coding consistency. First, all text passages that had been coded into a specific node were read carefully. This led to exclusion of passages from a node if meaning differences were identified, merging of nodes where meanings were identified as being the same, and revision of the node labels. The transcripts were then re-read to identify passages accidentally omitted during the initial analysis. The inductively developed set of nodes covers a wide range of motivations, capabilities and opportunities and is presented in Tables 2–6.

The last step in the analysis involved cross-group comparison. The transcripts of the interviews with the scientists in Groups 1 and 2 were clustered and NVivo® query functions were applied to identify the number of references made to a specific motivation, capability or opportunity by each group, and how many scientists in the groups made these references. We considered the two groups to be different if the respondents from one of the groups made at least twice as many references as the other group to a certain motivating factor, capability or opportunity.

Results

OA publishing behaviour

To analyse the OA publishing behaviour of the researchers interviewed, we examine how often they provided journal-mediated OA. We found significant behavioural differences between the two groups before and after the introduction of the RCUK OA policy. Before the policy change in 2012, Group 1 provided OA to 74.09% and Group 2 to 45.11% of papers published in 2010 and 2011. The independent sample t-test shows that the difference is statistically significant ($t(14.29) = 2.2 (p < 0.05)$). In the period 2014–2015, after the launch of RCUK's OA policy and after our interviews, Group 1 provided OA to 84.80% of publications. The paired sample t-test indicates that the increase from 74.09% in 2010–2011 to 84.80% in 2014–2015 is marginally significant ($t(11) = -1.342 (p = 0.103)$). This compares with Group 2, which provided OA to 49.55% of their papers in 2014–2015; the increase from 45.11% in 2010–2011 is not significant ($t(9) = -0.303, (p > 0.05)$). The difference between the groups in 2014–2015 remains statistically significant ($t(12.73) = 3.85 (p < 0.05)$). The findings indicate very different behavioural responses to the OA mandates from the two groups.

Motivations for OA publishing

A wide range of motivations for OA publishing and differences between the two groups are revealed by the content analysis of the interview transcripts. Table 2 illustrates the reflective and automatic motivations referred to by scientists ordered by the decreasing number of

references. References to reflective motivations dominate. Automatic motivations include references to the habit of publishing in OA journals while reflective motivational factors include evaluation of the costs of OA publishing, need for OA, moral judgements related to OA publishing, evaluation of the impacts of OA publishing on self, readership, innovation, science, universities and the publishing system.

While both groups are worried about the costs of OA, across-group differences in the motivations of bioscientists are clear. Group 1 made 60 positive evaluations that might motivate authors to engage in OA publishing (see evaluations with (+) sign in Table 2) and 36 negative evaluations that might demotivate them (see evaluations with (-) sign in Table 2), while Group 2 made 31 motivating and 50 demotivating evaluations. To gain more insight into the differences between groups, we identified the motivating/demotivating factors referred to by one group at least twice as many times as the other group. These comparisons show that Group 1 had stronger moral convictions about the 'rightness' or 'goodness' of OA publishing. For example, one respondent stated 'fundamentally personally I feel it's the right thing' (13091902), while another considered 'it's a good thing to do' (13092701). Group 1 expressed more beliefs that OA publishing would increase readership of scholarly papers and bring personal benefits to adoptees in the form of better access to the literature, more citations, and new contacts and collaborations. One scientist explained that:

Obviously if the paper is OA there is going to be more people reading it and it's going to be easier to cite, and it's going to get more citations. There's a very clear relationship that has been shown forever. So it's better for me. If I make them OA I get much better, much quicker response to my papers. (13092502)

It is interesting that citations are considered mainly a personal benefit rather than a sign of scientific progress. In referring to the citation advantages of OA papers, only two scientists referred to advancing scientific knowledge while five linked citation to being read more widely or becoming more famous or improving one's h-index. The belief that OA publishing 'is a way to break [the] stranglehold' (13100201) of publishers, although not frequent, was more prevalent in Group 1. Also, this group includes comparatively more individuals with an already developed habit of OA publishing; thus, their behaviour is driven by automatic forces. In contrast, Group 2 expressed stronger negative beliefs demotivating authors from OA publishing, such as negative evaluations of the need for OA and its potential to stimulate innovation. The response of one scientist captures these points well: 'If you think where most of innovation is going to happen, it's going to be in your leading research universities or the companies, both of whom would have access to all the information anyway prior to OA' (14011601). Group 2 also made more negative evaluations of the cost of APCs. Many found APCs expensive: 'these fees are just ridiculous' (140123). The analysis reveals that Group 1 is more strongly motivated to adopt OA publishing than Group 2. The former holds strong moral convictions and beliefs in the personal and other benefits of OA publishing, while perceptions are mixed in the latter.

