European Commission

Comparative scientometric assessment of the results of ERC funded projects

Peer-review evaluation of highly ranked publications from scientometric assessment (D8)

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Preface

This document, prepared by RAND Europe and Observatoire des sciences et des technologies (OST), serves as the final deliverable 'Peer-review evaluation of highly ranked publications from scientometric assessment' (deliverable: D8) for the study "Comparative scientometric assessment of the results of ERC funded projects" for the European Research Council Executive Agency (ERCEA).

In addition to this report, other analysis and findings from this study are reported in:

- D3: Field classification report
- D4: Data coverage report
- D5: Bibliometric assessment report
- D6: Patent analysis report
- D7: Alternative metrics report
- D11: Final synthesis report

The authors would like to acknowledge the support of ERCEA, in particular Boris Kragelj, members of the ERC Scientific Council and other ERC staff members who have provided useful feedback, data and advice throughout the study. We would also like to thank our quality assurance reviewers, Yves Gingras, Susan Guthrie and David Kryl, for their constructive comments and timely review.

This document has been peer reviewed in accordance with RAND Europe's quality assurance standards.

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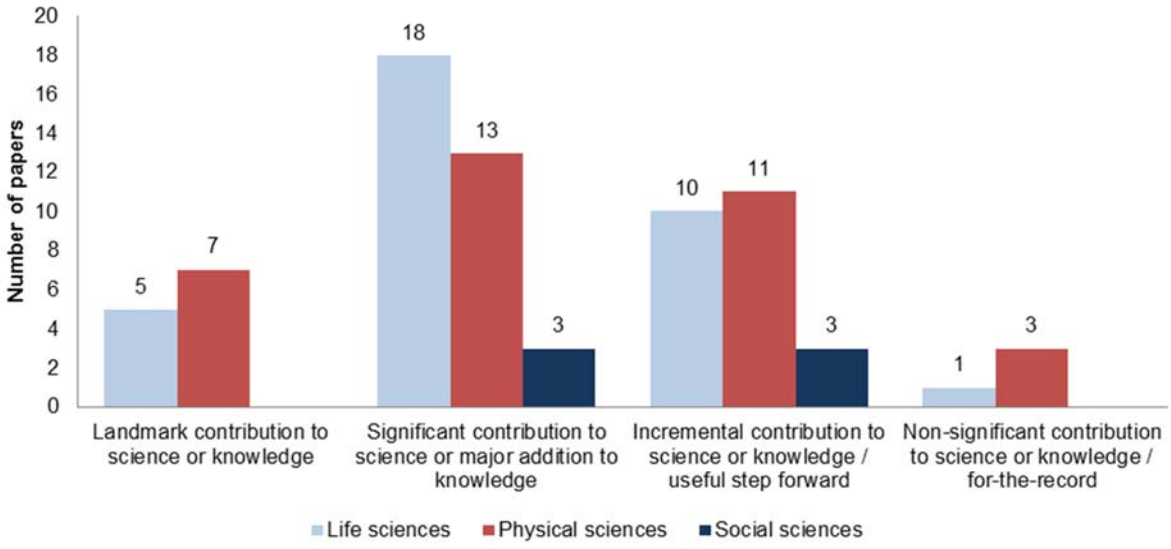
1. SUMMARY

This paper was commissioned by the European Research Council Executive Agency (ERCEA) as part of a scientometric evaluation of the European Research Council's funded research. While the main focus of the study is a comparative quantitative analysis, incorporating bibliometric measures, patent analysis and alternative metrics of social media attention, a qualitative peer review assessment was also carried out to support the quantitative analyses and provide a qualitative assessment of the contribution made by a sample of highly cited ERC-supported papers to their respective fields. This assessment was carried out through an online survey, in which expert reviewers were asked to comment on a paper's overall contribution to its field and the characteristics of the paper which might be associated with it becoming highly cited or attracting social media attention. An initial sample of 100 ERC-funded papers was drawn from the top 1% of highly cited papers in their respective fields. Reviews were obtained from 95 experts, covering 56 of these papers. As such, the sample for this analysis comprises a selection of the highest performing papers to have been produced from ERC funding and can in no way be considered representative of the wider population of ERC-supported research.

As shown in Figure 1-1, reviewers considered 21% of the papers reviewed to have made a landmark contribution to their field, including the identification of new entities or phenomena, methodological advances in the study of a topic and the elaboration of theoretical principles. As a group, these papers scored consistently higher on indicators of citation and social media attention than those considered not to have made a landmark contribution. We should, however, interpret this with caution given the very small sample size. The majority of papers (61%) were considered to have made a significant contribution to science or major addition to knowledge.

Figure 1-1. Overall contribution of papers to the advancement of science or knowledge

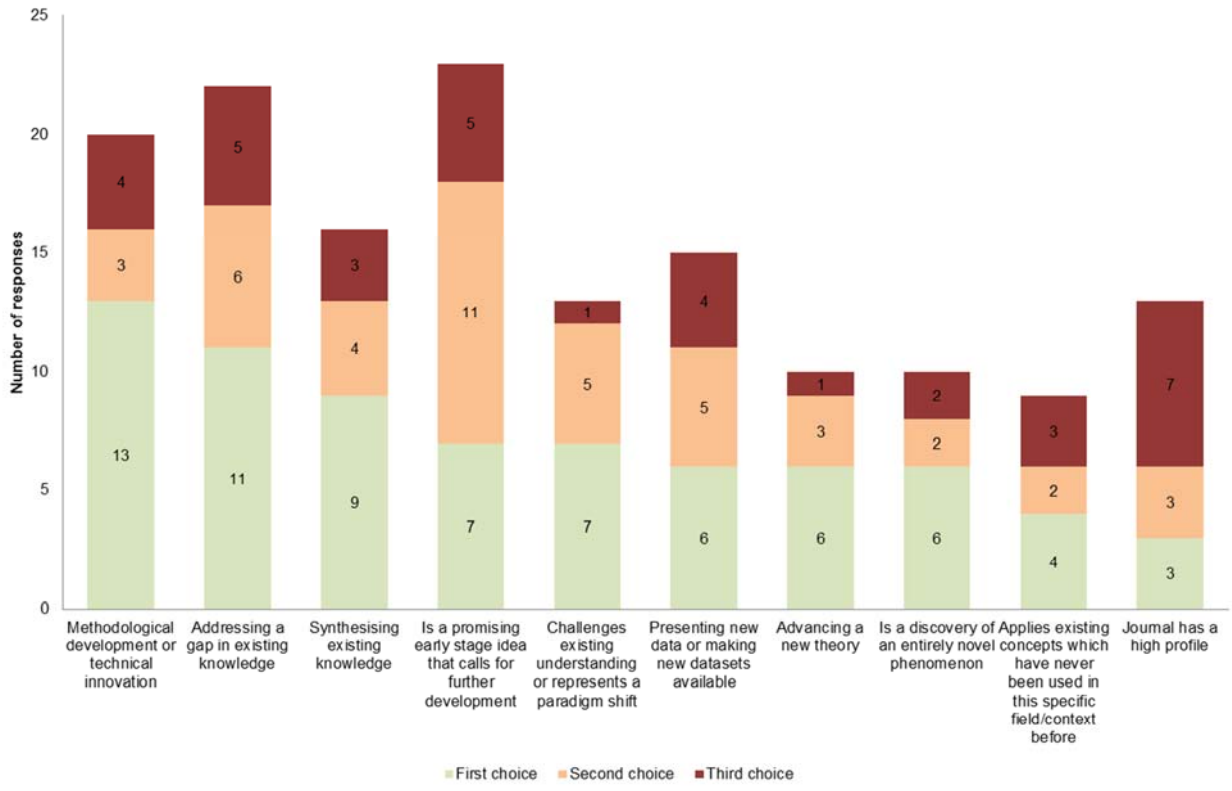


Reviewers were also asked to indicate which of a range of characteristics applied to each paper. The assessment showed that the most highly cited ERC-supported research is likely to have been authored by a well-known researcher based in an institution with a strong reputation, and is also likely to be published in a top journal. Many papers were considered to be interdisciplinary in some way, and to be putting forward an early stage idea which is likely to have an impact within academia by informing future research. Looking at impact beyond academia, 23% of papers in the sample were expected to lead to benefits in the relevant sector of practice, but economic benefits and social and cultural impacts were rarely anticipated. This latter finding is consistent both with existing literature and with the ERC's focus on frontier research which aims to produce fundamental advances in science and knowledge.

When considering the different domains in which the ERC supports research, reviewers noted that methodological developments occurred more frequently in the physical sciences and engineering (PE) domain than in the life sciences (LS) (50% of PE papers reviewed; 27% of LS). In contrast, LS papers were more likely to be addressing a gap in existing knowledge (58% in the LS domain; 23% in PE) or advancing a new theory (35% in LS; 8% in PE).

The survey also asked reviewers to select the three characteristics they thought were most likely to have contributed to the paper becoming highly cited. The majority of the reasons selected related to the scientific content of the paper or the type of finding it reported (71% of first choice reasons), with methodological contributions considered to be particularly important. Figure 1-2 shows the characteristics most frequently selected as likely reasons for papers being highly cited.

Figure 1-2. Reasons selected by reviewers for papers being highly cited



Content and findings again featured prominently among reviewers' suggestions of characteristics that might contribute to a paper receiving social media attention, but there also appeared to be a greater emphasis on the potential future impact of the research beyond the academic realm. However, this question was only answered in relation to a subset of the sampled papers and so we must be very cautious in extrapolating from a small sample.

In interpreting the results of this assessment it is important to bear in mind a number of methodological caveats: all papers were selected from the top 1% most highly cited publications in their fields and so are not representative of the wider body of ERC-funded research; peer review exercises are, by definition, based on subjective judgement; we know little about the research profiles or backgrounds of the expert reviewers; and the sample of papers is small (95 reviews of 56 papers).

Nevertheless, reviewers' assessments support the conclusion that the 'top' ERC-funded research is making an important contribution to the advancement of science and knowledge, and that bibliometric indicators are a valid way of measuring this contribution, particularly given the ERC's focus on advancing knowledge through the support of frontier research. The use of social media metrics as tools in research evaluation is something which needs further exploration and there is not sufficient evidence from this study to support their use as indicators of research quality, importance or impact.

2. INTRODUCTION AND BACKGROUND

2.1. ABOUT THE STUDY

This report was commissioned by the European Research Council Executive Agency (ERCEA) as part of a wider evaluation of the outputs from ERC-funded research. The main focus of the larger project was on conducting a comprehensive scientometric assessment of publications arising from ERC grants, including analysis of a range of bibliometric indicators, analysis of patent applications, and analysis of alternative metrics which serve as indicators of social media attention. The evaluation takes a comparative perspective, examining ERC-funded outputs in relation to those of other research funders, and aims to deliver a robust framework which will allow for continuous updates of ERC scientific achievements in the future. The part of the evaluation covered in this report is a peer review assessment which aimed to support the quantitative analyses and provide a qualitative assessment of the contribution made by a sample of highly cited ERC-supported papers to their respective fields.

2.2. INTRODUCTION

As is the case with any evaluation tool, scientometric measures have a range of strengths and limitations. While bibliometrics is able to provide a reliable and comparable means of measuring the output and scientific impact of researchers, institutions and countries, there remain doubts over whether such metrics can be considered true measures of research quality and the extent to which they can capture the more diverse range of impacts that research might produce outside the scholarly community.

More recently, a range of heterogeneous social media metrics have begun to be used as alternative measures of research impact including, for example, Twitter mentions, Mendeley readership, mentions in blogs and news articles, and Facebook posts. Termed “altmetrics” (Priem et al., 2010), it has been suggested that these diverse measures may provide both a broader view of an article’s impact and a timelier measure of impact than is possible with citations (Li et al., 2012; Piwowar, 2013). However, there remain many unanswered questions about what exactly is being measured by altmetrics and how they should most appropriately be used (see, for example, Wouters & Costas, 2012; and Thelwall et al., 2013).

Thus while scientometric indicators can provide a comprehensive and comparable assessment of the utility of research outputs, a purely quantitative analysis can tell us little about why a particular paper has been cited, the nature of the knowledge it contains, or how we should interpret a high level of citation or social media attention.

Peer review has long been viewed as a respected process of quality assurance for scientific research. While it also has weaknesses (see, for example, Guthrie et al., 2013), it is popular with researchers (Wooding & Grant, 2004) and has been described as “the most effective and respected way to assess the quality of research outputs” (Royal Society, 1995). Using a qualitative assessment tool such as peer review alongside quantitative metrics can provide a more complete picture of the impact of research and help validate newer measures which have not yet been extensively tested in research evaluation.

In this paper we set out the findings of an exercise which used peer review of a sample of publications to explore the validity of the scientometric indicators used in assessing the research outputs of ERC-funded research. Specifically, the review exercise had two main aims:

- to examine the validity/meaning of the scientometric indicators; and
- to evaluate the overall contribution of the 'top' publications to the advancement of their respective scientific fields.

This paper first sets out the methodology for the assessment in Chapter 3, presents results in Chapter 4 and then discusses conclusions relating to the two key aims in Chapter 5.

3. METHODS

The objective of the exercise was to use a qualitative evaluation of a sample of highly cited publications resulting from ERC-funded research to critically evaluate the overall contribution of these papers to the advancement of their respective scientific fields and to explore the reasons for their citation and, where relevant, visibility in social media. The study sample consisted of 100 publications, and the aim was to have each of these reviewed by two experts in the corresponding scientific field by way of a brief online survey. Where possible, reviews were then compared with the corresponding scientometric indicators from other phases of the wider study.

3.1. THE SURVEY

As outlined above, the main aim of the peer review assessment was to explore the meaning and context of the scientometric indicators analysed in the earlier stages of this study. As part of this, the study's Advisory Committee requested that the expert reviewers assess the publications on the basis of their scientific quality, importance and potential impact. In order to explore in more detail the reasons why some publications have performed particularly well in the scientometric assessment, we also asked reviewers to assess each paper according to a number of other criteria, for example, in terms of its visibility in the research community and the wider context of the particular research field. More detail on the dimensions explored is provided below.

A short online survey was used to collect the review data. There were two main reasons for taking this approach: first, using a series of closed questions ensured that data were collected in a form which was possible to compare systematically with the scientometric data; and secondly, it imposed a minimal burden on reviewers, which was an important consideration given the likely workload of the desired respondents and restricted timeframe for completion of the assessment.

3.1.1. Contribution to advancement of science/knowledge

As part of the commissioning brief for the study, the ERCEA asked that papers be assessed on the quality of their contribution to science or knowledge, using a four point scale previously used for this purpose within the ERC (covering non-significant, incremental, significant and landmark contributions). This measure allowed us to verify whether the top papers according to bibliometric measures are also considered by experts as making an important contribution in their respective fields.

3.1.2. Type of content and nature of finding

The options in this section of the survey allowed us to characterise the scientific content of the paper, according to both the type of content (e.g. advancing a theory, synthesising evidence) and the type of finding reported (e.g. a novel phenomenon, early stage idea). These sections allowed us to explore whether particular types of paper were more likely to be highly cited or attract social media attention, and whether this differed between ERC domains.

3.1.3. Novelty and innovation

The ERC considers innovation and novelty to be two key attributes of the frontier research that it funds. Both of these dimensions can be demonstrated in a number of ways; for example, through the development of new concepts, the combination of different scientific principles, or the application of an existing concept in a new field. This section of the survey allowed us to investigate the existence of these attributes in highly cited ERC-funded research.

3.1.4. Interdisciplinarity

Interdisciplinarity is also considered by the ERC to be a key aspect of its research portfolio; one of the characteristics of 'frontier research' is that it should not be constrained by traditional disciplinary boundaries.[1] Previous work has demonstrated the existence of a relationship between interdisciplinarity and citation rate, but that the nature of this relationship varies by field (Larivière & Gingras, 2010). In the survey we looked at interdisciplinarity in several ways, including building on findings from another field, bringing together different fields and having the potential for impacts in other fields.

3.1.5. Potential impact

Given that ERC funding began relatively recently and that it can take somewhere in the region of 20 years for wider societal impacts to materialise (see, for example, Morris et al., 2011), it is unlikely that such impacts will be measurable at this point. Therefore, it was considered important to examine the potential future impact of the work. This was done by asking reviewers to categorise potential impacts according to the categories of impact set out in the Payback Framework, a well-established tool for assessing research impact.[2] Though originally designed for the biomedical sciences, the Framework has been shown to be suitable in a range of disciplines, from health to social sciences, the arts and humanities (see, for example, Levitt et al., 2010).

3.1.6. Non-content related characteristics

In addition to the scientific merit and importance of a paper's findings, a number of other characteristics have been suggested as potential reasons for a paper being cited, such as publishing in an open access journal (Antelman, 2004), involving collaboration or having a large number of authors (Figg et al., 2006).

The full questionnaire developed for the expert reviewers to qualitatively assess the highly ranked publications is presented in Appendix A.

3.2. Selecting the papers

The list of papers for the qualitative task was provided by the ERCEA after an internal selection exercise. The following selection criteria were used in compiling the list:

- each publication was an original research article (i.e. reviews were excluded);
- each publication was among the global top 1% in terms of citation in its particular field; and
- the sample covered all three ERC research domains and a range of panels within them.

The sample of papers was matched to the bibliometric database to obtain complete bibliographic information. This was possible for 94 of the 113 papers from the primary list and 36 papers from

[1] See http://erc.europa.eu/about-erc/mission (accessed May 2015)

[2] The Framework was developed by the Health Economics Research Group at Brunel University (Buxton & Hanney, 1996), and subsequently refined in collaboration with RAND Europe (Hanney et al., 2004; Wooding et al., 2004; Wooding et al., 2011).

the reserve list. The remaining papers were duplicates or were published too recently to be included in the bibliometric database. To create a final sample of 100 papers, a further six publications were selected from the reserve list. These were selected to retain as far as possible a similar distribution across panels to that of the list initially specified by the ERCEA and to minimise the duplication of PIs in the sample. Where there were a number of possible papers to select from for a particular panel, a selection was made randomly. The selected papers covered 22 of the 25 ERC panels under the three main disciplinary domains (i.e. Physical Sciences and Engineering (PE), Life Sciences (LS), and Social Sciences and Humanities (SH)). The final list of papers is provided in Appendix B and includes 51 PE papers, 43 LS papers and 6 SH papers.

3.3. Selecting reviewers

Experts to review papers were initially selected on the basis of membership of editorial boards of leading journals in the relevant fields. Journals were identified according to their Impact Factor, as set out in Thomson Reuters Journal Citation Reports for 2013. Email addresses were identified for potential reviewers and personalised email invitations were sent, accompanied by a letter of support from the ERC. The initial selection of potential reviewers primarily targeted journals with a fairly broad coverage of topics, reflecting the diverse range of fields of ERC-funded research. It was hoped that many editorial board members of such journals would have the expertise to review papers in a number of areas. However, this approach was altered during the study, due to feedback from several experts that they did not feel qualified to review the papers in the sample, and in the latter stages of the assessment more specialised journals were targeted in the fields where reviewers had not yet been found.