Physical opportunities for OA publishing

We identified a range of environmental factors that enable, facilitate and constrain OA publishing. Table 3 presents physical environment factors mentioned by the scientists in order of decreasing numbers of references. Group 1 made 33 positive references and 17 negative references to environmental factors, while the respective numbers for Group 2

Table 2. Motivations for OA publishing

Automatic and reflective motivations for OA publishing	Coding references (number of respondents)	
	GR 1	GR 2
<i>57 evaluations of costs of OA, of which:</i>	30 (10)	27 (9)
(-) APCs are expensive	5 (3)	10 (7)
(-) APCs not proportional to value added by publishers	1 (1)	2 (2)
(-) negative evaluation of availability of institutional funds for APCs	24 (8)	15 (5)
<i>32 evaluations of the need for OA, of which:</i>	9 (7)	23 (10)
(+) Need for OA	8 (6)	9 (7)
(-) No need for OA	1 (1)	14 (6)
<i>26 moral judgement of OA, of which:</i>	18 (9)	8 (4)
(+) OA is the good/right thing to do	17 (8)	8 (4)
(-) Doubts about OA being the right thing	1 (1)	0 (0)
<i>14 evaluations of OA's impact on readership, of which:</i>	11 (6)	3 (3)
(+) OA will increase readership	10 (6)	3 (3)
(-) Doubts about the public's abilities to comprehend scientific papers	1 (1)	0 (0)
<i>14 evaluations of personal benefits from OA, of which:</i>	10 (6)	4 (3)
(+) OA will generate more citations	4 (4)	2 (1)
(+) OA makes it easier for me to create databases	2 (2)	0 (0)
(+) OA gives me access to wider range of journals	1 (1)	1 (1)
(+) OA helps to establish contacts abroad	1 (1)	0 (0)
(+) OA preprint protects the claim to priority over an idea	1 (1)	0 (0)
(+) OA will give me quicker response to my papers	1 (1)	0 (0)
(+) OA will help to create new collaborations	0 (0)	1 (1)
<i>13 evaluations of OA's impact on innovation, of which:</i>	3 (2)	10 (7)
(+) OA stimulates innovation (SMEs, academia/industry outside UK)	2 (1)	2 (2)
(-) Doubts about OA's positive impact on innovation	1 (1)	6 (5)
(-) OA information can be put to ill use	0 (0)	2 (2)
<i>10 references to automatic motivation, of which: (+) Habit* of OA publishing</i>	8 (5)	2 (2)
<i>5 evaluations of OA's impact on transformation of publishing system, of which:</i>	4 (3)	1 (1)
(-) People may be priced out of being able to publish	1 (1)	0 (0)
(+) Authors, not libraries, will be the gatekeepers of what is accessible	1 (1)	0 (0)
(+) OA may lead to fewer but better publications	1 (1)	0 (0)
(+) Subscription-based publishers will become more open	0 (0)	1 (1)
(+) The stranglehold of publishers will be broken	1 (1)	0 (0)
<i>4 evaluations of OA's impact on science, of which:</i>	1 (1)	3 (1)
(-) Doubting that OA will advance science	0 (0)	1 (1)
(+) OA will advance science	1 (1)	2 (1)
<i>2 evaluations of OA's impact on university</i>	2 (2)	0 (0)
(-) OA does not help universities to increase competitiveness	1 (1)	0 (0)
(+) University libraries will save money	1 (1)	0 (0)

Note: The motivational factors are presented according to the decreasing number of references. Total numbers in bold are broken down in following lines.

*Habits represent automatic motivations; other factors are reflective motivations.

were 25 and 24. There were no significant differences in the groups' perceptions of their physical environments, with the exception that Group 2 reported not having the time to archive in repositories.

Both groups of scientists referred to the availability of appropriate journals with OA policies as a key environmental factor affecting OA publishing. Most respondents can identify appropriate journals with OA policies in their field, but it was noted that some fully OA

journals ‘are really not reputable’ (13092502) and ‘not so highly rated in their impact factor’ (131212). Note that impact factor improvement takes time and relatively new fully OA journals may well improve their impact factors over time. There were no concerns about the quality of established journals that enable authors to choose an OA licence (hybrid journals), but as their APCs tend to be expensive, scientists are faced with the dilemma of whether to publish cheaply or to publish in what they consider a reputable journal: ‘Shall I pay a smaller amount and go for a lower impact or should I pay a larger amount and go for a higher impact?’ (13092602). While some respondents did not recognize a trade-off between OA and impact factor in their fields, others made it clear that the impact factor mattered more to them than OA:

When you are deciding on what journal you want to publish in, it has got to do with the discipline and the impact factor of the journal. It has got nothing to do with whether it is OA or not. Usually, these journals will then say to you: ‘Do you want it to be OA?’ You go: ‘Yes.’ They say: ‘That will be £4,000.’ (131212)

The comment suggests that the importance of impact factor in publishing decisions makes the provision of journal-mediated OA dependent on the authors’ ability to pay the APC, if this is charged by the journal. University systems and processes were identified as factors affecting OA publishing. Although no one had been denied funds for APCs, scientists expressed worries about adopting quality/impact-factor-based criteria for fund allocation.

Social opportunities for OA publishing

The content analysis reveals three sources of social pressure: peer academics, research funders and employing universities. Scientists experienced both encouragement for and resistance to OA publishing among their peers. Research funders were seen as sending the clear message that OA matters, but their policies receive both positive and negative evaluations. The influence of universities varied. Some scientists think that OA is important to their university while others provided examples that show the university did not actively encourage OA publishing. In addition to direct social pressures, scientists made a few references to the norm of pro-openness in biosciences, which facilitates the adoption of OA publishing; for example: ‘As far as I can tell, everybody I know is supportive of those ideas and would naturally go for that’ (13100101). Table 4 presents the social influences and social norms referred to by scientists as decreasing numbers of references.

There are some differences between the two groups. Group 2 more often cited pressure from research funders as the reason for adopting OA publishing: ‘It was a reaction rather than something that was thought about beforehand’ (131204). In contrast, for Group 1, peer pressure was the more salient social force affecting adoption of OA publishing. Resistance to sharing APC costs in international collaborations (where some co-authors may not be affected by OA policies) was noted as a problem: ‘certainly on a number of occasions we’ve ended up just shouldering the whole lot, just because we have to get it out at a certain time but they don’t’ (13092602).

Given that industry partners may influence publications, we enquired about their impact on the uptake of OA publishing. According to the interviewed scientists, engagement with industry does not restrict the opportunities to provide OA for published work. Commercial partners do not object to publishing under OA licences in OA journals or in hybrid journals, and patenting too is compatible with OA (or non-OA) publishing as long as the patent

Table 3. Physical opportunities for OA publishing

Physical opportunities for OA publishing	Coding references (number of respondents)	
	GR 1	GR 2
<i>61 references to the availability of suitable fully OA journals, of which:</i>	30 (11)	31 (8)
(+) availability of suitable OA journals (relevant or good quality or high-impact factor journals)	22 (10)	18 (7)
(-) unavailability of suitable OA journals	8 (7)	13 (5)
<i>21 references to university process for allocation of funds for APCs, of which:</i>	11 (8)	10 (5)
(+) university fund allocation process is clear or easy	4 (3)	4 (3)
(-) university funds allocation process is unclear	2 (2)	3 (2)
(-) university does not have a system for allocation of OA funds	1 (1)	1 (1)
(-) researchers no longer have control over funds for APCs within research project budget	4 (4)	2 (1)
<i>10 references to the availability of funds for APCs, of which:</i>	7 (5)	3 (2)
(+) availability of institutional grant funds for APCs	7 (5)	3 (2)
<i>5 references to the availability of time for archiving, of which:</i>	0 (0)	5 (3)
(-) no time for self-archiving	0 (0)	5 (3)
<i>2 references to publishers' errors, of which:</i>	2 (1)	0 (0)
(-) publisher fails to make a paper openly accessible even though APC is paid	2 (1)	0 (0)