Separate surveys were set up in each of the three ERC domains. The experts approached were provided with the link to the most appropriate of the three surveys and invited to select for review the paper they felt was most relevant to their own expertise. They were able to complete reviews of multiple papers if they felt that they had expertise relevant to more than one paper.

After internal piloting of the survey within the research team, the first group of experts was invited to complete the survey during the week commencing 19 January 2015. Further invitations were sent out on a weekly basis, with two rounds of email reminders also sent to those contacted previously. The surveys remained open until 8 May 2015.

4. Results

In this chapter we set out a series of analyses based on the data obtained from the online peer review assessment. Firstly, we present an overview of the sampled papers and key findings from the survey data, followed by an in-depth analysis of the LS and PE papers. Due to the relatively small sample of papers in the SH domain, we do not analyse these findings in isolation, but present them within the overview section below.

As expected, the papers that were selected for peer review cover a wide range of topics across the three primary ERC domains. A word cloud highlighting the 200 most frequently occurring words within the titles of all the submitted publications is shown in Figure 4-1.[3] This only provides a visual complement to the core analysis covered in this chapter but highlights the diversity of topics the ERC is supporting through high quality research.

Figure 4-1. Word cloud highlighting the most frequently occurring words in the titles of all the highly cited articles used in the peer review task

4.1. Overview of all responses

The results discussed below draw primarily from the survey data, complemented by data on the sampled papers from our bibliometric analysis. We present key findings on the overall contribution

[3] The titles of all the highly cited articles that were shortlisted for the qualitative task were input to an online word cloud generating software (http://www.jasondavies.com/wordcloud/). The more times a word appears in the titles of the publications, the bigger the word is in the resulting word cloud visualisation.

of the papers identified to science/knowledge, the characteristics of these papers and reasons for high citation and social media attention. Due to the small sample size and the fact that the papers selected are not representative of the ERC's funded outputs as a whole, it is not appropriate to use more complex statistical analysis techniques in this exercise and we present the data as raw numbers and proportions only.

4.1.1. Respondents and response rate

For each research domain, recognised experts in the corresponding scientific fields were identified to carry out the survey. The survey was sent to a total of 892 experts (981 when rejections and undelivered emails are included) across the three research domains (LS, PE, SH).

The response rate was lower than expected. The majority of invited experts who contacted the research team to decline the invitation to participate did so either because they could not commit any time to the exercise or because they did not feel suitably qualified to review any of the papers selected. This latter point reflected the fact that while the sampled papers covered a wide range of fields across all three of the ERC's research domains, the individual papers themselves were often narrowly focused on a specific research area, meaning that the task required experts from a large number of areas with very specific knowledge, rather than experts with a broad expertise across a range of research areas. We had also hoped that by identifying individuals with expertise in a range of areas, many would be willing to review more than one paper, but the specific nature of the papers in the sample prevented this from being feasible in most cases.

Additionally, identification of potential reviewers was more resource intensive than anticipated, as initial plans to contact lists of grant reviewers held by the ERC were altered due to concerns about the independence of reviewers for the task. Overall we had 95 responses (10.7%), with varying response rates across each of the domains (see Appendix C for detailed breakdown of responses).

Across the 95 completed responses a total of 56 papers were reviewed (46 in LS, 40 in PE, 9 in SH). Within these, 26 papers received more than one review.[4] A breakdown across the ERC domains is presented in Appendix C.

4.1.2. Overall contribution of papers to science/knowledge

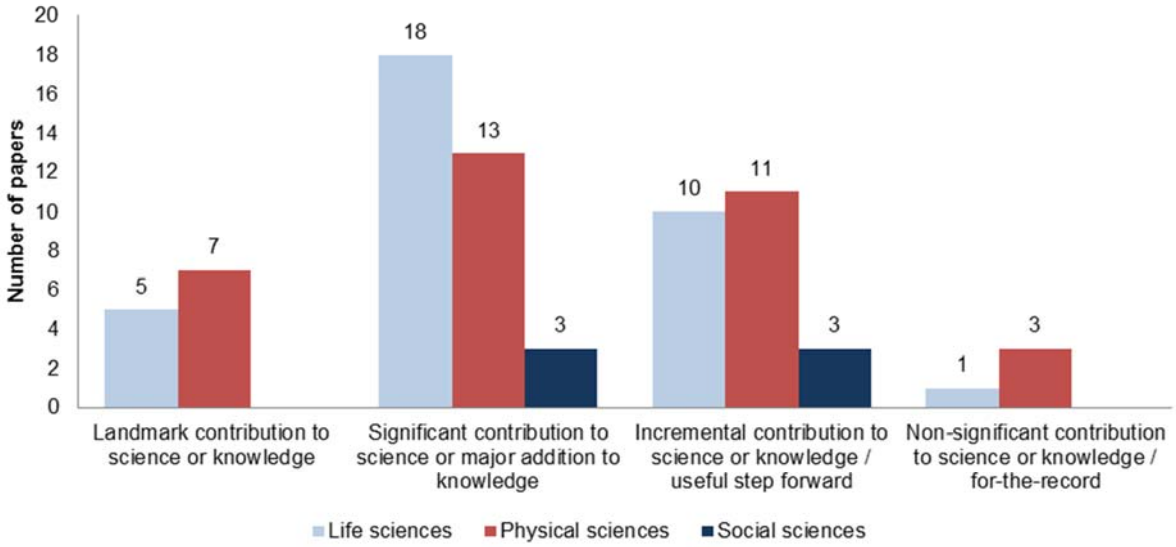
The first section of the survey asked respondents to comment on the overall contribution of the paper to science and/or knowledge generation.

Figure 4-2 below shows the overall contribution of papers to science/knowledge across each of the three domains, as reported by survey respondents.[5] Of the 56 papers reviewed, over 60% were considered to make a significant contribution to science or a major addition to knowledge. Twenty-one per cent of papers were considered to make a landmark contribution to science or knowledge. A list of all the reviewed papers with the corresponding reviewer ratings for this question is provided in Appendix D.

[4] Of the papers which received more than one review, five received 3 reviews, two received 4 reviews and one received 5 reviews

[5] Papers which received more than one review, where reviewers disagreed on the contribution of the paper are double counted in the graph below. Detailed analysis of these instances can be found in Section 4.2.1 and 4.3.1.

Figure 4-2. Overall contribution of papers across each of the three domains



A final free-text question in the survey asked reviewers to summarise the nature of the contribution made by the reviewed paper. These comments provide a flavour of the ERC-funded research considered by experts in the corresponding fields to be making the most important contributions to the advancement of science and knowledge. The reviewers' comments corresponding to the papers selected as landmark contributions are shown in Table 4-1. A further analysis of reviewers' comments about these 'landmark' articles is provided in Section 4.1.3.

Table 4-1. Reviewer comments on papers considered as landmark contributions

Research category	Comments on landmark papers
Life sciences	*They identify principles of long range chromosomal organization in a specific repressed state that is found in every female mammalian alive.*
	The paper identifies SAMHD1 as a restriction factor of HIV.
	This paper was the first to clearly show that there are different sources of myeloid cells in the body, and that the resident cells associated with tissues throughout life are largely generated very early in the embryonic yolk sac, while the bone marrow gives rise to the circulating cells later and throughout life. This has led to new insights as to the roles of tissue-resident macrophages in multiple physiologic settings, e.g. their role in adipose tissue and insulin sensitivity and their functions in solid tumors. These insights will eventually result in new therapeutic approaches for multiple diseases.
	This study uses computational modeling to explore resistance to chemotherapy in cancer that would have been otherwise not understood.
	An important step to understand the DNA language used to regulate genes by identifying sequence motifs recognised by transcription factors
Physical sciences and engineering	*The paper concerns the discovery of the Higgs boson, a new particle predicted in the Standard Model of particle physics.*
	The use of a completely novel material (the two-dimensional crystal Graphene, whose technical realization was recognized by the Nobel Prize in Physics 2010) to cleverly design a functional electronic device. The working principle gives rise to a number of questions, which are interesting from the perspective of fundamental solid-state physics. On the other hand, the demonstrated functionality is promising for applied research and development.
	This article is an experimental demonstration of Majorana particles which were predicted in a completely different context in 1938 by E. Majorana. This paper opens new avenue of research allowing to access non-Abelian braiding statistics of anyons (i.e. Majorana zero modes).
	A first description of a novel type of 2D material based transistor at the time of publication. this is a critical point in the field of condense matter physics, electronics, etc.
	The paper reports the discovery of Majorana fermions in superconductors. They belong to a fundamentally new class of particles and at the same time they are envisioned to be building blocks of a fault-tolerant quantum computer.
	High potential of a hype PV material in a new, promising, simpler structure is demonstrated.
	The article is the first step towards the development of new devices with great potential. It is also based on ground breaking theories which suggest a novel behavior of specially tailored materials.

4.1.3. Characteristics of papers reviewed

The second section of the survey asked respondents to indicate which characteristics applied to the paper they were reviewing. Multiple characteristics could be selected and they were categorised into six overarching groups as presented in Table 4-2 (each of the overarching groups has been colour-coded throughout this report).

Table 4-2. Characteristics grouped by overarching group

Overarching group	Characteristic
The type of content is...	Addressing a gap in existing knowledge
	Presenting new data or making new datasets available
	Advancing a new theory
	Synthesising existing knowledge
	Methodological development or technical innovation
The main finding...	Is a discovery of an entirely novel phenomenon
	Challenges existing understanding or represents a paradigm shift
	Is a disputed finding
	Is a promising early stage idea that calls for further development
	Makes previous contributions obsolete
The research is novel/ innovative in that it...	Creates and applies entirely new concepts that did not exist before
	Applies existing concepts which have never been used in this specific field/context before
	Creates and applies new combinations of related scientific principles
	Creates and applies new combinations of previously unrelated scientific principles
The research approach is inter-disciplinary in that it...	Brings together concepts from different but related fields
	Brings together concepts from previously unrelated fields
	Produces findings that could lead to progress in fields other than its own
	Builds on findings from a field other than its own
The research has a potential impact beyond generating knowledge, by...	Informing the direction of future research
	Informing policy
	Contributing to product/process development
	Producing economic benefits to society
	Producing benefits in the relevant sector (e.g. healthcare, engineering)
	Producing wider social or cultural impacts
Looking beyond the article's scientific content, the...	Author is well-known
	Institution has a strong reputation
	Journal has a high profile
	Journal is open access
	Article has a large number of authors
	Research involved wide collaboration
	Dissemination of the study's findings has been extensive
	Study has been promoted by a high profile individual or organisation
	Content is particularly topical or in the public eye
	Title is attention-grabbing
	Use of graphics/charts/statistics is particularly effective

Table 4-3 below presents the top ten characteristics of the 56 papers reviewed. Across all reviews, the most commonly highlighted characteristic was that the paper was published in a high profile journal. The next most popular characteristic selected by reviewers was that the research has a potential impact beyond generating knowledge by 'informing the direction of future research'. Other characteristics not associated with the research, such as the author being well-known and from an institution with a strong reputation were also amongst the top characteristics reported by reviewers. A breakdown of the characteristics selected within each overarching group is presented below.

Table 4-3. Top ten characteristics selected by respondents across all research categories

Characteristic	Total number of responses
Journal has a high profile	76
Informing the direction of future research	58
Author is well-known	57
Institution has a strong reputation	54
Creates and applies new combinations of related scientific principles	48
Is a promising early stage idea that calls for further development	36
Brings together concepts from different but related fields	33
Addressing a gap in existing knowledge	32
Presenting new data or making new datasets available	31
Applies existing concepts which have never been used in this specific field/context before	30

When looking at LS and PE papers separately, many of the characteristics were reported with similar frequency in the two domains. However, there were differences in some aspects: LS papers were more often considered to be addressing a gap in knowledge, advancing a new theory and challenging existing understanding, while PE papers were more likely to involve a methodological development, relate to a particularly topical issue, have a large number of authors/wide collaboration and have been promoted by a high-profile individual.

A detailed breakdown of papers' characteristics in each domain, arranged according to the overarching groups presented in Table 4-2 above, is provided in Appendix E.

Characteristics of landmark papers

This section briefly looks at some of the survey responses that relate to the papers that were considered to make a landmark contribution to science or knowledge. The analysis attempts to provide a high-level flavour of a small sample of ERC-funded research that is considered, by peers in the corresponding fields, to be making highly significant and notable contributions to the advancement of science and knowledge. It must be stressed, however, that since the sample is very small and not representative of the wider body of ERC-funded work, caution is advised in drawing any broader conclusions from this analysis. As noted previously, 12 of the 56 papers reviewed (21%) were considered to make a landmark contribution to science or knowledge. Seven of these papers belonged to the PE domain while the remaining five were LS papers.

The 12 'landmark' papers scored highly on the scientometric indicators included in other parts of this study. In terms of normalised citation impact, all were in the top 0.3% of papers of a similar age in their field, and half were in the top 0.05%. Both the mean and median relative citation scores were higher than those for the papers not judged by reviewers as landmark contributions. This pattern was repeated for both Twitter mentions and Mendeley readership, and thus despite the very small numbers in the sample, we do see a consistently high performance among the 'landmark' papers in comparison to the rest of the sample. Mean and median scores for citation and social media attention of 'landmark' and 'non-landmark' papers are provided in Appendix F.

In terms of the type of content of each article, five of the seven 'landmark' PE papers were considered to involve methodological development or technical innovation. To illustrate this point,

one of the reviewers for a highly cited PE paper[6] noted the following: "*…the use of a completely novel material (the two-dimensional crystal Graphene, whose technical realization was recognized by the Nobel Prize in Physics 2010) to cleverly design a functional electronic device.*" In contrast, four of the five 'landmark' LS papers were considered to address a gap in existing knowledge. This is exemplified by the following comment about one of the LS papers in the sample: "*this paper was the first to clearly show that there are different sources of myeloid cells in the body, and that the resident cells associated with tissues throughout life are largely generated very early in the embryonic yolk sac, while the bone marrow gives rise to the circulating cells later and throughout life*."[7]

While similar numbers of papers in both LS and PE were considered to synthesise existing knowledge and present new data, a larger number of LS papers were considered as addressing a gap in existing knowledge and advancing new theories, and more PE papers were considered to involve methodological development. The research approach in two-thirds of the papers was noted to be inter-disciplinary: the main reasons cited for this were that the research brought together concepts from previously unrelated fields or different but related fields, or that the research had produced findings that could lead to progress in fields other than its own.

As would be expected of a 'landmark' paper, the research in all the papers was described as being novel or innovative, the key reason for this being that the research created and applied new combinations of related scientific principles. Another reason provided by reviewers for novelty was that the research applied existing concepts which had never been used in this specific field before. For example, one of the PE reviewers remarked that the research described in the paper[8] was "*a first description of a novel type of 2D material based transistor at the time of publication… this is a critical point in the field of condense matter physics, electronics, etc.*"

Across the majority of the 'landmark' papers, reviewers felt that the research had a potential impact beyond generating knowledge by informing the direction of future research (9 of 12 papers), and in 6 cases, an impact in terms of contributing to product or process development was anticipated. For example, with regards to one of the PE papers,[9] a reviewer remarked that "*…this paper opens new avenue[s] of research allowing to access non-Abelian braiding statistics of anyons*". For another PE paper,[10] a reviewer commented that "*the article is the first step towards the development of new devices with great potential.*" In addition, some of the reviewers noted that wider societal impact was expected beyond the generation of knowledge, whether that was in terms of producing benefits in the relevant sector of practice (e.g. healthcare, engineering), economic benefits to society, or wider social or cultural impacts. This characteristic is nicely captured by one of the LS reviewers[11] who noted that "*these insights will eventually result in new therapeutic approaches for multiple diseases.*"

Finally, all the reviewers who had indicated the papers had made a landmark contribution noted that beyond the articles' scientific content, the papers had been published in high profile journals. Indeed, eight of the 12 papers were published in either *Science* (4) or *Nature* (4), arguably two of the highest profile scientific journals. Furthermore, in the majority of cases (10 of the 12 papers), the reviewers noted that the author was well-known and/or the corresponding institution had a strong reputation.

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[6] Britnell-L et al. 2012. 'Field-Effect Tunneling Transistor Based on Vertical Graphene Heterostructures.' *Science.*

[7] Schulz-C et al. 2012. 'A Lineage of Myeloid Cells Independent of Myb and Hematopoietic Stem Cells.' *Science*.

[8] Radisavljevic-B et al. 2011. 'Single-layer MoS2 transistors.' Nature Nanotechnology.

[9] Mourik-V et al. 2012. 'Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nanowire Devices.' *Science*.

[10] Wu-ZS et al. 2012. '3D Nitrogen-Doped Graphene Aerogel-Supported Fe3O4 Nanoparticles as Efficient Eletrocatalysts for the Oxygen Reduction Reaction.' *Journal of the American Chemical Society*.

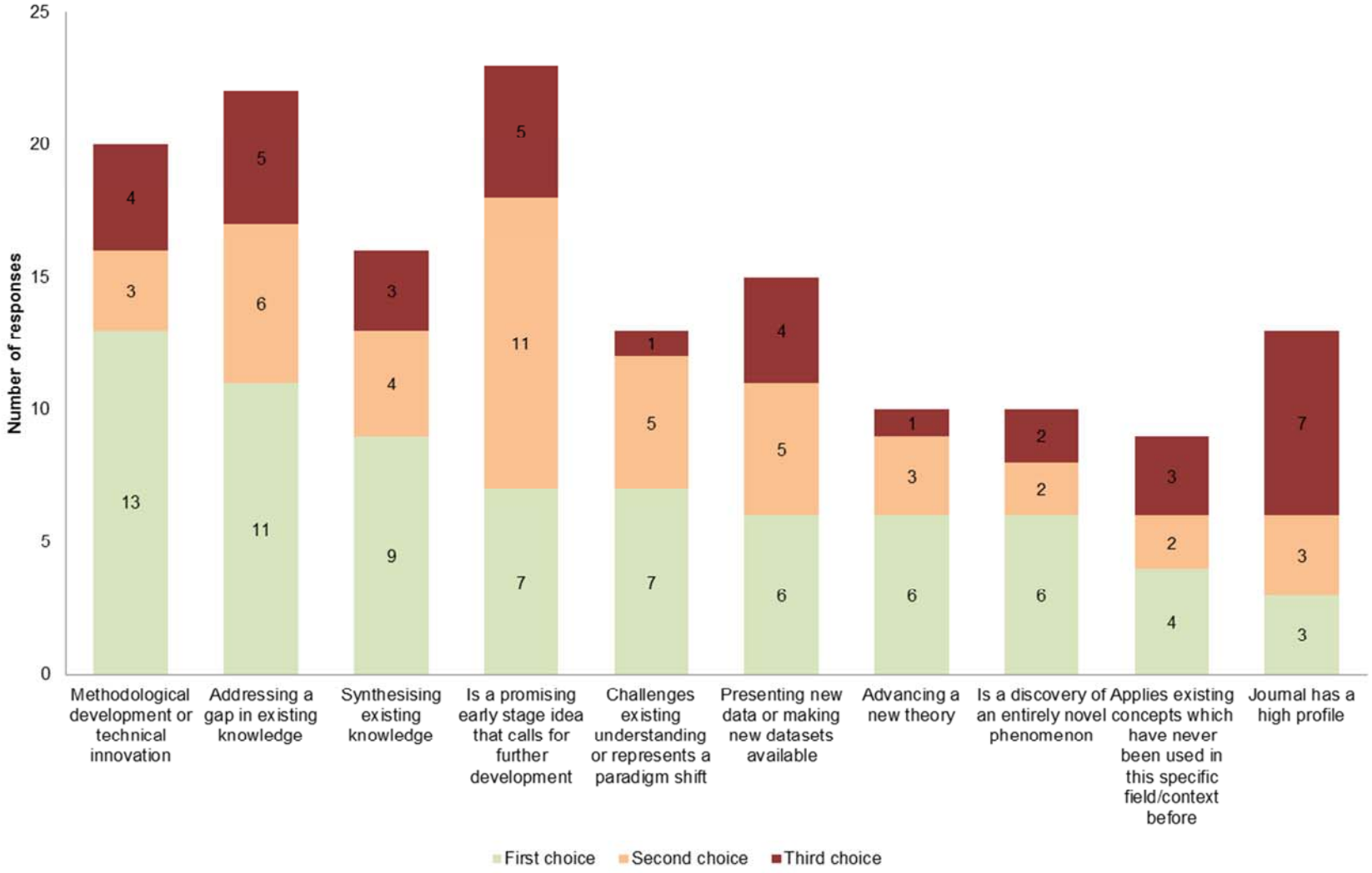
[11] Schulz-C et al. 2012. 'A Lineage of Myeloid Cells Independent of Myb and Hematopoietic Stem Cells.' *Science*.