Total numbers in bold are broken down in following lines.

application has been filed before publication in a journal, or within a so-called 'grace period' allowed by some patent offices. Although engagement with industry and commercialisation of research outputs are not barriers to publishing under an OA licence, they can constrain scientists' ability to write 'openly' about their scientific work (see Table 5). Scientists in Group 2, unlike those in Group 1, have significant engagement with industry and commercialisation. They reported that they are restricted as to what they can write in their papers and that publications are delayed and occasionally halted by industrial partners. Some have taken the strategic decision not to publish their work in order to facilitate commercial exploitation of their research. Numerous examples of content restrictions were provided: 'If you're working on a compound called "blah, blah, blah", you have to take that out, for example. Or if you're working on a specific strain, species name, you have to take that out' (140120). These restrictions are not trivial since they render it impossible for the reader to replicate the research and use what is described in a publication. In summary, although industrial partners do not oppose OA publishing, scientists working with industry and engaged in commercialisation are well aware that commercially valuable information is not always published in academic journals, regardless of whether a paper is made openly accessible. This may, in part, explain why Group 2 expressed many doubts about OA publishing's potential to stimulate innovation.

Psychological capabilities for OA publishing

Capabilities were rarely mentioned in relation to uptake of OA publishing and there were no great differences between the two groups (see Table 6). Unsurprisingly, no references were made to physical capabilities for OA publishing. Scientists talked about their limited understanding of copyright law for self-archiving and the computer skills needed to provide links to papers on a website without violating copyright. One scientist commented: 'We

don't quite understand what you are allowed to do and what you are not allowed to do, by law, and in practice those are different things' (13100101). Some were simply not aware of the possibilities of self-archiving. One scientist who wanted to publish under an OA licence admitted to abandoning the idea because the publisher's system was too difficult to understand:

I think I did let one of those [papers] go. I must say and I just thought 'We'll forget that one and I won't report it [to the funder].' ... It was so complicated with the particular journal; I just looked at it and thought 'You know this isn't worth it.' (13092501)

While the few comments about capabilities provide valuable insights, capabilities were not generally recognised by interviewees as an important factor in their publishing behaviour and there were no differences between the two groups.

Discussion of behavioural systems across groups

This study embraced a psychological perspective, namely the COM-B framework, which has not been applied in previous STI studies in analysis of the motivations, capabilities and opportunities for OA publishing. Our approach generates new empirical insights into within-discipline differences in drivers, enablers and inhibitors of OA publishing, which have significant implications for managing the transition to an OA model of academic publishing.

We uncovered researchers' motivations for publishing in fully OA as well as hybrid journals. We extend previous work, which focuses exclusively on OA monographs (Collins and Milloy, 2012) or fully OA journals (Park, 2009). In line with past studies, we find that belief in personal benefits dominated (Bernius *et al.*, 2009; Park, 2009; Collins and Milloy, 2012). However, we also find many pro-OA moral convictions and negative evaluations of the costs of OA. Most importantly, our study contributes to the emerging body of work investigating

Table 4. Social factors stimulating or constraining OA publishing

Social opportunities for OA publishing	Coding references (number of respondents)	
	GR 1	GR 2
<i>15 references to social pressure from peers, of which:</i>	14 (8)	1 (1)
(-) difficulties in sharing OA cost in collaborative projects	6 (4)	1 (1)
(-) co-authors decide to publish without providing OA	3 (3)	0 (0)
(-) international collaborators do not understand the need for gold OA	3 (3)	0 (0)
(+) my co-authors want to have OA publications	2 (1)	0 (0)
<i>14 references to social pressure from research funders, of which:</i>	3 (3)	11 (6)
(+) now research funders expect me to provide OA	3 (3)	11 (6)
<i>9 references to social clue/pressure from employing universities, of which:</i>	4 (4)	5 (2)
(-) universities do not brief staff on OA requirements of funding bodies	1 (1)	0 (0)
(-) university postgraduate education does not include OA agenda	0 (0)	1 (1)
(-) university promotion policies – high-impact journals matter regardless of their OA policies	1 (1)	1 (1)
(+) university encourages staff to adopt OA publishing	2 (2)	2 (1)
(+) university strategy includes OA agenda	0 (0)	1 (1)
<i>3 references to social norm of pro-openness in the discipline, of which:</i>	3 (2)	2 (1)

Total numbers in bold are broken down in following lines.

Table 5. Social factors constraining publishing (OA or non-OA)

	Coding references(number of respondents)	
	GR 1	GR 2
Opportunities for publishing		
<i>21 references to barriers related to collaborative research with industrial partners, of which:</i>	3 (2)	18 (7)
(-) commercial partner restricts the content of a publication	2 (2)	10 (6)
(-) commercial partner delays a publication	1 (1)	5 (4)
(-) commercial research partner prohibits a publication	0 (0)	3 (2)
<i>11 references to barriers related to patenting and commercialisation of university IP, of which:</i>	0 (0)	11 (6)
(-) publication is not undertaken for strategic reasons (weak patent, plans for more patents, lack of IPR protection)	0 (0)	8 (5)
(-) commercial partner restricts the content of a publication	0 (0)	1 (1)
(-) patenting process delays a publication	0 (0)	1 (1)
(-) commercial partner prohibits a publication	0 (0)	1 (1)
<i>5 references to barriers related to contract research, of which:</i>	0 (0)	5 (1)
(-) commercial partner's restrictions on the content of publications	0 (0)	2 (1)
(-) research material is not scientifically interesting	0 (0)	1 (1)
(-) research material not methodologically robust for a publication	0 (0)	1 (1)
(-) publication is not undertaken for strategic reasons (secrecy enables future contract research)	0 (0)	1 (1)

Total numbers in bold are broken down in following lines.

how drivers, enablers and inhibitors of OA publishing vary within academic disciplines (Table 7). While Park (2009) shows that the impact of motivations on the adoption of OA publishing is moderated by the researcher's tenure status, we find major motivational and behavioural differences among scientists with different past knowledge-disclosure practices.

Given the correlational nature of our data, we are not claiming that past practices of knowledge disclosure (related to data and technologies) determine subsequent motivations, capabilities and opportunities for OA publishing behaviour; we are simply highlighting within-discipline differences. Our study found that Group 1 was strongly motivated to adopt OA publishing, based mainly on moral convictions and beliefs that OA would bring personal benefits. Group 2 expressed fewer pro-OA convictions, and held beliefs that could demotivate individuals from OA publishing. Our quantitative analysis reveals that the former group is involved in OA publication more frequently than the latter group.

The COM-B framework allows a broader analytical focus than is evident in past studies (Park, 2009; Collins and Milloy, 2012) and provides insights not only into within-discipline differences in motivations, but also into how bioscientists experience their physical and social environments. We find that all our interviewee bioscientists face similar obstacles and enablers in their physical environment, but experience their social environments differently. Group 1 has more experience of negative and positive peer pressures while Group 2 feels under more pressure from the OA mandates of research funders.

Acknowledging the correlational nature of our data, we speculate that the strong motivation for OA publishing among Group 1 drives its members to overcome the numerous obstacles in their social and physical environments (see Table 7). In contrast, members of Group 2 lack strong motivation to overcome the same obstacles and seek OA for their publications less frequently. Although they feel the pressure imposed by research funders to adopt OA, it appears that this social pressure does not compensate for the weak motivation resulting from salient disbeliefs in the positive impacts of OA publishing.

Table 6. Capabilities for OA publishing

Psychological capabilities	Coding references (number of respondents)	
	GR 1	GR 2
5 references to psychological capabilities related to repository-mediated OA, of which:	2 (2)	3 (2)
(-) not understanding the legal rules on self-archiving (copyright)	1 (1)	1 (1)
(-) lack of awareness of the possibility of self-archiving pre-prints	0 (0)	1 (1)
(-) lack of awareness of institutional OA repository	0 (0)	1 (1)
(-) lack of computer skills for self-archiving	1 (1)	0 (0)
2 references to psychological capabilities related to journal-mediated OA, of which:	1 (1)	1 (1)
(-) not understanding systems provided by publishers	1 (1)	0 (0)
(-) lack of awareness that paying an APC makes a paper OA	0 (0)	1 (1)

Total numbers in bold are broken down in following lines.