4.1.4. Reasons for citation

Respondents were then asked to choose from the characteristics they had selected the top three reasons they thought contributed the most to the article being highly cited in its field. Figure 4-3 shows the top ten characteristics selected across all of the research domains.

While the characteristics most commonly attributed to papers overall tended not to be associated with the research content (as set out in Section 4.1.3), when considering likely reasons for a paper being highly cited, respondents did most frequently choose characteristics directly related to the paper's content and findings as the key characteristics: addressing a gap in existing knowledge, methodological development or technical innovation and promising early stage ideas.

Figure 4-3. Top ten reasons for papers being highly cited (across all three research domains), as suggested by reviewers

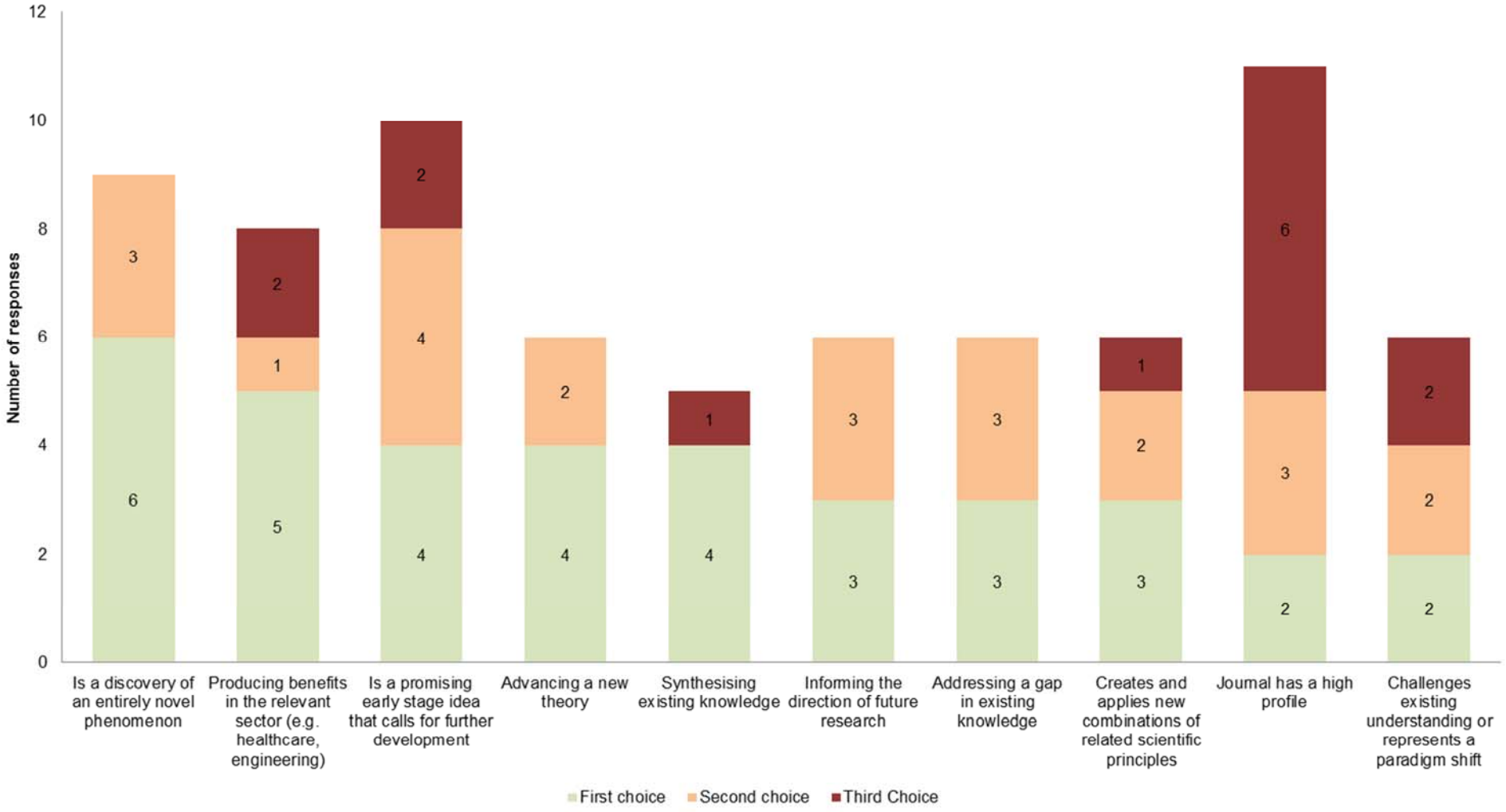


4.1.5. Reasons for social media attention

The final section of the survey asked respondents to choose from the characteristics they had selected the top three reasons they thought might contribute to the article receiving social media attention. Figure 4-4 shows the top ten characteristics across all of the research domains. It is worth noting that while all papers in the sample were in the top 1% of highly-cited publications in their respective fields, there was no intentional selection of papers which scored highly on altmetric measures. As a result, there was much more variation within the sample in the amount of social media attention the papers attracted. Reviewers were not told how each paper had scored in this respect.

Around one-third of respondents felt that one or more of the characteristics they had selected may contribute to a paper receiving social media attention. A finding that is the discovery of an entirely novel phenomenon, a promising early stage idea that calls for further development and research that produces wider benefits in its relevant sector were seen as the key characteristics. Publishing in a journal with a high profile was also seen as a contributing factor to a paper receiving high social media attention.

Figure 4-4. Top reasons suggested by reviewers that might lead to a paper receiving social media attention (across all three research domains)



4.1.6. Characteristics of papers gaining social media attention

Twitter

Data on Twitter mentions was available for 38 of the 56 papers receiving reviews in our sample. The median number of Twitter mentions of reviewed papers was four (the median was used due to a skewed distribution and the presence of one extreme outlier). Reviewed papers were split into two groups according to whether they had received four or fewer tweets, or more than four tweets.

Table 4-4 shows papers' contribution to the advancement of science or knowledge (as judged by reviewers) compared with their level of attention on social media, as indicated by receiving more or fewer Twitter mentions than the median for the sample. While a greater proportion of the 'more tweeted' papers were considered to have made a landmark contribution than those 'less tweeted', this relationship was reversed for papers considered to make a significant contribution, and caution is needed in drawing any meaningful conclusion from these results because of the very small sample size.

Table 4-4. Contribution of papers as judged by reviewers for papers receiving more or less than the median number of Twitter mentions (median = 4)[12]

Overall contribution to the advancement of science/knowledge	Tweets > median		Tweets ≤ median	
	Responses	%	Responses	%
Landmark contribution to science or knowledge	9	30%	4	12%
Significant contribution to science or major addition to knowledge	10	33%	20	61%
Incremental contribution to science or knowledge / useful step forward	8	27%	9	27%
Non-significant contribution to science or knowledge / for-the-record	3	10%	0	0%

When looking at the characteristics of the papers reviewed, there is generally little difference in the occurrence of each characteristic between the 'more tweeted' and 'less tweeted' groups. Nevertheless, the three largest differences are found in relation to a potential contribution to product or process development, effective use of graphics or charts, and publication in a high profile journal. All of these were found more often in papers tweeted more than four times (i.e. above the median). While these observations might intuitively seem to make sense, we must again be extremely cautious in drawing even tentative conclusions from this analysis due to the small number of papers for which we had both reviews and Twitter data available (as described above). A full breakdown of paper characteristics by group is provided in Appendix G.

Mendeley

Data on Mendeley readership was available for 52 of the 56 reviewed papers. The median number of Mendeley readers of reviewed papers was 186.5 and, as for the Twitter data, papers were split into two groups depending on whether their score fell above or below the median.

[12] Note that numbers represent number of reviews not number of papers, since reviewers did not always agree on the contribution made by a particular paper.

Table 4-5 shows the overall contribution of papers, as judged by reviewers, for papers scoring higher or lower than the median for Mendeley readership. A greater proportion of the papers scoring higher on Mendeley were considered to make a landmark contribution in their field than of the papers scoring below the median (22% vs 6%), while more of the lower scoring papers were judged to have made an incremental contribution.

Table 4-5. Contribution of papers as judged by reviewers for papers with Mendeley readership above or below the median (median = 186.5)[13]

Overall contribution to the advancement of science/knowledge	Mendeley readership > median		Mendeley readership ≤ median	
	Responses	%	Responses	%
Landmark contribution to science or knowledge	10	22%	3	6%
Significant contribution to science or major addition to knowledge	22	49%	22	51%
Incremental contribution to science or knowledge / useful step forward	11	24%	17	40%
Non-significant contribution to science or knowledge / for-the-record	2	4%	1	2%

When we look at the characteristics of the papers reviewed, many were reported with similar frequency in the two groups. However, methodological developments and research which was considered as potentially contributing to product or process development were more common among the higher scoring papers. As is the case throughout the analysis, it is important to bear in mind the small sample size in interpreting these results. A full breakdown of paper characteristics by group is provided in Appendix G.

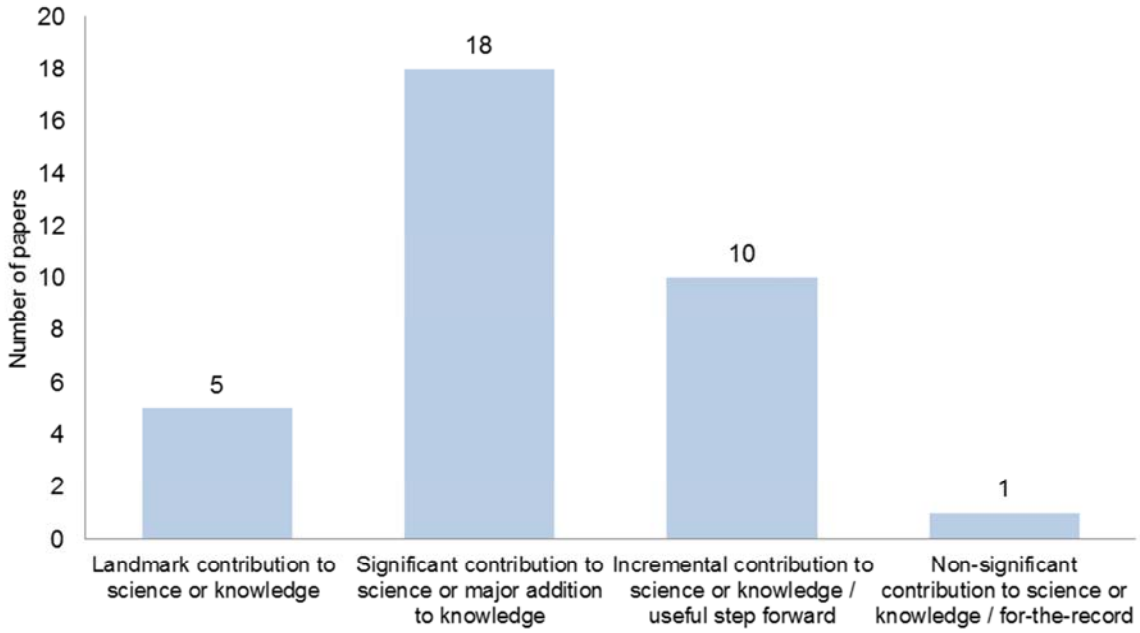
4.2. Life sciences

4.2.1. Overall contribution of papers to science/knowledge

Of the 26 Life sciences papers reviewed, the majority (53%) were considered either landmark or significant contributions to science or knowledge. The distribution of responses across the papers reviewed is shown in Figure 4-5 below.

[13] Note that numbers represent number of reviews not number of papers, since reviewers did not always agree on the contribution made by a particular paper.

Figure 4-5. Overall contribution of LS papers



Of the 14 papers with more than one review, reviewers agreed on the level of contribution in the majority of cases (i.e. in nine of the 15). An overview of reviewers' judgements on each paper's contribution to its field, as well as the degree of agreement between reviewers, is provided in Appendix D.

4.2.2. Characteristics of papers reviewed

Table 4-6 below highlights the top ten characteristics attributed to LS papers reviewed by survey respondents. Across all the LS reviews, the most common characteristic was that the paper was published in a journal that had a high profile – this was selected for 88% of the papers that were reviewed. The next most frequently selected characteristic (77% of papers reviewed) was that the research has a potential impact beyond generating knowledge by "informing the direction of future research". Other characteristics not directly associated with the paper's content, such as the author being well-known (77% of papers reviewed) and the corresponding institution having a strong reputation (69% of papers reviewed) were also amongst the most common characteristics indicated by reviewers.

Table 4-6. Top ten characteristics attributed to LS papers

Characteristic	Number of responses	Number of papers	% of papers reviewed displaying characteristic
Journal has a high profile	37	23	88%
Informing the direction of future research	26	20	77%
Author is well-known	28	20	77%
Institution has a strong reputation	25	18	69%
Addressing a gap in existing knowledge	21	15	58%
Creates and applies new combinations of related scientific principles	19	15	58%

Is a promising early stage idea that calls for further development	17	13	50%
Brings together concepts from different but related fields	15	12	46%
Produces findings that could lead to progress in fields other than its own	14	12	46%
Challenges existing understanding or represents a paradigm shift	14	11	42%

4.2.3. Reasons for citation

When LS reviewers were asked to rank (in descending order of importance) the top three characteristics which they thought contributed the most to the article being highly cited within its field, "addressing a gap in existing knowledge" and "challenges existing understanding or represents a paradigm shift" were the two most frequently selected 'first choice' reasons. These were followed by "synthesising existing knowledge" and "is a promising early stage idea that calls for further development". The full list of reasons suggested by reviewers is provided in Appendix H.

As described above, the occurrence of each characteristic, and thus the possibility that it could be a reason for citation, varies across the sample of papers. Any particular characteristic can only be chosen as a reason for citation if it is actually a characteristic of the paper in question, and so the characteristics chosen most often should be considered in the context of the frequency with which they occur in papers across the whole sample. For example, of the ten LS papers considered "synthesising existing knowledge", this characteristic was selected as being the main reason for the paper being highly cited in 40% of cases. Interestingly, the top eight characteristics in this respect relate to the paper's findings or type of content. Table 4-7 shows each of the 'first choice' reasons selected, as a proportion of the papers in which it occurred.

Table 4-7. Percentage of LS papers where a characteristic selected is the 'first choice' for highly cited

Characteristic	Number of papers in which characteristic selected as first choice	Number of papers in total displaying characteristic	%
Challenges existing understanding or represents a paradigm shift	6	11	55%
Is a discovery of an entirely novel phenomenon	3	6	50%
Addressing a gap in existing knowledge	7	15	47%
Synthesising existing knowledge	4	10	40%
Presenting new data or making new datasets available	3	8	38%
Advancing a new theory	3	9	33%
Is a promising early stage idea that calls for further development	4	13	31%
Methodological development or technical innovation	2	7	29%
Content is particularly topical or in the public eye	1	5	20%
Producing benefits in the relevant sector (e.g. healthcare, engineering)	1	6	17%
Applies existing concepts which have never been used in this specific field/context before	1	10	10%
Journal has a high profile	2	23	9%
Brings together concepts from different but related fields	1	12	8%
Creates and applies new combinations of related scientific principles	1	15	7%

4.2.4. Reasons for social media attention

The top two 'first choice' characteristics selected by LS reviewers to explain the reasons for the article receiving high levels of attention on social media were "producing benefits in the relevant sector" and "addressing a gap in existing knowledge". Once again, the full list of reasons selected by reviewers is presented in Appendix H.

As discussed above, any particular characteristic can only be chosen as a reason for likely social media attention if it is actually a characteristic of the paper in question, and so the characteristics chosen most often should be considered in the context of the frequency with which they occur in papers across the whole sample. Table 4-8, below, shows the occurrence of each characteristic in relation to the frequency of its selection as potentially leading to social media attention. For example, of the six LS papers considered as 'Producing benefits in the relevant sector', this characteristic was selected as being the main reason that the paper might attract social media attention in 67% of cases. However, it is important to note that the response rate was low, with only 65% of reviewers completing this question.