Conclusions

The comprehensive conceptualisation of behavioural systems in the COM-B framework, combined with qualitative exploratory methods, enabled us to generate new empirical insights into the drivers, enablers and inhibitors of OA publishing, and to document some differences within the biosciences. Because of its exploratory aims and qualitative methodology, our study is based on a small sample of scientists in a single discipline. The findings are not generalizable to a larger population. However, the rich qualitative insights from our work pave the way for more extensive analyses of the drivers, enablers and inhibitors of adoption of OA publishing. Future studies employing surveys or mixed methods could build on our work to examine larger populations across different disciplines and countries, and enhance our understanding of the publishing behaviour of academic researchers in different contexts. Moreover, future qualitative studies could examine the issues identified in our study, but not explored in depth, such as the intertwined perceptions of a journal's quality, impact factor and OA policies. These shape authors' views on the journal's suitability as a publication outlet. Our small sample size does not allow us to make definitive recommendations for policy and practice, but could be useful for discussion of the practical implications, and to illustrate how psychological assessments of scientists' behaviour could inform science policy and organisational interventions aimed at changing their behaviour.

This paper's focus on researchers' motivations does not imply that the slow uptake of OA is solely or even largely attributable to researchers' attitudes. To be effective, intervention strategies should address the deficits in scientists' motivations and capabilities and also the wider social and political systems that constrain their opportunities to adopt OA. Our study shows that while scientists in the biosciences face similar external constraints, their motivations and social opportunities for OA publishing vary. This implies that the transition towards OA publishing in the biosciences cannot be achieved through one-size-fits-all interventions from governments, funders and universities. Nor can it be achieved by interventions that target basic capabilities, such as awareness of OA policies, since these are not lacking among bioscientists. For example, educational events, such as OA days (often held in UK universities with the aim of raising awareness of OA publishing, OA mandates and university procedures for allocation of OA funds), would likely be ineffective in the case of our sample of bioscientists.

Table 7. Cross-group comparison

	Group 1	Group 2
Behaviour	• Before RCUK OA policy: provided OA to 74.09% of publications in 2010–2011 • After RCUK OA policy: provided OA to 84.80% of publications in 2014–2015	• Before RCUK OA policy: provided OA to 45.11% of publications in 2010–2011 • After RCUK OA policy: provided OA to 49.55% of publications in 2014–2015
Drivers/ enablers of OA publishing	• Reflective motivations (52 references): beliefs in morality of OA, personal benefits from OA, positive impact on readership, need for OA, positive impacts on innovation, publishing system, science, universities • Enablers in physical environments (33 references): availability of suitable journals, easy university processes for funding allocation, availability of funds • Habit of OA publishing (8 references) • Drivers in social environment (10 references): encouragement from peers, pressure by funders and employer, norm of pro-openness	• Reflective motivations (29 references): beliefs in need for OA, morality of OA, personal benefits from OA, positive impacts on readership, innovation, publishing system, science • Enablers in physical environments (25 references): availability of suitable journals, easy university processes for funding allocations, availability of funds • Drivers in social environment (16 references): pressure by funders and employers, norm of pro-openness • Habit of OA publishing (2 references)
Inhibitors of OA publishing	• Obstacles in a physical environment (17 references): unavailability of suitable journals, cumbersome university processes for allocation of funds for OA fees, publisher's mistakes • Reflective (de)motivations (36 references): negative evaluation of OA costs; disbelief in the need for OA; disbelief in morality of OA; disbelief in positive impacts on readership, innovation and universities; beliefs in negative impacts on publishing system • Inhibitors in social environment (14 references): problems with co-authors, OA not valued by employers • Limited psychological capability (3 references)	• Reflective (de)motivations (50 references): negative evaluation of OA costs, disbelief in the need for OA, disbelief in positive impact on innovation and science, belief in negative impacts on innovation • Obstacles in physical environment (24 references): unavailability of suitable journals, cumbersome university processes for allocation of funds for OA fees, no time for archiving • Limited psychological capability (4 references) • Inhibitors in social environment (3 references): OA not valued by employers

Note: Enablers, drivers and inhibitors are listed in order of prevalence.

Table 8. Examples of interventions targeting identified barriers and inhibitors in Group 2

COM-B	Reflective motivation	Barriers/inhibitors	Potentially useful intervention functions (Michie <i>et al.</i> , 2011)	Examples of university interventions
		Disbelief in the need for OA Disbelief in positive impact on innovation and science Belief in negative impacts on innovation	<i>Educate or persuade</i> to create more positive beliefs about providing OA <i>Persuade, incentivise, coerce, model</i> or <i>enable</i> to feel positively about providing OA and negatively about failing to provide OA	To educate – collect reliable evidence of OA's benefits and present in departmental meetings To persuade – in departmental meetings present pros and cons of OA, comparative images of the future of academic publishing, induce anticipated regret To incentivise – announce that publishing in recent peer-reviewed fully OA journals will be valued by the university as much as in established high-quality non-OA journals To coerce – require that any articles to be considered in an annual appraisal/promotion must be archived in an open repository Develop user-friendly, fair and transparent APC allocation processes that do not disadvantage OA journals that have not had time to earn prestige or impact factors (e.g. allocate annual self-managed OA funds to each research-active employee) Support academics in launching OA journals Reward academics who serve as editors or referees for OA journals
			<i>Enable</i> funds for OA <i>Restrict</i> charging for OA <i>Restructure</i> environment to reduce the costs of OA <i>Restructure</i> the university processes for allocation of funds for OA <i>Restructure</i> the environment to increase availability of suitable journals	Allocate resources for helping academics deposit articles in an institutional repository Provide instructions on self-archiving in the institutional repositories (in person or online videos) Identify model university OA policies Revise recruitment, appraisal and promotion policies (at least, do not penalise faculty for publishing in recent peer-reviewed fully OA journals: at best, incentivise journal and/or repository-mediated OA) Create user-friendly institutional repository Inform about SHERPA/RoMEO service Inform about available repositories Provide instructions on self-archiving in the institutional repositories (in person or online videos)
			<i>Train</i> or <i>restructure environment</i> to reduce time demand	
			<i>Restructure</i> the social environment to shape employees' ways of thinking Identify <i>model</i> social environments	
	Social opportunity	OA not valued by employers		
	Psychological capability	Knowledge of self-archiving	<i>Educate</i> about ways of self-archiving <i>Train</i> in cognitive skills required for self-archiving <i>Enable</i> development of self-archiving skills	

It is necessary to take account of individual differences within disciplines when designing interventions targeted at any deficit in a specific component of the behavioural system (Michie *et al.*, 2011). To increase uptake of OA publishing among bioscientists who are motivated but inhibited by the obstacles in their physical and social environments, the opportunities for OA publishing must be maximised. This could be achieved through interventions aimed at 'environmental restructuring' and 'enablement' (Michie *et al.*, 2011). The UK government's policy of providing some universities with funding for OA is one example of an intervention enabling provision of OA. Another intervention that would address the deficit in social opportunities would be a policy for sharing the costs of APCs for publications co-authored by scientists from different institutions and countries.

However, on their own, these interventions are unlikely to be effective in the case of bioscientists who are not motivated to adopt OA publishing and also face obstacles in their physical and social environments. To increase their uptake of OA publishing, the opportunities should be maximised and the motivations for OA publishing should be strengthened. We used the behaviour change wheel (Michie *et al.*, 2011) to identify intervention functions that might address the motivation and opportunity deficits we identified among the bioscientists in this group. Table 8 presents examples of potentially effective interventions that might be undertaken by universities to overcome the inhibitors and barriers experienced by the less motivated group of bioscientists. Of course, there are other interventions that could be undertaken by universities, governments, funding bodies or the scientists themselves. Given our pro-OA position, we see interventions stimulating uptake of OA publishing as desirable and would like to see all parties actively involved in promoting OA. However, political and moral questions, such as whether and what interventions potentially should be carried out, and where and by whom, need to be carefully considered before any action is implemented.

To conclude, the psychological perspective adopted in this study has generated new empirical insights that enhance our understanding of the drivers, enablers and inhibitors of adoption of OA publishing among academic researchers. It has also helped to reveal the within-discipline differences in the biosciences. We have shown how such insights could be used by universities, funders and governments to manage the transition towards the OA model of academic publishing with more targeted interventions aimed at changing researchers' publishing behaviour. This study opens the way to increased use of psychological assessments for the design of science policy.

Notes

1. A service showing the copyright and open access self-archiving policies of academic journals.
2. See the debate on academic publishing in *Prometheus*, 2010, 28, 1.

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