Table 4-8. Percentage of LS papers where a characteristic selected is the 'first choice' for social media attention

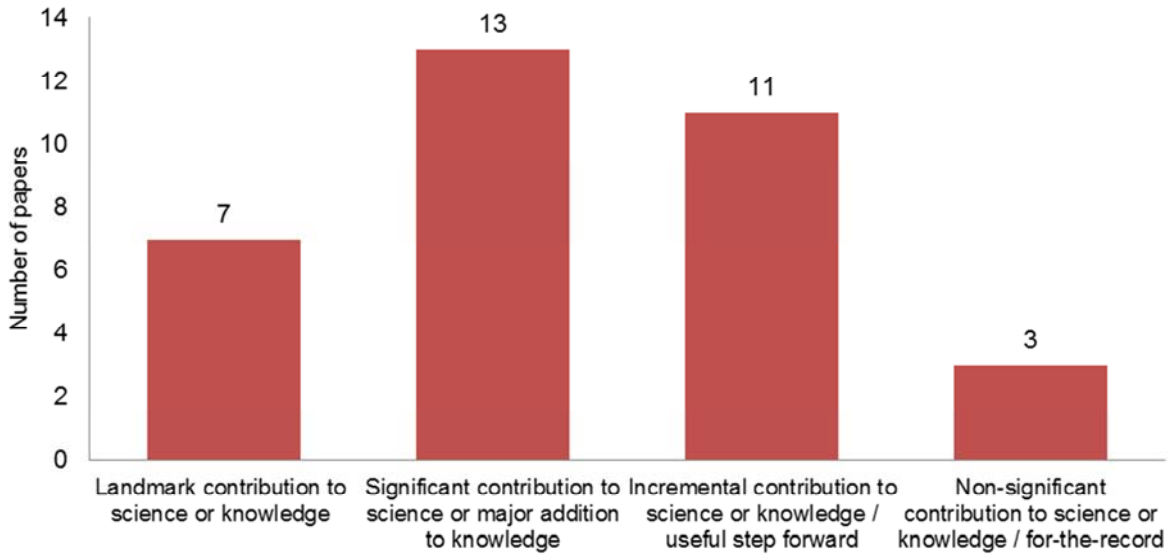
Characteristic	Number of papers in which characteristic selected as first choice	Number of papers in total displaying characteristic	%
Producing benefits in the relevant sector (e.g. healthcare, engineering)	4	6	67%
Content is particularly topical or in the public eye	2	5	40%
Is a discovery of an entirely novel phenomenon	2	6	33%
Makes previous contributions obsolete	1	3	33%
Producing wider social or cultural impacts	1	4	25%
Advancing a new theory	2	9	22%
Addressing a gap in existing knowledge	3	15	20%
Synthesising existing knowledge	2	10	20%
Challenges existing understanding or represents a paradigm shift	2	11	18%
Is a promising early stage idea that calls for further development	2	13	15%
Title is attention-grabbing	1	7	14%
Methodological development or technical innovation	1	7	14%
Presenting new data or making new datasets available	1	8	13%
Produces findings that could lead to progress in fields other than its own	1	12	8%
Creates and applies new combinations of related scientific principles	1	15	7%
Institution has a strong reputation	1	18	6%
Author is well-known	1	20	5%
Informing the direction of future research	1	20	5%
Journal has a high profile	1	23	4%

4.3. Physical sciences and engineering

4.3.1. Overall contribution of papers to science/knowledge

Of the 26 PE papers reviewed, the majority (77%) were considered as either landmark or significant contributions to science or knowledge. The distribution of responses across the papers reviewed is shown in Figure 4-6 below.

Figure 4-6. Overall contribution of PE papers



Of the nine papers with more than one review, there was only agreement between reviewers on the overall contribution of the paper in five instances. However, in all but one case judgements did not differ by more than one point on the four-point scale. An overview of reviewers' judgements on each paper's contribution to its field, as well as the degree of agreement between reviewers, is provided in Appendix D.

4.3.2. Characteristics of papers reviewed

Table 4-9 below highlights the ten characteristics most frequently attributed to PE papers reviewed by survey respondents.

Table 4-9. Top ten characteristics attributed to PE papers

Characteristic	Number of responses	Number of papers	% of papers reviewed displaying characteristic
Journal has a high profile	34	22	85%
Author is well-known	25	18	69%
Informing the direction of future research	26	17	65%
Institution has a strong reputation	25	17	65%
Creates and applies new combinations of related scientific principles	19	15	58%

Is a promising early stage idea that calls for further development	17	14	54%
Methodological development or technical innovation	14	13	50%
Brings together concepts from different but related fields	15	11	42%
Produces findings that could lead to progress in fields other than its own	11	11	42%
Article has a large number of authors	13	11	42%

4.3.3. Reasons for citation

When PE reviewers ranked the top three characteristics which they thought contributed the most to an article being highly cited within its field, "methodological development of technological innovation" was the most common 'first choice' reason, selected in nine instances. This was followed by "synthesising existing knowledge" and "addressing a gap in existing knowledge". The full list of reasons suggested by reviewers is provided in Appendix I.

As discussed in relation to the LS papers previously, the occurrence of each characteristic, and thus the possibility that it could be a reason for citation, varies across the papers. For example, of the PE papers considered as "addressing a gap in existing knowledge", this characteristic was selected as being the main reason for the paper being highly cited in 67% of cases (see Table 4-10). Similarly to the LS papers, the most frequently selected characteristics in this respect also relate to the papers' findings or type of content.

Table 4-10. Percentage of PE papers where a characteristic selected is the 'first choice' for highly cited

Characteristic	Number of papers in which characteristic selected as first choice	Number of papers in total displaying characteristic	%
Is a discovery of an entirely novel phenomenon	2	3	67%
Addressing a gap in existing knowledge	4	6	67%
Methodological development or technical innovation	7	13	54%
Synthesising existing knowledge	4	9	44%
Applies existing concepts which have never been used in this specific field/context before	3	9	33%
Challenges existing understanding or represents a paradigm shift	1	4	25%
Is a promising early stage idea that calls for further development	3	14	21%
Presenting new data or making new datasets available	2	10	20%
Informing the direction of future research	2	17	12%
Brings together concepts from different but related fields	1	11	9%
Produces findings that could lead to progress in fields other than its own	1	11	9%
Author is well-known	1	18	6%
Journal has a high profile	1	22	5%

4.3.4. Reasons for social media attention

The most frequently selected 'first choice' characteristic as a reason for an article potentially receiving high levels of attention on social media was "is a discovery of an entirely novel

phenomenon". This reason was followed by the characteristics "synthesising existing knowledge", "creates and applies new combinations of related scientific principles", "informing the direction of future research" and "is a promising early stage idea that calls for further development", all of which were selected by the same number of reviewers (two). Again, the full list of reasons selected by reviewers is presented in Appendix I.

Table 4-11 below shows the occurrence of each characteristic in relation to the frequency of its selection as potentially leading to social media attention. For example, of the LS papers considered as "informing policy", this characteristic was selected as being the main reason for the paper being highly cited in 50% of cases.

Table 4-11. Percentage of PE papers where a characteristic selected is the 'first choice' for social media attention

Characteristic	Number of papers in which characteristic selected as first choice	Number of papers in total displaying characteristic	%
Is a discovery of an entirely novel phenomenon	3	3	100%
Informing policy	1	2	50%
Producing wider social or cultural impacts	1	3	33%
Producing economic benefits to society	1	4	25%
Synthesising existing knowledge	2	9	22%
Title is attention-grabbing	1	7	14%
Is a promising early stage idea that calls for further development	2	14	14%
Creates and applies new combinations of related scientific principles	2	15	13%
Informing the direction of future research	2	17	12%
Applies existing concepts which have never been used in this specific field/context before	1	9	11%
Presenting new data or making new datasets available	1	10	10%
Brings together concepts from different but related fields	1	11	9%
Produces findings that could lead to progress in fields other than its own	1	11	9%
Methodological development or technical innovation	1	13	8%
Journal has a high profile	1	22	5%

5. Discussion

In this paper we have aimed to explore the meaning of the scientometric indicators compiled as part of the wider study, focusing on a sample of papers drawn from the top 1% of highly cited papers in their respective fields. We also considered the overall contribution made by these papers to the advancement of science and knowledge.

5.1. Some methodological caveats

In interpreting the findings of this assessment, it is important to bear in mind a number of limitations of the survey and the data collected.

First, the sample size is small, with only 95 reviews across 56 papers. While each of these reviews contains rich data allowing interesting analysis, caution is needed in drawing firm conclusions or in extrapolating to the wider body of ERC-funded research.

Second, as with any peer review exercise, our dataset consists of a series of subjective judgements made by peer reviewers. In exploring the characteristics of the sampled papers, we limited the influence of subjectivity as far as possible by using multiple-choice questions to obtain a set of characteristics that could create a consistent 'profile' for each paper. However, even within this section of the survey there was not perfect agreement between experts reviewing the same paper.

Third, it is important to bear in mind the nature of the papers sampled and reviewed. Our sample was drawn from ERC-funded papers appearing in the top 1% of highly cited papers in their respective fields, and thus we cannot generalise from this sample to allow us to comment on the entire corpus of ERC-funded publications. Furthermore, experts invited to complete the survey were offered a free choice of the papers within their domain of expertise (i.e. LS, PE, SH). This may have led to papers which were, for example, particularly high-profile, current or concerning more 'accessible' topics being preferentially selected, or to a bias towards particular topic areas (since we do not have sufficient information on reviewers' backgrounds to compare the distribution of their expertise with the distribution of topics in the sample of papers). It is also possible that papers published in high profile journals were more familiar to reviewers, and thus their review may have been influenced by the publicity given to these papers.

Finally, to preserve anonymity and minimise the burden for reviewers, we did not collect data regarding demographics or research profile. While the survey stated that reviewers should not select papers on which they were an author, there are a number of other potential influences that cannot be ruled out, such as familiarity with the paper's authors or their institution, being a current or past ERC grant recipient or being a reviewer of ERC grant proposals. While these are possibilities to be aware of, there would seem to be very little incentive for reviewers to intentionally be biased in their responses and so these are likely to be minor concerns at most.

5.2. What kinds of contributions has ERC-funded research made?

Reviewers considered 21% of the papers reviewed to have made a landmark contribution to their field. These contributions were in a range of different fields in the life and physical sciences and included the identification of new entities or phenomena, methodological advances in the study of a topic and the elaboration of theoretical principles. As a group, these papers scored consistently higher on indicators of citation and social media attention than papers considered not to have made a landmark contribution. We should, however, interpret this with caution, given the very small sample size.

The majority of papers (61%) were considered to have made a significant contribution to science or major addition to knowledge, while only four papers in total (7%) were considered by reviewers to have made a non-significant contribution. When interpreting these results, however, one should bear in mind that of the 23 papers which received more than one review, there was only complete agreement between the reviewers in nine instances. These discrepancies in the perceived value of a paper's content may be due to factors such as the bearing of the paper's findings on the reviewer's own particular field, their familiarity with the topic in question, or their own beliefs about areas which may prove particularly important to the future development of the field. As we chose to preserve reviewers' anonymity as far as possible and minimise the burden in responding to the survey, we are unable to explore these possibilities further in the present dataset.

5.3. What does highly cited ERC research look like?

From the list of possible paper characteristics presented to reviewers we are able to identify common features which characterise highly cited papers stemming from ERC-funded research. Unsurprisingly, papers cited in the top 1% in their field tend to appear in high-profile journals, a finding which is likely to reflect both the quality/importance of the research and the fact that publication in such a journal makes a paper more visible and hence more likely to be cited. Among papers considered to have made a landmark contribution, two-thirds (eight out of 12) were published in just two journals, *Nature* and *Science*. Top papers were also likely to have been authored by well-known researchers who were based in institutions with a strong reputation, findings which, again, are as one might expect. While the difference is small, it is worth noting that all three of these characteristics were more common among papers in the LS domain than in PE. On the other hand, reviewers noted that 31% of PE papers reviewed had been promoted by a high-profile individual, in comparison to a single LS paper (4%). PE papers were also more likely than LS to involve wide collaboration and relate to issues which were particularly topical or in the public eye.

The other most commonly selected characteristics of papers were in many cases common across both LS and PE domains. Around half of papers presented an early stage idea that called for further development and, likely related to this, the majority of papers (71%) were expected to have an impact in informing the direction of future research. Many papers (including all of those considered to have made a landmark contribution) demonstrated novelty and/or interdisciplinarity, through creating and applying new combinations of related scientific principles (58% of papers), bringing together concepts from different but related fields (44% of papers), or producing findings which may have an impact on fields other than that in which the research was carried out (44% of papers).

Regarding the type of content of the papers, while the synthesis of knowledge (37% of papers) and presentation of new datasets (46% of papers) was similarly common in LS and PE domains, methodological developments occurred more frequently in PE than LS papers (50% in PE vs 27% in LS), while LS papers were more likely to address a gap in existing knowledge (58% vs 23% in PE) or advance a new theory (35% vs 8% in PE). LS papers were also more likely to challenge existing understanding or represent a paradigm shift in the field (42% vs 15% in PE).

Measuring the wider societal impact of research has become an area of particular focus for many research funders in recent years, in part because of an increased need to demonstrate the effective use of public money in funding research which will ultimately bring benefits to society. As noted previously, ERC funding began only recently and as a result it is likely to be too early to see many of the wider impacts that can arise from scientific research. To take this into account we asked reviewers to consider the potential *future* impact of each paper. The most common anticipated impact was for the paper to inform the direction of future research, something which is very much in-line with the ERC's mission of supporting frontier research which pushes the boundaries of current knowledge. Moving outside the realm of academia and knowledge creation, a substantial number of papers (23%) were also expected to contribute to producing benefits in the relevant sector (e.g. healthcare, engineering, etc.). In the life sciences, the same proportion was also expected to inform policy, a figure which was much lower in the PE domain (8%). This may be because in health and biomedical sciences, policy development is often a step on the way to having an impact in health and healthcare (through, for example, influencing clinical guidelines), whereas research in the physical sciences may be able to have a more direct impact in terms of practical application. Few papers were expected to have economic impacts or wider social or cultural impacts, a finding which is entirely consistent with previous research demonstrating the distribution of different kinds of impact: while most studies will produce knowledge and other impacts within academia, not all can be expected to produce wider societal impacts and the likelihood of these decreases as we move further along the translation pathway (e.g. Wooding et al., 2011; 2013).

5.4. Why were papers highly cited?

Reviewers were asked to indicate the three characteristics of the papers which they felt were most likely to have contributed to it being highly cited. The characteristics selected related overwhelmingly to the type of content of the paper or the type of finding it reported (52% of all responses, 71% of first choices), supporting the assertion that citation is an appropriate measure of the scientific value or quality of research. However, within these categories, there was some variation in the specific kinds of content and findings which reviewers considered likely to lead to high citation. In particular, where a reviewer indicated that a paper made a methodological contribution, this was then selected as the primary reason for citation by 54% of reviewers (64% in PE). Where a paper addressed a gap in the existing knowledge, this was indicated as the main reason for citation by 34% of reviewers, while a promising early idea calling for further development was only selected as the primary reason for citation in 19% of cases where it was indicated to be a characteristic of the paper.

While features of papers not relating to content were commonly recorded by reviewers as characteristics of the paper being reviewed (as discussed above), these were rarely subsequently suggested as reasons for a paper being highly cited. The one exception to this observation was publication in a high-profile journal, which, although selected as the primary reason by only three reviewers (3% of those who attributed this characteristic to the paper being reviewed), was more commonly suggested as a second or third choice (a further 11% of reviewers). This made it the sixth most commonly selected reason when inclusion in any place in a reviewer's top three was considered. This would suggest that, according to the perceptions of reviewers, while publishing in a top journal is not enough on its own for a paper to become highly cited, it may facilitate this when the content/findings are considered important. This is consistent with existing evidence that citations are indeed correlated with journal impact factors through a 'Matthew Effect' (Larivière & Gingras, 2010). It would seem feasible that this might be due to the paper having increased visibility to other researchers.

5.5. What leads to social media attention?

Unlike for citation, the sampled papers were not selected on the basis of their social media visibility, meaning that our selection contains both papers which have attracted a lot of attention on social media and papers which have not. This allows us to look at two different aspects of the role of social media: firstly, characteristics of a paper that might be associated with it being highly tweeted or having a large number of Mendeley readers, and secondly, the characteristics that researchers perceive as likely to lead to social media attention.

We are limited in what we can conclude on the characteristics of papers which receive a lot of Twitter mentions, due to the small number of papers for which we have both reviews and Twitter data (38 papers). Nevertheless, the three characteristics for which we observed the greatest difference in occurrence between our 'more tweeted' and 'less tweeted' groups were the potential for a paper to contribute to product or process development, effective use of graphics or charts, and publication in a high profile journal. These are not inconsistent with ideas in the wider literature, where it has been suggested that social media metrics may provide an insight into impact outside the academic realm (e.g. Mohammadi & Thelwall, 2013) and that Twitter metrics may have some association with measures of journal impact (Haustein et al., 2014).

While data on Mendeley readership was available for a larger proportion of the papers reviewed, there was less variability among the papers in the sample: overall the papers selected scored highly in comparison to the wider body of ERC-supported research (see the alternative metrics report for this study: D7). This limits the extent to which we can compare features of high and low scoring papers within this group, as many of those scoring below the median would be considered high scoring in the wider context. Despite this caveat, papers with high Mendeley readership counts were more frequently perceived as making a landmark contribution to science or knowledge, and were also more likely to present a methodological development or have the potential to contribute to product or process development.

In looking at reviewers' perceptions of the characteristics that might lead to attention on social media we must be cautious about sample size, since only around one-third of reviewers thought the characteristics of the paper they had selected would lead to it receiving social media attention. However, this subset of our data does allow us to draw some tentative conclusions. Many of the perceived reasons for citation again featured prominently in responses, namely characteristics relating to the paper's content and findings. Similarly, publication in a high-profile journal, while rarely selected as the primary reason for a paper attracting attention on social media, was commonly selected as an additional reason (chosen by 14% of reviewers as one of their top three reasons). However, there is a notable difference in the perceived importance of potential future impacts to a paper's performance. Of the 19 reviewers who indicated that a paper might lead to future benefits in its associated sector of practice, eight (42%) suggested that this characteristic might lead to attention on social media, compared with four (21%) who suggested that this might lead to it being highly cited. Similarly, although numbers are small, four of the eight reviewers who indicated potential future economic benefits also selected this as a likely reason for social media attention, compared with only one who thought this might lead to high citation. Intuitively, this makes sense, since the potential audience for social media platforms is likely to be broader than for a scientific journal, taking covering different stakeholder groups, but further research is needed on a much larger dataset to determine how and by whom Mendeley is used, who Twitter mentions reach and any impact that stems from this dissemination.

5.6. In conclusion

Overall, the findings from the expert peer review exercise support the conclusion that the 'top' ERC-funded research is making an important contribution to the advancement of science and knowledge, and that bibliometric indicators are a valid way of measuring this contribution,

particularly given the ERC's focus on advancing knowledge through the support of frontier research. The use of Mendeley readership and Twitter mentions as tools in research evaluation is something which needs further exploration and, on the basis of this exercise's data, cannot yet be reliably used as an indicator of research quality, importance or impact.

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Appendices

Appendix A: List of questions used for the online peer-review evaluation of highly cited papers

Figure A-1. Questions for expert reviewers undertaking the qualitative assessment of highly ranked publications from the scientometric assessment

Questionnaire for qualitative assessment

PAGE 1:

INTRO:

Many thanks for taking the time to assist us with this study. The articles listed below have been published as a result of ERC-supported research in the [life sciences / physical sciences and engineering / social sciences and humanities] domain.

Please enter your name*

[BOX]

Please select an article that you feel you have suitable expertise to review. You will then be asked a brief series of questions relating to the characteristics and contribution of the research. The questions should take around 10 minutes.

PLEASE ONLY SELECT ONE ARTICLE

If you are willing to review more than one article, please redo the survey following the link in your invitation email.

[LIST OF PAPERS IN RELEVANT DOMAIN]

- On selection:

Please confirm that this is the article you wish to review and that you are not an author on this paper or a member of the journal's editorial board. (Please type "OK" in the box below to confirm)

[BOX]

If you have any questions, you can contact the research team at

---

PAGE 2:

Q1. How would you rate this article's overall contribution to the advancement of science/knowledge? Please select one of the following options, basing your judgement on the findings of this paper alone:

- Landmark contribution to science or knowledge
- Significant contribution to science or major addition to knowledge
- Incremental contribution to science or knowledge / useful step forward
- Non-significant contribution to science or knowledge / for-the-record

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PAGE 3:

Q2. Please indicate which of the following characteristics apply to the article. Multiple characteristics can be selected.

As the study is covering research across the physical sciences, life sciences, social sciences and humanities, some questions may not be relevant to every article. Please complete only sections that apply and leave blank any item which does not apply to this article.

- The type of content is...
  - Methodological development or technical innovation
  - Advancing a new theory
  - Synthesising existing knowledge
  - Addressing a gap in existing knowledge
  - Presenting new data or making new datasets available
  - Other (please specify)

- The main finding...
  - Is discovery of an entirely novel phenomenon
  - Challenges existing understanding or represents a paradigm shift
  - Is a disputed finding
  - Is a promising early stage idea that calls for further development
  - Makes previous contributions obsolete
  - Other (please specify)

- The research is novel/innovative in that it...
  - Creates and applies entirely new concepts that did not exist before
  - Applies existing concepts which have never been used in this specific field/context before
  - Creates and applies new combinations of related scientific principles
  - Creates and applies new combinations of previously unrelated scientific principles
  - Other (please specify)

- The research approach is inter-disciplinary in that it...
  - Brings together concepts from different but related fields
  - Brings together concepts from previously unrelated fields
  - Produces findings that could lead to progress in fields other than its own
  - Builds on findings from a field other than its own
  - Other (please specify)

- The research has a potential impact beyond generating knowledge, by...
  - Informing the direction of future research
  - Informing policy
  - Contributing to product/process development
  - Producing economic benefits to society
  - Producing benefits in the relevant sector (e.g. healthcare, engineering)
  - Producing wider social or cultural impacts
  - Other (please specify)

- Looking beyond the article's scientific content, the...
  - Author is well-known
  - Institution has a strong reputation
  - Journal has a high profile
  - Journal is open access
  - Article has a large number of authors
  - Research involved wide collaboration
  - Dissemination of the study's findings has been extensive
  - Study has been promoted by a high profile individual or organisation
  - Content is particularly topical or in the public eye
  - Title is attention-grabbing
  - Use of graphics/charts/statistics is particularly effective
  - Other (please specify)

PAGE 4:

Q3. Of the characteristics you selected, which do you think have contributed the most to the article being highly cited in its field?

Please select three characteristics and rank them in descending order of importance.

[All options checked in Q2 displayed here as possible reasons. There will also be an option to add other reasons not yet mentioned.]

Other reason for citation not previously mentioned:

[BOX]

PAGE 5:

Q4. Do you think that any of these characteristics would lead to the article receiving a high level of attention on social media (e.g. being shared on Twitter)?

If so, please select up to three characteristics, ranked in descending order of importance. Otherwise, please leave this question blank.

[Options listed as in Q3]

PAGE 6:

Q5. [Open question] Please briefly summarise the nature of the paper's contribution to science/knowledge or its potential impact on society. Please do so in one or two sentences and in language accessible to a non-expert audience.

Appendix B: List of highly cited papers selected for peer-review evaluation

Table B-1. List of highly cited papers selected for the peer-review evaluation task

S.No.	Paper title	Publication year	Journal title	ERC domain	Relative citations	Twitter mentions	Mendeley readership
1	Multivesicular bodies associate with components of miRNA effector complexes and modulate miRNA activity	2009	NATURE CELL BIOLOGY	LS	11.027	1	330
2	Characterizing the RNA targets and position-dependent splicing regulation by TDP-43	2011	NATURE NEUROSCIENCE	LS	21.214	0	232
3	A MicroRNA Superfamily Regulates Nucleotide Binding Site-Leucine-Rich Repeats and Other mRNAs	2012	PLANT CELL	LS	7.801	4	143
4	Fiji: an open-source platform for biological-image analysis	2012	NATURE METHODS	LS	57.28	15	719
5	Diagnostic Exome Sequencing in Persons with Severe Intellectual Disability	2012	NEW ENGLAND JOURNAL OF MEDICINE	LS	24.634	62	216
6	Unresponsiveness of colon cancer to BRAF(V600E) inhibition through feedback activation of EGFR	2012	NATURE	LS	39.136	17	335
7	Options and considerations when selecting a quantitative proteomics strategy	2010	NATURE BIOTECHNOLOGY	LS	7.992		319
8	Epigenome-wide association data implicate DNA methylation as an intermediary of genetic risk in rheumatoid arthritis	2013	NATURE BIOTECHNOLOGY	LS	48.705	66	205
9	JASPAR 2010: the greatly expanded open-access database of transcription factor binding profiles	2010	NUCLEIC ACIDS RESEARCH	LS	15.025		202
10	Three-Dimensional Folding and Functional Organization Principles of the Drosophila Genome	2012	CELL	LS	29.197	23	451
11	Spatial partitioning of the regulatory landscape of the X-inactivation centre	2012	NATURE	LS	21.161	3	351
12	RDP3: a flexible and fast computer program for analyzing recombination	2010	BIOINFORMATICS	LS	37.402		225
13	ProtTest 3: fast selection of best-fit models of protein evolution	2011	BIOINFORMATICS	LS	21.019		6
14	Rapid, combinatorial analysis of membrane compartments in intact plants with a multicolor marker set	2009	PLANT JOURNAL	LS	8.402		146
15	Defining the mode of tumour growth by clonal analysis	2012	NATURE	LS	22.298	52	549
16	Dynamics of Hippocampal Neurogenesis in Adult Humans	2013	CELL	LS	28.16	351	35
17	AMPK regulates energy expenditure by modulating NAD(+) metabolism and SIRT1 activity	2009	NATURE	LS	20.415	0	408
18	AKT Inhibition Relieves Feedback Suppression of Receptor Tyrosine Kinase Expression and Activity	2011	CANCER CELL	LS	20.045	2	198
19	Intestinal Tumorigenesis Initiated by Dedifferentiation and Acquisition of Stem-Cell-like Properties	2013	CELL	LS	41.676	16	278
20	DNA-Binding Specificities of Human Transcription Factors	2013	CELL	LS	19.149	18	346
21	Circulating MicroRNAs in Patients With Coronary Artery Disease	2010	CIRCULATION RESEARCH	LS	20.021		95
22	Patient-Specific Induced Pluripotent Stem-Cell Models for Long-QT Syndrome.	2010	NEW ENGLAND JOURNAL OF MEDICINE	LS	28.736	0	185
23	Atheroprotective communication between endothelial cells and smooth muscle cells through miRNAs	2012	NATURE CELL BIOLOGY	LS	22.956	10	234
24	Micro-RNA Profiling Reveals a Role for miR-29 in Human and Murine Liver Fibrosis	2011	HEPATOLOGY	LS	14.895		51
25	Cortical oscillations and speech processing: emerging computational principles and operations	2012	NATURE NEUROSCIENCE	LS	12.353	15	332
26	The Social Neuroscience of Empathy	2009	ANNALS OF THE NEW YORK ACADEMY OF SCIE	LS	6.307		587
27	Meta-analytic evidence for common and distinct neural networks associated with directly experienced pain and empathy for pain	2011	NEUROIMAGE	LS	18.222	0	346
28	The Transcellular Spread of Cytosolic Amyloids, Prions, and Prionoids	2009	NEURON	LS	7.854		156
29	Allele-specific FKBP5 DNA demethylation mediates gene-childhood trauma interactions	2013	NATURE NEUROSCIENCE	LS	48.612	20	188
30	Macrophage plasticity and polarization: in vivo veritas	2012	JOURNAL OF CLINICAL INVESTIGATION	LS	72.238	1	466
31	Recognition of RNA virus by RIG-I results in activation of CARD9 and inflammasome signaling for interleukin 1 beta production	2010	NATURE IMMUNOLOGY	LS	11.241	0	157
32	A Lineage of Myeloid Cells Independent of Myb and Hematopoietic Stem Cells	2012	SCIENCE	LS	29.352	35	9
33	Microglia emerge from erythromyeloid precursors via Pu.1- and Irf8-dependent pathways	2013	NATURE NEUROSCIENCE	LS	41.463	4	149
34	Nod1 and Nod2 direct autophagy by recruiting ATG16L1 to the plasma membrane at the site of bacterial entry	2010	NATURE IMMUNOLOGY	LS	25.095	0	210
35	SAMHD1 is the dendritic- and myeloid-cell-specific HIV-1 restriction factor counteracted by Vpx	2011	NATURE	LS	20.654	3	219
36	Genome divergence during evolutionary diversification as revealed in replicate lake-stream stickleback population pairs	2012	MOLECULAR ECOLOGY	LS	10.822	1	163
37	Variation in plastic responses of a globally distributed picoplankton species to ocean acidification	2013	NATURE CLIMATE CHANGE	LS	6.81	4	53
38	GREENBEARDS	2010	EVOLUTION	LS	4.074	0	27
39	The genetical theory of kin selection	2011	JOURNAL OF EVOLUTIONARY BIOLOGY	LS	5.097		174
40	Regional carbon dioxide implications of forest bioenergy production	2011	NATURE CLIMATE CHANGE	LS	5.026	9	65
41	Salicylic Acid Suppresses Jasmonic Acid Signaling Downstream of SCFCOI1-JAZ by Targeting GCC Promoter Motifs via Transcription Factor ORA59	2013	PLANT CELL	LS	2.253	2	117
42	Broadly Neutralizing Antibody PGT121 Allosterically Modulates CD4 Binding via Recognition of the HIV-1 gp120 V3 Base and Multiple Surrounding Glycans	2013	PLOS PATHOGENS	LS	13.384	1	35
43	Gradient estimates via non-linear potentials	2011	AMERICAN JOURNAL OF MATHEMATICS	PE	13.789		
44	Mountain Pass solutions for non-local elliptic operators	2012	JOURNAL OF MATHEMATICAL ANALYSIS AND A	PE	17.592		8
45	Hitchhiker's guide to the fractional Sobolev spaces	2012	BULLETIN DES SCIENCES MATHEMATIQUES	PE	35.183		41
46	Convergence Rates of Best N-term Galerkin Approximations for a Class of Elliptic sPDEs	2010	FOUNDATIONS OF COMPUTATIONAL MATHEN	PE	13.671		17
47	An expert judgement assessment of future sea level rise from the ice sheets	2013	NATURE CLIMATE CHANGE	PE	22.701	44	
48	S40RTS: a degree-40 shear-velocity model for the mantle from new Rayleigh wave dispersion, teleseismic traveltime and normal-mode splitting function measurements	2011	GEOPHYSICAL JOURNAL INTERNATIONAL	PE	15.169		80
49	Assessing confidence in Pliocene sea surface temperatures to evaluate predictive models	2012	NATURE CLIMATE CHANGE	PE	7.18	4	50
50	The origins and concentrations of water, carbon, nitrogen and noble gases on Earth	2012	EARTH AND PLANETARY SCIENCE LETTERS	PE	18.136	1	78

S.No.	Paper title	Publication year	Journal title	ERC domain			
51	Indication of Electron Neutrino Appearance from an Accelerator-Produced Off-Axis Muon Neutrino Beam	2011	PHYSICAL REVIEW LETTERS	PE	90.276	24	58
52	Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC	2012	PHYSICS LETTERS B	PE	200.35	221	1
53	First Evidence for the Decay B-s(0) -> mu(+) mu(-)	2013	PHYSICAL REVIEW LETTERS	PE	89.948	15	9
54	Bose-Einstein Condensation of Erbium	2012	PHYSICAL REVIEW LETTERS	PE	39.435	5	84
55	Quantum-coherent coupling of a mechanical oscillator to an optical cavity mode	2012	NATURE	PE	24.573	5	289
56	Creating, moving and merging Dirac points with a Fermi gas in a tunable honeycomb lattice	2012	NATURE	PE	22.753	6	226
57	Quantum repeaters based on atomic ensembles and linear optics	2011	REVIEWS OF MODERN PHYSICS	PE	30.16		208
58	Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC	2012	PHYSICS LETTERS B	PE	189.897	256	115
59	Control of Graphene's Properties by Reversible Hydrogenation: Evidence for Graphane	2009	SCIENCE	PE	43.778	0	574
60	Field-Effect Tunneling Transistor Based on Vertical Graphene Heterostructures	2012	SCIENCE	PE	46.644	33	484
61	Uniaxial strain in graphene by Raman spectroscopy: G peak splitting, Gruneisen parameters, and sample orientation	2009	PHYSICAL REVIEW B	PE	29.097		333
62	Production, properties and potential of graphene	2010	CARBON	PE	26.733		492
63	Low-temperature processed meso-superstructured to thin-film perovskite solar cells	2013	ENERGY AND ENVIRONMENTAL SCIENCE	PE	56.585	0	346
64	Single-layer MoS2 transistors	2011	NATURE NANOTECHNOLOGY	PE	92.927	1	807
65	Ultrasensitive photodetectors based on monolayer MoS2	2013	NATURE NANOTECHNOLOGY	PE	10.587	8	251
66	Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nanowire Devices	2012	SCIENCE	PE	69.17	52	461
67	Efficient Hybrid Solar Cells Based on Meso-Superstructured Organometal Halide Perovskites	2012	SCIENCE	PE	22.526	26	772
68	Efficient planar heterojunction perovskite solar cells by vapour deposition	2013	NATURE	PE	18.09	30	818
69	Zero-bias peaks and splitting in an Al-InAs nanowire topological superconductor as a signature of Majorana fermions	2012	NATURE PHYSICS	PE	53.572	1	124
70	3D Nitrogen-Doped Graphene Aerogel-Supported Fe3O4 Nanoparticles as Efficient Eletrocatalysts for the Oxygen Reduction Reaction	2012	JOURNAL OF THE AMERICAN CHEMICAL SOCIE	PE	18.355	1	93
71	Bandgap opening in graphene induced by patterned hydrogen adsorption	2010	NATURE MATERIALS	PE	34.72		412
72	Extracellular-matrix tethering regulates stem-cell fate	2012	NATURE MATERIALS	LS	35.267	4	18
73	Three-Dimensional Nitrogen and Boron Co-doped Graphene for High-Performance All-Solid-State Supercapacitors	2012	ADVANCED MATERIALS	PE	16.277	0	79
74	Van der Waals density functionals applied to solids	2011	PHYSICAL REVIEW B	PE	31.116		226
75	Porous metal-organic-framework nanoscale carriers as a potential platform for drug delivery and imaging	2010	NATURE MATERIALS	PE	42.37	0	210
76	GROMACS 4.5: a high-throughput and highly parallel open source molecular simulation toolkit	2013	BIOINFORMATICS	PE	58.033	4	260
77	Two-Dimensional Nanosheets Produced by Liquid Exfoliation of Layered Materials	2011	SCIENCE	PE	46.925	1	700
78	Porphyrin-Sensitized Solar Cells with Cobalt (II/III)-Based Redox Electrolyte Exceed 12 Percent Efficiency	2011	SCIENCE	PE	110.97	12	654
79	Single-nanowire solar cells beyond the Shockley-Queisser limit	2013	NATURE PHOTONICS	PE	83.182	18	192
80	Cp*Rh-Catalyzed C-H Activations: Versatile Dehydrogenative Cross-Couplings of C-sp2 C-H Positions with Olefins, Alkynes, and Arenes	2012	ALDRICHIMICA ACTA	PE	23.125		
81	C-H bond activation enables the rapid construction and late-stage diversification of functional molecules	2013	NATURE CHEMISTRY	PE	38.844	13	76
82	Hydrogen evolution catalyzed by MoS3 and MoS2 particles	2012	ENERGY AND ENVIRONMENTAL SCIENCE	PE	17.076		52
83	Task-Driven Dictionary Learning	2012	IEEE TRANSACTIONS ON PATTERN ANALYSIS A	PE	10.441		196
84	SLIC Superpixels Compared to State-of-the-Art Superpixel Methods	2012	IEEE TRANSACTIONS ON PATTERN ANALYSIS A	PE	22.781		306
85	Graphene Mode-Locked Ultrafast Laser	2010	ACS NANO	PE	29.031		181
86	Convex Optimization-Based Beamforming	2010	IEEE SIGNAL PROCESSING MAGAZINE	PE	8.631		52
87	Cooperative Multicell Precoding: Rate Region Characterization and Distributed Strategies With Instantaneous and Statistical CSI	2010	IEEE TRANSACTIONS ON SIGNAL PROCESSING	PE	9.767		59
88	VERY HIGH GAS FRACTIONS AND EXTENDED GAS RESERVOIRS IN z=1.5 DISK GALAXIES	2010	ASTROPHYSICAL JOURNAL	PE	15.159		13
89	KECK SPECTROSCOPY OF 3 < z < 7 FAINT LYMAN BREAK GALAXIES: THE IMPORTANCE OF NEBULAR EMISSION IN UNDERSTANDING THE SPECIFIC STAR FORMATION RATE AND STELLA	2013	ASTROPHYSICAL JOURNAL	PE	18.514		35
90	Baryon acoustic oscillations in the Sloan Digital Sky Survey Data Release 7 galaxy sample	2010	MONTHLY NOTICES OF THE ROYAL ASTRONOM	PE	44.907	0	41
91	Phanerozoic polar wander, palaeogeography and dynamics	2012	EARTH-SCIENCE REVIEWS	PE	8.435	0	
92	Laser cooling of a nanomechanical oscillator into its quantum ground state	2011	NATURE	PE	23.009	7	384
93	Updated global analysis of Higgs couplings	2013	JOURNAL OF HIGH ENERGY PHYSICS	PE	26.075		6
94	The missing link: Merging neutron stars naturally produce jet-like structures and can power short Gamma-Ray Bursts	2011	ASTROPHYSICAL JOURNAL LETTERS	PE	8.306		41
95	Intersection Bounds: Estimation and Inference	2013	ECONOMETRICA	SH	16.103		33
96	Dependency of global primary bioenergy crop potentials in 2050 on food systems, yields, biodiversity conservation and political stability	2012	ENERGY POLICY	SH	5.88	4	46
97	Role of physical activity in the relationship between urban green space and health	2013	PUBLIC HEALTH	SH	2.793	3	
98	Beyond single syllables: Large-scale modeling of reading aloud with the Connectionist Dual Process (CDP++) model	2010	COGNITIVE PSYCHOLOGY	SH	4.551		
99	Mechanisms of Intentional Binding and Sensory Attenuation: The Role of Temporal Prediction, Temporal Control, Identity Prediction, and Motor Prediction	2013	PSYCHOLOGICAL BULLETIN	SH	27.252	1	
100	Brain mechanisms for emotional influences on perception and attention: What is magic and what is not	2013	BIOLOGICAL PSYCHOLOGY	SH	14.058		

Appendix C: Respondents and response rate

Figure C-1. Response rates by research domain

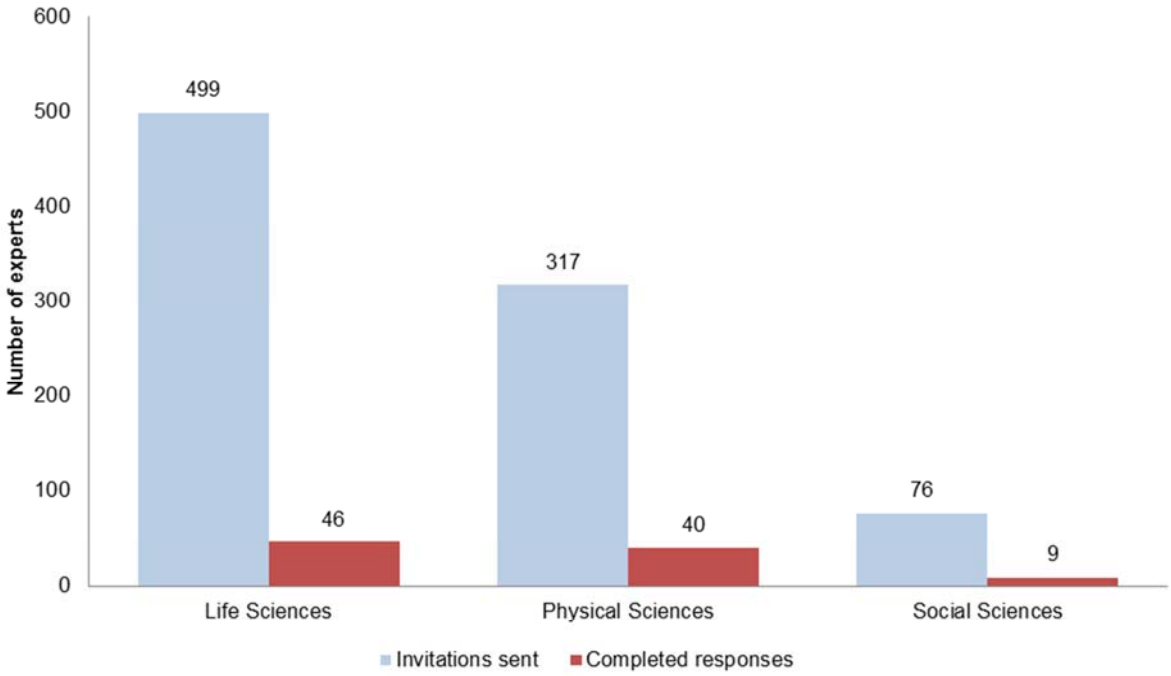


Table C-1. Breakdown of responses by research domain

Research category	Number of reviews	Total number of papers	Number of papers reviewed	% of papers reviewed	Number of papers with more than 1 review	% of papers with more than 1 review
Life Sciences	46	43	26	60%	14	33%
Physical Sciences and Engineering	40	51	26	51%	9	18%
Social Sciences and Humanities	9	6	4	67%	3	50%

Appendix D: Reviewer ratings for the article's overall contribution to the advancement of science / knowledge

Table D-1. List of reviewer ratings for the article's overall contribution to the advancement of science/knowledge (landmark contribution; significant contribution; incremental contribution / useful step forward; non-significant contribution / for-the-record)

Paper reviewed	How would you rate this article's overall contribution to the advancement of science/knowledge?
Nora-EP et al. (2012) Spatial partitioning of the regulatory landscape of the X-inactivation centre, NATU	Significant contribution to science or major addition to knowledge
Darriba-D et al. (2011) ProtTest 3: fast selection of best-fit models of protein evolution, BIOINFORMATI	Incremental contribution to science or knowledge / useful step forward
Hudiburg-TW et al. (2011) Regional carbon dioxide implications of forest bioenergy production, NAT CL	Incremental contribution to science or knowledge / useful step forward
Fichtlscherer-S et al. (2010) Circulating MicroRNAs in Patients With Coronary Artery Disease, CIRC R	Significant contribution to science or major addition to knowledge
Nora-EP et al. (2012) Spatial partitioning of the regulatory landscape of the X-inactivation centre, NATU	Significant contribution to science or major addition to knowledge
Gardner-A & West-S (2010) GREENBEARDS, EVOLUTION	Significant contribution to science or major addition to knowledge
Martin-DP et al. (2010) RDP3: a flexible and fast computer program for analyzing recombination, BIOIN	Incremental contribution to science or knowledge / useful step forward
Nora-EP et al. (2012) Spatial partitioning of the regulatory landscape of the X-inactivation centre, NATU	Significant contribution to science or major addition to knowledge
Gardner-A & West-S (2010) GREENBEARDS, EVOLUTION	Significant contribution to science or major addition to knowledge
Sexton-T et al. (2012) Three-Dimensional Folding and Functional Organization Principles of the Drosop	Significant contribution to science or major addition to knowledge
Roesti-M et al. (2012) Genome divergence during evolutionary diversification as revealed in replicate lal	Significant contribution to science or major addition to knowledge
Jolma-A et al. (2013) DNA-Binding Specificities of Human Transcription Factors, CELL	Incremental contribution to science or knowledge / useful step forward
Giraud-AL & Poeppel-D (2012) Cortical oscillations and speech processing: emerging computational p	Significant contribution to science or major addition to knowledge
Klengel-T et al. (2013) Allele-specific FKBP5 DNA demethylation mediates gene-childhood trauma inte	Non-significant contribution to science or knowledge / for-the-record
Nora-EP et al. (2012) Spatial partitioning of the regulatory landscape of the X-inactivation centre, NATU	Landmark contribution to science or knowledge
deLigt-J et al. (2012) Diagnostic Exome Sequencing in Persons with Severe Intellectual Disability, N EN	Significant contribution to science or major addition to knowledge
Darriba-D et al. (2011) ProtTest 3: fast selection of best-fit models of protein evolution, BIOINFORMATI	Incremental contribution to science or knowledge / useful step forward
deLigt-J et al. (2012) Diagnostic Exome Sequencing in Persons with Severe Intellectual Disability, N EN	Incremental contribution to science or knowledge / useful step forward
Aguzzi-A & Rajendran-L (2009) The Transcellular Spread of Cytosolic Amyloids, Prions, and Prionoids	Significant contribution to science or major addition to knowledge
Moretti-A et al. (2010) Patient-Specific Induced Pluripotent Stem-Cell Models for Long-QT Syndrome., N	Incremental contribution to science or knowledge / useful step forward
Aguzzi-A & Rajendran-L (2009) The Transcellular Spread of Cytosolic Amyloids, Prions, and Prionoids	Significant contribution to science or major addition to knowledge
Laguette-N et al. (2011) SAMHD1 is the dendritic- and myeloid-cell-specific HIV-1 restriction factor cou	Landmark contribution to science or knowledge
deLigt-J et al. (2012) Diagnostic Exome Sequencing in Persons with Severe Intellectual Disability, N EN	Incremental contribution to science or knowledge / useful step forward
Sexton-T et al. (2012) Three-Dimensional Folding and Functional Organization Principles of the Drosop	Significant contribution to science or major addition to knowledge
Schulz-C et al. (2012) A Lineage of Myeloid Cells Independent of Myb and Hematopoietic Stem Cells, S	Landmark contribution to science or knowledge
Tollervey-JR et al. (2011) Characterizing the RNA targets and position-dependent splicing regulation by	Significant contribution to science or major addition to knowledge
Schaum-E et al. (2013) Variation in plastic responses of a globally distributed picoplankton species to c	Significant contribution to science or major addition to knowledge
deLigt-J et al. (2012) Diagnostic Exome Sequencing in Persons with Severe Intellectual Disability, N EN	Significant contribution to science or major addition to knowledge
Gardner-A et al. (2011) The genetical theory of kin selection, J EVOLUTION BIOL	Significant contribution to science or major addition to knowledge
Chandarlapaty-S et al. (2011) AKT Inhibition Relieves Feedback Suppression of Receptor Tyrosine Kin	Significant contribution to science or major addition to knowledge
Prahallad-A et al. (2012) Unresponsiveness of colon cancer to BRAF(V600E) inhibition through feedbac	Incremental contribution to science or knowledge / useful step forward
Giraud-AL & Poeppel-D (2012) Cortical oscillations and speech processing: emerging computational p	Incremental contribution to science or knowledge / useful step forward
Prahallad-A et al. (2012) Unresponsiveness of colon cancer to BRAF(V600E) inhibition through feedbac	Landmark contribution to science or knowledge
Singer-T & Lamm-C (2009) The Social Neuroscience of Empathy, ANN N Y ACAD SCI	Significant contribution to science or major addition to knowledge
Singer-T & Lamm-C (2009) The Social Neuroscience of Empathy, ANN N Y ACAD SCI	Significant contribution to science or major addition to knowledge
Prahallad-A et al. (2012) Unresponsiveness of colon cancer to BRAF(V600E) inhibition through feedbac	Significant contribution to science or major addition to knowledge
Martin-DP et al. (2010) RDP3: a flexible and fast computer program for analyzing recombination, BIOIN	Incremental contribution to science or knowledge / useful step forward
Jolma-A et al. (2013) DNA-Binding Specificities of Human Transcription Factors, CELL	Landmark contribution to science or knowledge
Driessens-G et al. (2012) Defining the mode of tumour growth by clonal analysis, NATURE	Significant contribution to science or major addition to knowledge
Schaum-E et al. (2013) Variation in plastic responses of a globally distributed picoplankton species to c	Incremental contribution to science or knowledge / useful step forward
Lamm-C et al. (2011) Meta-analytic evidence for common and distinct neural networks associated with	Significant contribution to science or major addition to knowledge
deLigt-J et al. (2012) Diagnostic Exome Sequencing in Persons with Severe Intellectual Disability, N EN	Incremental contribution to science or knowledge / useful step forward
Poeck-H et al. (2010) Recognition of RNA virus by RIG-I results in activation of CARD9 and inflammasc	Significant contribution to science or major addition to knowledge
Tollervey-JR et al. (2011) Characterizing the RNA targets and position-dependent splicing regulation by	Significant contribution to science or major addition to knowledge
Shivaprasad-PV et al. (2012) A MicroRNA Superfamily Regulates Nucleotide Binding Site-Leucine-Rich	Significant contribution to science or major addition to knowledge
Roesti-M et al. (2012) Genome divergence during evolutionary diversification as revealed in replicate lal	Incremental contribution to science or knowledge / useful step forward
Mohiuddin-TMG et al. (2009) Uniaxial strain in graphene by Raman spectroscopy: G peak splitting, Grur	Incremental contribution to science or knowledge / useful step forward
Cohen-A et al. (2010) Convergence Rates of Best N-term Galerkin Approximations for a Class of Ellipti	Incremental contribution to science or knowledge / useful step forward
Radisavljevic-B et al. (2011) Single-layer MoS2 transistors, NATURE NANOTECHNOLOGY	Significant contribution to science or major addition to knowledge
Das-A et al. (2012) Zero-bias peaks and splitting in an Al-InAs nanowire topological superconductor as	Significant contribution to science or major addition to knowledge
Das-A et al. (2012) Zero-bias peaks and splitting in an Al-InAs nanowire topological superconductor as	Incremental contribution to science or knowledge / useful step forward
Rezzolla-L et al. (2011) The missing link: Merging neutron stars naturally produce jet-like structures an	Non-significant contribution to science or knowledge / for-the-record
Pronk-S et al. (2013) GROMACS 4.5: a high-throughput and highly parallel open source molecular simu	Significant contribution to science or major addition to knowledge
Bamber-JL & Aspinall-W (2013) An expert judgement assessment of future sea level rise from the ice s	Non-significant contribution to science or knowledge / for-the-record
Gershman-AB et al. (2010) Convex Optimization-Based Beamforming, IEEE SIGNAL PROCESSING M	Significant contribution to science or major addition to knowledge
Gershman-AB et al. (2010) Convex Optimization-Based Beamforming, IEEE SIGNAL PROCESSING M	Significant contribution to science or major addition to knowledge
Gershman-AB et al. (2010) Convex Optimization-Based Beamforming, IEEE SIGNAL PROCESSING M	Incremental contribution to science or knowledge / useful step forward

Paper reviewed	How would you rate this article's overall contribution to the advancement of science/knowledge?
Lee-MM et al. (2012) Efficient Hybrid Solar Cells Based on Meso-Superstructured Organometal Halide	Landmark contribution to science or knowledge
Verhagen-E et al. (2012) Quantum-coherent coupling of a mechanical oscillator to an optical cavity mo	Incremental contribution to science or knowledge / useful step forward
Dowsett-HJ et al. (2012) Assessing confidence in Pliocene sea surface temperatures to evaluate predi	Incremental contribution to science or knowledge / useful step forward
Sun-ZP et al. (2010) Graphene Mode-Locked Ultrafast Laser, ACS NANO	Significant contribution to science or major addition to knowledge
Aad-G et al. (2012) Observation of a new particle in the search for the Standard Model Higgs boson wit	Significant contribution to science or major addition to knowledge
Ellis-J & You-T (2013) Updated global analysis of Higgs couplings, JOURNAL OF HIGH ENERGY PHYS	Incremental contribution to science or knowledge / useful step forward
Krogstrup-P et al. (2013) Single-nanowire solar cells beyond the Shockley-Queisser limit, NATURE PH	Non-significant contribution to science or knowledge / for-the-record
Aad-G et al. (2012) Observation of a new particle in the search for the Standard Model Higgs boson wit	Landmark contribution to science or knowledge
Horcajada-P et al. (2010) Porous metal-organic-framework nanoscale carriers as a potential platform f	Incremental contribution to science or knowledge / useful step forward
Percival-WJ et al. (2010) Baryon acoustic oscillations in the Sloan Digital Sky Survey Data Release 7 g	Significant contribution to science or major addition to knowledge
Rezzolla-L et al. (2011) The missing link: Merging neutron stars naturally produce jet-like structures an	Significant contribution to science or major addition to knowledge
Yella-A et al. (2011) Porphyrin-Sensitized Solar Cells with Cobalt (II/III)-Based Redox Electrolyte Exceed	Significant contribution to science or major addition to knowledge
Britnell-L et al. (2012) Field-Effect Tunneling Transistor Based on Vertical Graphene Heterostructures,	Landmark contribution to science or knowledge
Bjornson-E et al. (2010) Cooperative Multicell Precoding: Rate Region Characterization and Distributed	Incremental contribution to science or knowledge / useful step forward
Mourik-V et al. (2012) Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nano	Landmark contribution to science or knowledge
Radisavljevic-B et al. (2011) Single-layer MoS2 transistors, NATURE NANOTECHNOLOGY	Landmark contribution to science or knowledge
Mourik-V et al. (2012) Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nano	Significant contribution to science or major addition to knowledge
Mourik-V et al. (2012) Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nano	Landmark contribution to science or knowledge
Balog-R et al. (2010) Bandgap opening in graphene induced by patterned hydrogen adsorption, NATUR	Significant contribution to science or major addition to knowledge
Duzaar-F & Mingione-G (2011) Gradient Estimates via Non-linear Potentials, AMERICAN JOURNAL OF	Significant contribution to science or major addition to knowledge
Ellis-J & You-T (2013) Updated global analysis of Higgs couplings, JOURNAL OF HIGH ENERGY PHYS	Incremental contribution to science or knowledge / useful step forward
Wu-ZS et al. (2012) 3D Nitrogen-Doped Graphene Aerogel-Supported Fe3O4 Nanoparticles as Efficien	Significant contribution to science or major addition to knowledge
Liu-MZ et al. (2013) Efficient planar heterojunction perovskite solar cells by vapour deposition, NATURE	Landmark contribution to science or knowledge
Balog-R et al. (2010) Bandgap opening in graphene induced by patterned hydrogen adsorption, NATUR	Significant contribution to science or major addition to knowledge
Rezzolla-L et al. (2011) The missing link: Merging neutron stars naturally produce jet-like structures an	Incremental contribution to science or knowledge / useful step forward
Wu-ZS et al. (2012) 3D Nitrogen-Doped Graphene Aerogel-Supported Fe3O4 Nanoparticles as Efficien	Significant contribution to science or major addition to knowledge
Vrubel-H et al. (2012) Hydrogen evolution catalyzed by MoS3 and MoS2 particles, ENERGY & ENVIRO	Incremental contribution to science or knowledge / useful step forward
Wu-ZS et al. (2012) 3D Nitrogen-Doped Graphene Aerogel-Supported Fe3O4 Nanoparticles as Efficien	Landmark contribution to science or knowledge
Chernozhukov-V et al. (2013) Intersection Bounds: Estimation and Inference, ECONOMETRICA	Significant contribution to science or major addition to knowledge
Chernozhukov-V et al. (2013) Intersection Bounds: Estimation and Inference, ECONOMETRICA	Incremental contribution to science or knowledge / useful step forward
Perry-C et al. (2010) Beyond single syllables: Large-scale modeling of reading aloud with the Connecti	Significant contribution to science or major addition to knowledge
Chernozhukov-V et al. (2013) Intersection Bounds: Estimation and Inference, ECONOMETRICA	Significant contribution to science or major addition to knowledge
Richardson-EA et al. (2013) Role of physical activity in the relationship between urban green space and	Incremental contribution to science or knowledge / useful step forward
Perry-C et al. (2010) Beyond single syllables: Large-scale modeling of reading aloud with the Connecti	Significant contribution to science or major addition to knowledge
Erb-KH et al. (2012) Dependency of global primary bioenergy crop potentials in 2050 on food systems,	Incremental contribution to science or knowledge / useful step forward
Richardson-EA et al. (2013) Role of physical activity in the relationship between urban green space and	Incremental contribution to science or knowledge / useful step forward
Richardson-EA et al. (2013) Role of physical activity in the relationship between urban green space and	Significant contribution to science or major addition to knowledge
Gershman-AB et al. (2010) Convex Optimization-Based Beamforming, IEEE SIGNAL PROCESSING M	Significant contribution to science or major addition to knowledge

Agreement between reviewers in the LS domain

Table D-2 highlights the degree of agreement between reviewers on the overall contribution of the paper. Responses where more than one reviewer agreed on the overall contribution are coloured green, whereas responses that differ are coloured in yellow. While there is disagreement on 5 of the 14 papers, the majority of reviewers appear to agree on the overall contribution of the paper.

Table D-2. Overall contribution of LS papers with more than one review to science/knowledge

	Landmark contribution to science or knowledge	Significant contribution to science or major addition to knowledge	Incremental contribution to science or knowledge / useful step forward	Non-significant contribution to science or knowledge / for-the-record
Aguzzi-A & Rajendran-L (2009) The Transcellular Spread of Cytosolic Amyloids, Prions, and Prionoids, NEURON		2		
Darriba-D et al. (2011) ProtTest 3: fast selection of best-fit models of protein evolution, BIOINFORMATICS			2	
deLigt-J et al. (2012) Diagnostic Exome Sequencing in Persons with Severe Intellectual Disability, N ENGL J MED		2	3	

Gardner-A & West-S (2010) GREENBEARDS, EVOLUTION		2		
Giraud-AL & Poeppel-D (2012) Cortical oscillations and speech processing: emerging computational principles and operations, NAT NEUROSCI		1	1	
Jolma-A et al. (2013) DNA-Binding Specificities of Human Transcription Factors, CELL	1		1	
Martin-DP et al. (2010) RDP3: a flexible and fast computer program for analyzing recombination, BIOINFORMATICS			2	
Nora-EP et al. (2012) Spatial partitioning of the regulatory landscape of the X-inactivation centre, NATURE	1	3		
Prahallad-A et al. (2012) Unresponsiveness of colon cancer to BRAF(V600E) inhibition through feedback activation of EGFR, NATURE	1	1	1	
Roesti-M et al. (2012) Genome divergence during evolutionary diversification as revealed in replicate lake-stream stickleback population pairs, MOL ECOL		1	1	
Schaum-E et al. (2013) Variation in plastic responses of a globally distributed picoplankton species to ocean acidification, NAT CLIM CHANGE		1	1	
Sexton-T et al. (2012) Three-Dimensional Folding and Functional Organization Principles of the Drosophila Genome, CELL		2		
Singer-T & Lamm-C (2009) The Social Neuroscience of Empathy, ANN N Y ACAD SCI		2		
Tollervey-JR et al. (2011) Characterizing the RNA targets and position-dependent splicing regulation by TDP-43, NAT NEUROSCI		2		

Agreement between reviewers in the PE domain

Table D-3 highlights the degree of agreement between reviewers on the overall contribution of the paper.

Table D-3. Overall contribution of PE papers with more than one review to science/knowledge

	Landmark contribution to science or knowledge	Significant contribution to science or major addition to knowledge	Incremental contribution to science or knowledge / useful step forward	Non-significant contribution to science or knowledge / for-the-record
Aad-G et al. (2012) Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, PHYSICS LETTERS B	1	1		
Balog-R et al. (2010) Bandgap opening in graphene induced by patterned hydrogen adsorption, NATURE MATERIALS		2		
Das-A et al. (2012) Zero-bias peaks and splitting in an Al-InAs nanowire topological superconductor as a signature of Majorana fermions, NATURE PHYSICS		1	1	
Ellis-J & You-T (2013) Updated global analysis of Higgs couplings, JOURNAL OF HIGH ENERGY PHYSICS			2	
Gershman-AB et al. (2010) Convex Optimization-Based Beamforming, IEEE SIGNAL PROCESSING MAGAZINE		2	1	

Mourik-V et al. (2012) Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nanowire Devices, SCIENCE	2	1		
Radisavljevic-B et al. (2011) Single-layer MoS2 transistors, NATURE NANOTECHNOLOGY	1	1		
Rezzolla-L et al. (2011) The missing link: Merging neutron stars naturally produce jet-like structures and can power short Gamma-Ray Bursts, ASTROPHYSICAL JOURNAL LETTERS		1	1	1
Wu-ZS et al. (2012) 3D Nitrogen-Doped Graphene Aerogel-Supported Fe3O4 Nanoparticles as Efficient Eletrocatalysts for the Oxygen Reduction Reaction, JOURNAL OF THE AMERICAN CHEMICAL SOCIETY	1	2		

Appendix E: Breakdown of papers' characteristics by overarching characteristic group and research domain

Figure E-1 below shows the number of papers displaying characteristics related to type of content, across each of the three research domains. While similar numbers of papers in both LS and PE were considered to synthesise existing knowledge and present new data, a larger number of LS papers were considered to address a gap in existing knowledge and advance new theories, while more PE papers were considered to involve methodological development.

Figure E-1. Number of characteristics by paper: The type of content is...

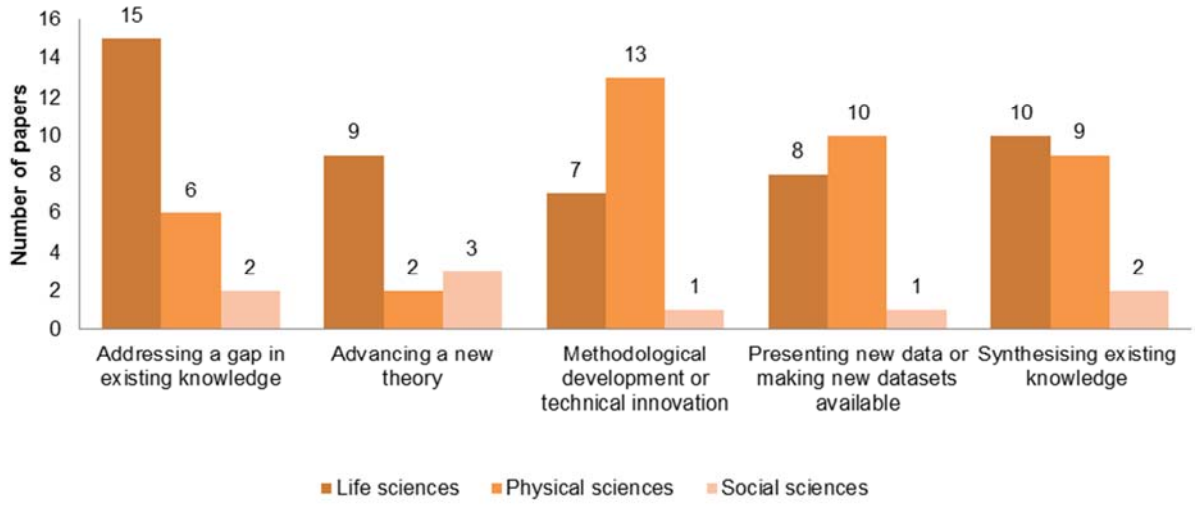


Figure E-2 below shows the number of papers displaying characteristics related to its main findings, across each of the three research domains. A similar numbers of papers in both LS and PE domains were considered to have main findings that are promising early stage ideas. Eleven of the LS papers presented findings that were considered as challenging existing understanding.

Figure E-2. Number of characteristics by paper: The main finding...

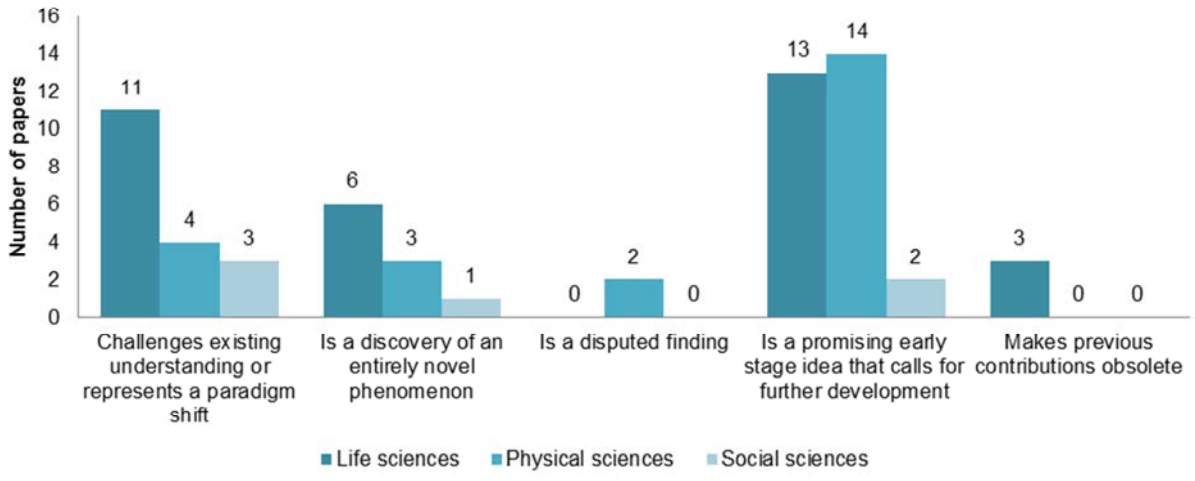


Figure E-3 below shows the number of papers displaying characteristics related to the research's novelty, across each of the three research domains. Here the pattern was similar across both LS and PE, with the majority of papers which demonstrated novelty being considered as applying new combinations of related scientific principles.

Figure E-3. Number of characteristics by paper: The research is novel/innovative in that it...

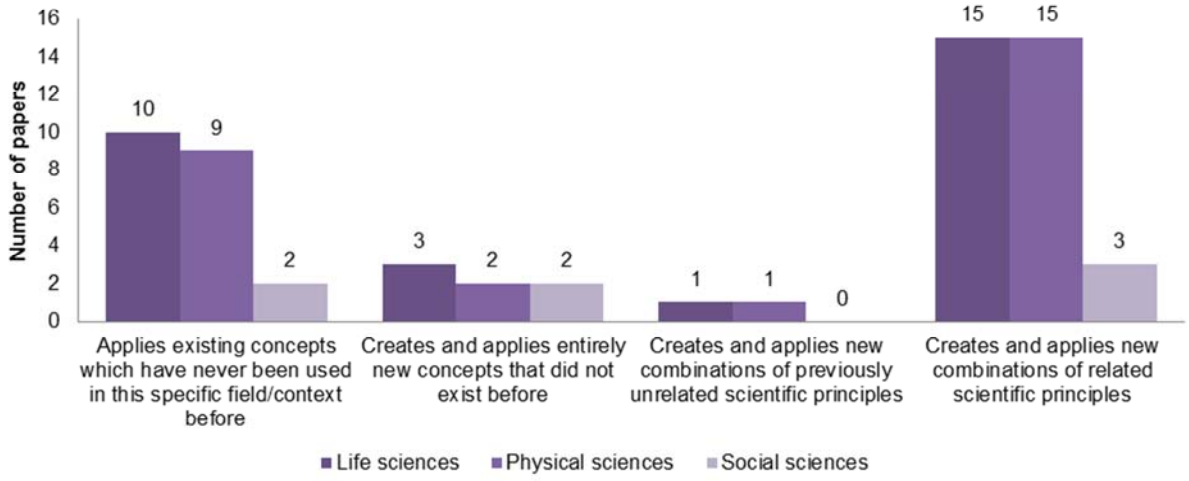


Figure E-4 below shows the number of papers displaying characteristics related to interdisciplinarity, across each of the three research domains. Again the pattern is similar across both LS and PE, with the majority of papers being considered as bringing together concepts from different but related fields and producing findings that could lead to progress in fields other than their own.

Figure E-4. Number of characteristics by paper: The research is inter-disciplinary in that it...

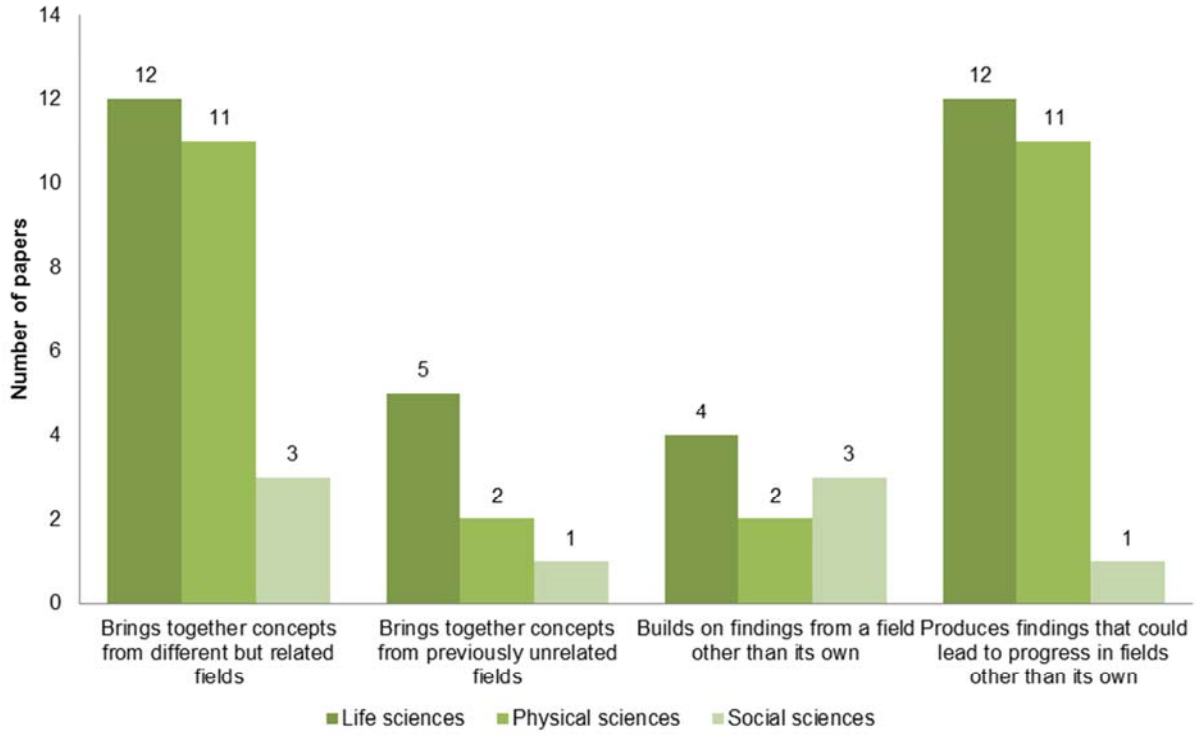
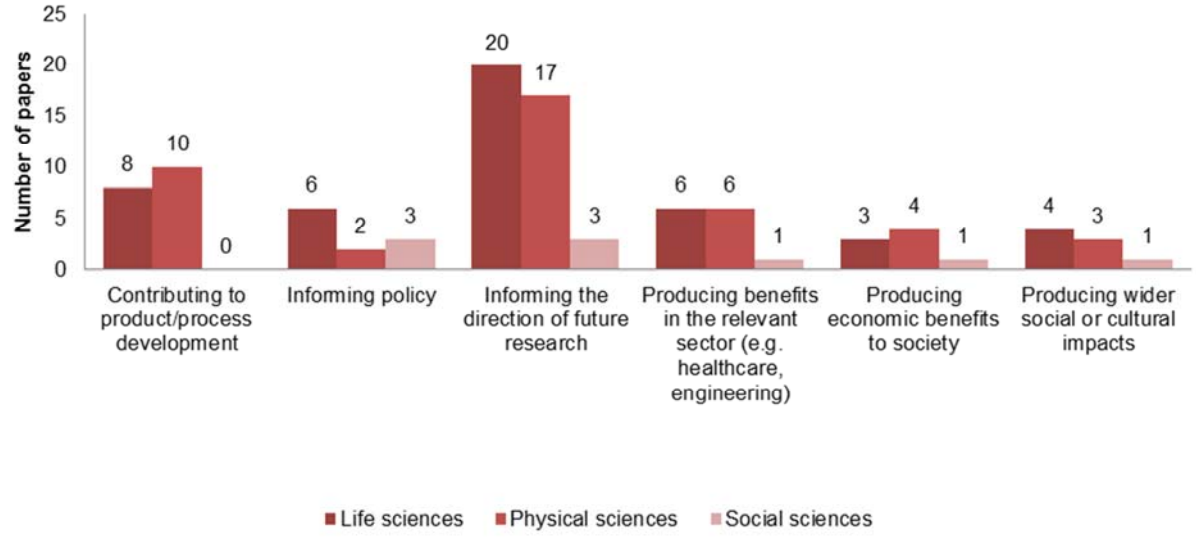


Figure E-5 below shows the number of papers displaying characteristics related to the potential impact of the research beyond generating knowledge. The majority of papers in both LS and PE were considered to have the potential to inform the direction of future research.

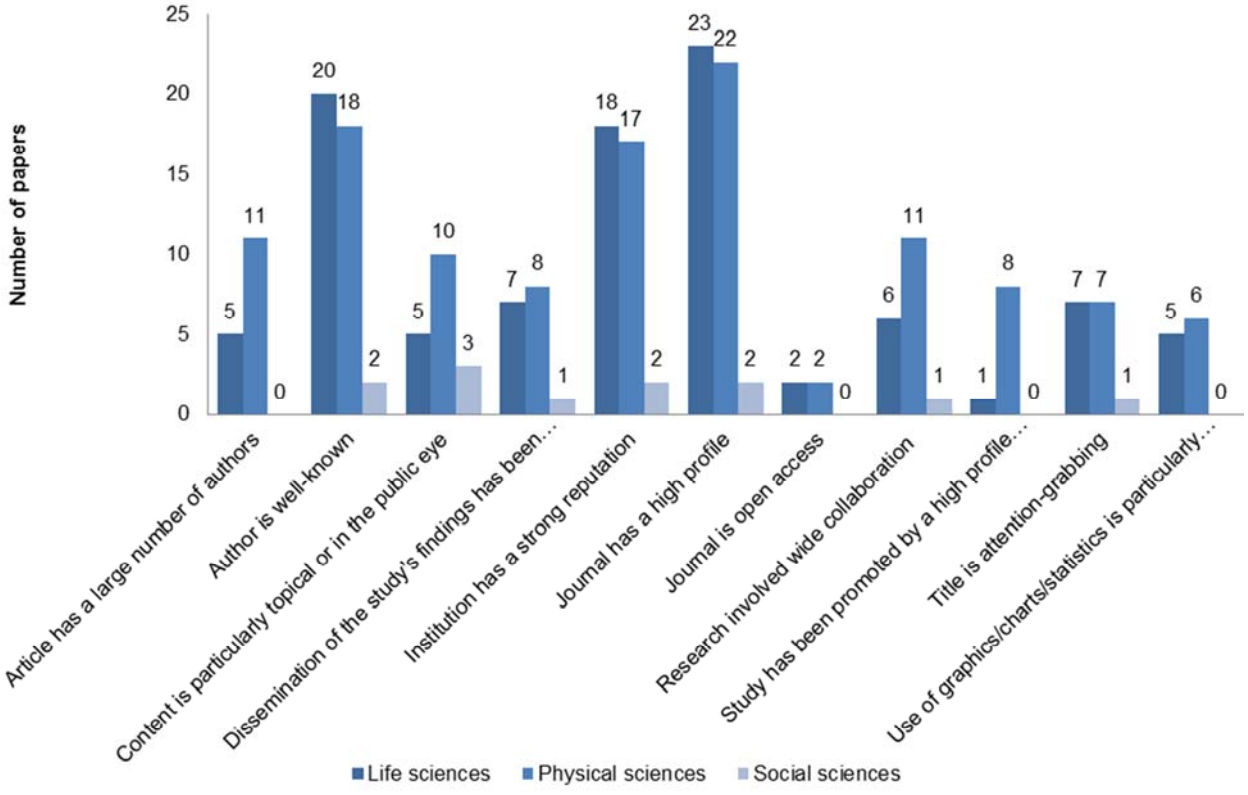
Figure E-5. Number of characteristics by paper: The research has a potential impact beyond generating knowledge, by...



Finally, Figure E-6 below shows the number of papers displaying other characteristics not related to the scientific content of the research. The majority of papers in both LS and PE were considered as being published in a high-profile journal, having a well-known author and being from an

institution with a strong reputation. In addition, a larger number of PE papers were considered to be particularly topical and had been promoted by a high-profile individual.

Figure E-6. Number of characteristics by paper: looking beyond the article's scientific content the…



Appendix F: 'Landmark' papers vs 'non-landmark' papers: comparing scientometric indicators

The following table compares papers considered by reviewers to have made a landmark contribution with the rest of the sample, in terms of citation and social media attention.

Table F-1. Comparison of 'landmark' papers with the rest of the sample for scientometric indicators

		Normalised citations	Twitter mentions	Mendeley readership
Landmark (n=12)	Mean	49.8	36.7	391.3
	Median	25.9	22.0	348.5
Non-landmark (n=44)	Mean	23.5	11.0	190.0
	Median	19.1	4.0	168.5

Appendix G: Breakdown of papers' characteristics by level of social media attention

Twitter

Table G-1. Characteristics of sampled papers (as indicated by reviewers) with (i) more than four Twitter mentions and (ii) four or fewer Twitter mentions. Green = more common in more tweeted papers; red = more common in less tweeted papers

Characteristic	Tweets > median		Tweets ≤ median		
	Papers	%	Papers	%	
Addressing a gap in existing knowledge	9	50%	8	40%	
Advancing a new theory	5	28%	3	15%	
Methodological development or technical innovation	8	44%	6	30%	
Presenting new data or making new datasets available	6	33%	10	50%	
Synthesising existing knowledge	5	28%	6	30%	
Challenges existing understanding or represents a paradigm shift	6	33%	8	40%	
Is a discovery of an entirely novel phenomenon	4	22%	5	25%	
Is a disputed finding	0	0%	0	0%	
Is a promising early stage idea that calls for further development	9	50%	9	45%	
Makes previous contributions obsolete	1	6%	2	10%	
Applies existing concepts which have never been used in this specific field/context before	9	50%	6	30%	
Creates and applies entirely new concepts that did not exist before	2	11%	3	15%	
Creates and applies new combinations of previously unrelated scientific principles	0	0%	0	0%	
Creates and applies new combinations of related scientific principles	8	44%	12	60%	
Brings together concepts from different but related fields	7	39%	9	45%	
Brings together concepts from previously unrelated fields	2	11%	3	15%	
Builds on findings from a field other than its own	2	11%	4	20%	
Produces findings that could lead to progress in fields other than its own	8	44%	8	40%	
Contributing to product/process development	9	50%	3	15%	
Informing policy	3	17%	5	25%	
Informing the direction of future research	11	61%	16	80%	
Producing benefits in the relevant sector (e.g. healthcare, engineering)	3	17%	5	25%	
Producing economic benefits to society	3	17%	2	10%	
Producing wider social or cultural impacts	4	22%	2	10%	
Article has a large number of authors	6	33%	7	35%	
Author is well-known	14	78%	13	65%	
Content is particularly topical or in the public eye	8	44%	6	30%	
Dissemination of the study's findings has been extensive	6	33%	5	25%	
Institution has a strong reputation	11	61%	16	80%	
Journal has a high profile	18	100%	15	75%	
Journal is open access	0	0%	3	15%	
Research involved wide collaboration	4	22%	8	40%	
Study has been promoted by a high profile individual or organisation	4	22%	2	10%	
Title is attention-grabbing	6	33%	4	20%	
Use of graphics/charts/statistics is particularly effective	6	33%	1	5%	

Mendeley

Table G-2. Characteristics of sampled papers (as indicated by reviewers) with (i) Mendeley readership higher than the median and (ii) Mendeley readership lower than the median. Green = more common in higher scoring papers; red = more common in lower scoring papers

Characteristic	Mendeley > median		Mendeley ≤ median		
	Papers	%	Papers	%	
Addressing a gap in existing knowledge	10	38%	12	46%	
Advancing a new theory	6	23%	6	23%	
Methodological development or technical innovation	13	50%	7	27%	
Presenting new data or making new datasets available	9	35%	9	35%	
Synthesising existing knowledge	10	38%	9	35%	
Challenges existing understanding or represents a paradigm shift	8	31%	9	35%	
Is a discovery of an entirely novel phenomenon	5	19%	5	19%	
Is a disputed finding	0	0%	2	8%	
Is a promising early stage idea that calls for further development	15	58%	12	46%	
Makes previous contributions obsolete	2	8%	1	4%	
Applies existing concepts which have never been used in this specific field/context before	9	35%	10	38%	
Creates and applies entirely new concepts that did not exist before	5	19%	1	4%	
Creates and applies new combinations of previously unrelated scientific principles	0	0%	2	8%	
Creates and applies new combinations of related scientific principles	16	62%	14	54%	
Brings together concepts from different but related fields	13	50%	11	42%	
Brings together concepts from previously unrelated fields	1	4%	6	23%	
Builds on findings from a field other than its own	3	12%	5	19%	
Produces findings that could lead to progress in fields other than its own	12	46%	12	46%	
Contributing to product/process development	12	46%	6	23%	
Informing policy	1	4%	8	31%	
Informing the direction of future research	17	65%	20	77%	
Producing benefits in the relevant sector (e.g. healthcare, engineering)	5	19%	7	27%	
Producing economic benefits to society	5	19%	3	12%	
Producing wider social or cultural impacts	3	12%	4	15%	
Article has a large number of authors	10	38%	6	23%	
Author is well-known	21	81%	18	69%	
Content is particularly topical or in the public eye	9	35%	8	31%	
Dissemination of the study's findings has been extensive	7	27%	8	31%	
Institution has a strong reputation	17	65%	19	73%	
Journal has a high profile	22	85%	22	85%	
Journal is open access	1	4%	3	12%	
Research involved wide collaboration	10	38%	7	27%	
Study has been promoted by a high profile individual or organisation	5	19%	4	15%	
Title is attention-grabbing	8	31%	5	19%	
Use of graphics/charts/statistics is particularly effective	5	19%	5	19%	

Appendix H: Reasons suggested by reviewers for citation and social media attention – life sciences

Figure H-1 presents the most frequently selected reasons for LS papers being highly cited.

Figure H-1. Top three reasons for LS papers being highly cited

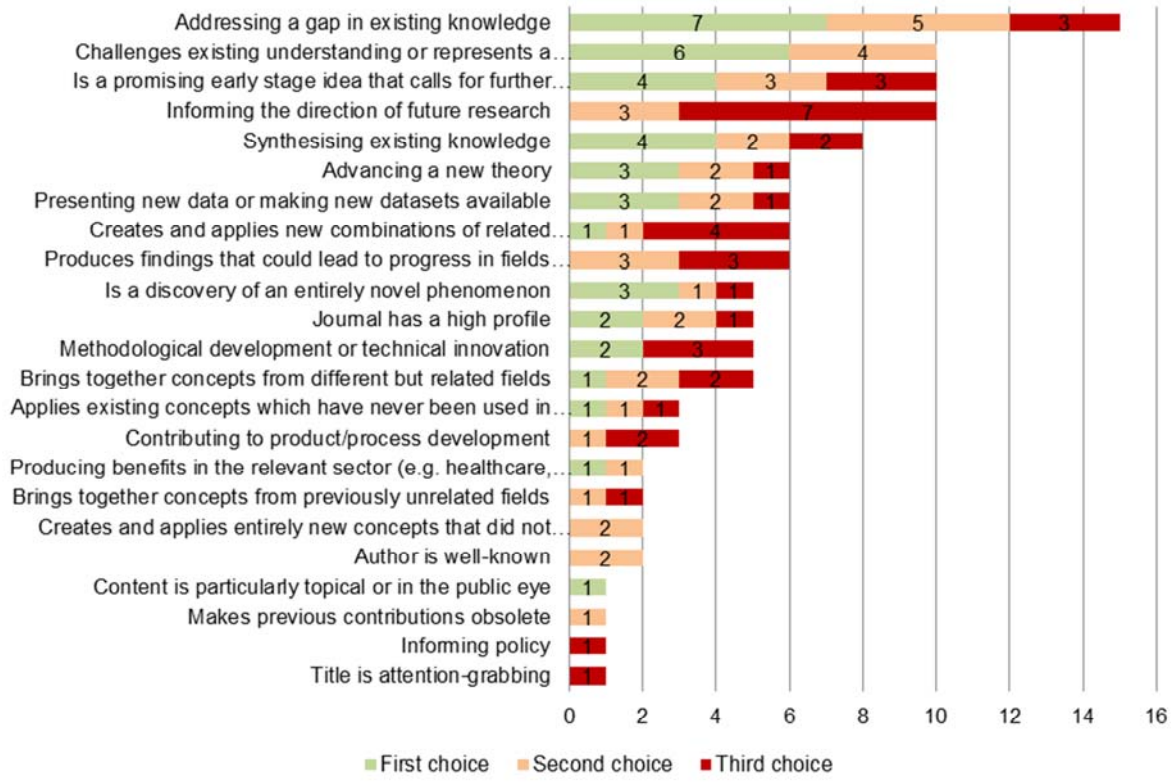
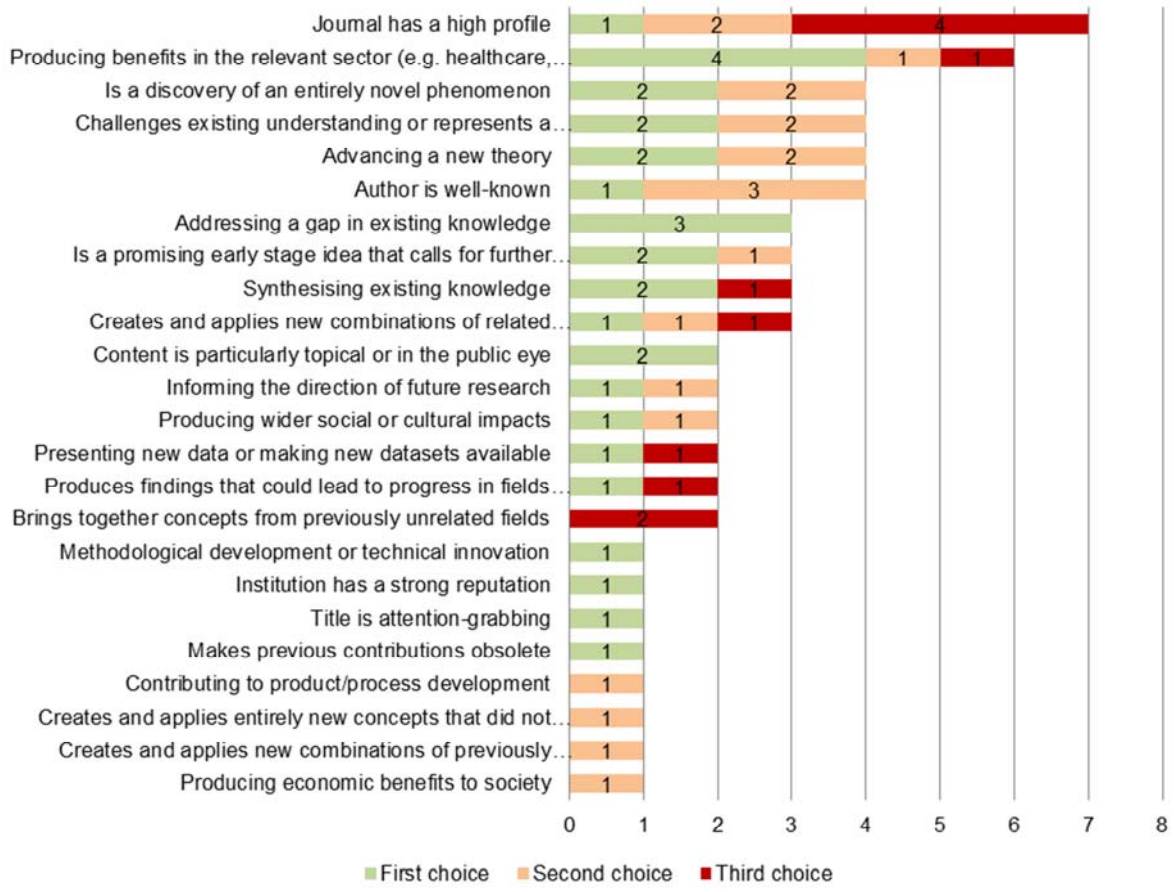


Figure H-2 presents the top three reasons suggested by reviewers for LS papers receiving social media attention.

Figure H-2. Top three reasons for LS papers receiving social media attention



Appendix I: Reasons suggested by reviewers for citation and social media attention – physical sciences and engineering

Figure I-1 presents the most frequently selected reasons suggested for PE papers being highly cited.

Figure I-1. Top three reasons for PE papers being highly cited

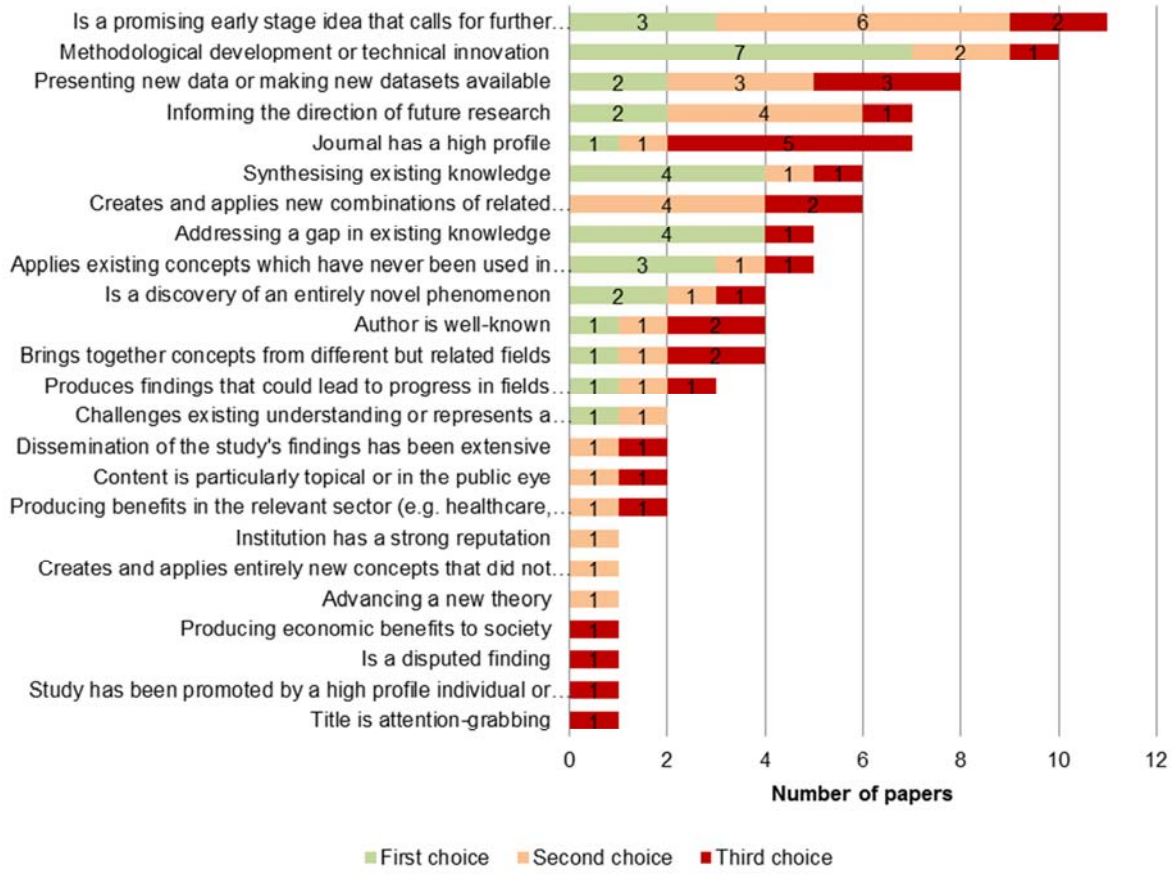
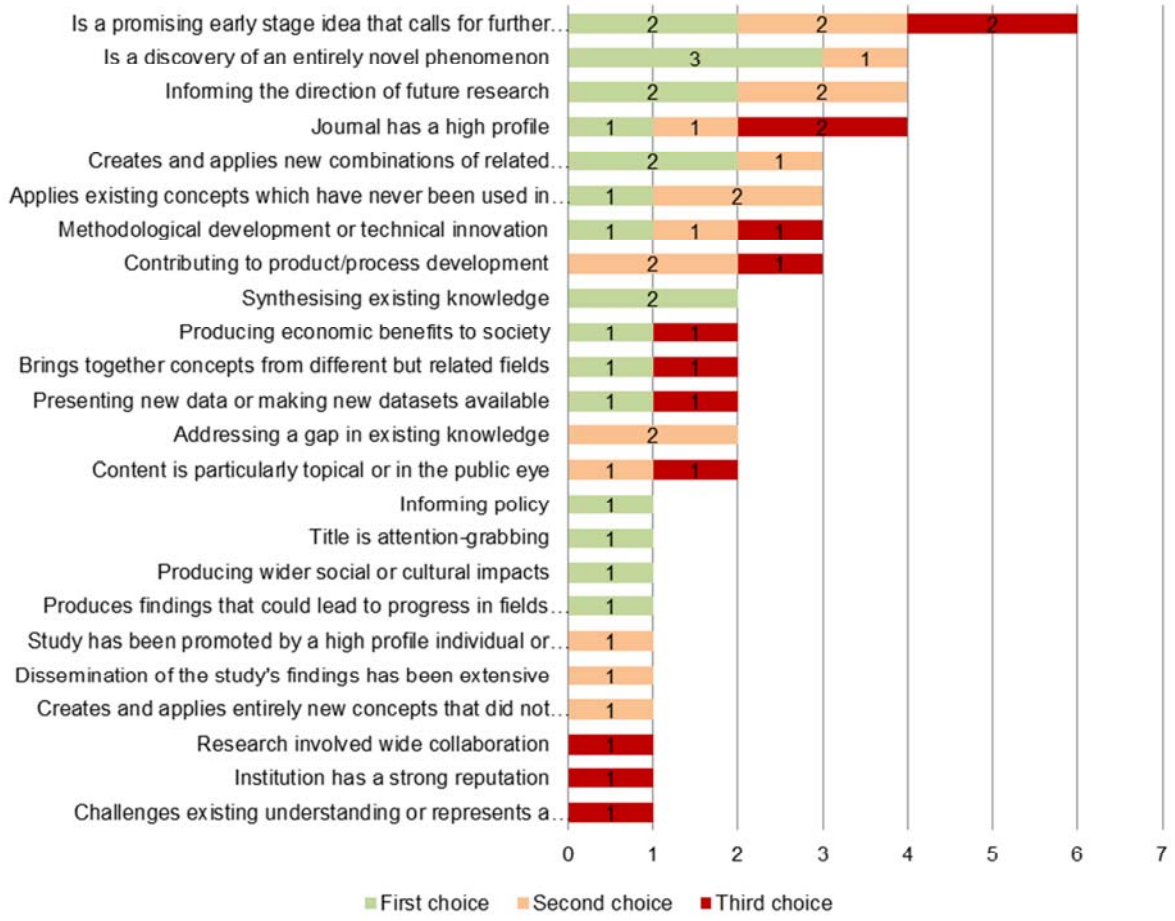


Figure I-2 presents the top three reasons suggested by reviewers for LS papers receiving social media attention.

Figure I-2. Top three reasons for PE papers receiving social media attention



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The European Research Council Executive Agency (ERCEA) asked RAND Europe and the Observatoire des sciences et des technologies (OST) to use innovative scientometric techniques, including bibliometrics, patent analysis and alternative metric analysis, in carrying out a comparative assessment of European Research Council funded projects. The four interrelated objectives of the study were: (i) to provide a systematic overview and assessment of results stemming from ERC-funded projects; (ii) benchmark results of ERC-funded research and researchers against European and US control groups; (iii) conduct a qualitative peer-review assessment to explore the kinds of contributions made by ERC-funded research; and (iv) provide a scientometric framework and consolidated database for future assessment of ERC funded research.

This document is the report on the peer-review evaluation of highly ranked publications from the study's scientometric assessment.

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