Researchers' perceptions of COVID-19 impact on Responsible Research and Innovation (RRI)-based practices and society's view of science in the first months of the pandemic

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Abstract: Over the last decade, national and international agencies have repeatedly called for research practices aligned with the Responsible Research and Innovation (RRI), with varied effects on different disciplines and countries. The COVID-19 pandemic made this need even more critical. This study aimed to explore whether and how, from researchers' point of view, the COVID-19 pandemic has led to changes in RRI-based research practices in the different disciplines and, more generally, society's perception of science. 1499 researchers in the three Catalan-speaking regions of Spain responded to an online questionnaire in the first months of the pandemic. Results showed that while only half perceived an impact on RRI-based practices, this proportion was higher for Health Sciences and Social Sciences researchers in all the dimensions. Most researchers perceived a positive impact on societal actors' views of science, although researchers in the Humanities were more sceptical than those in other disciplines. The analysis of open-ended questions revealed researchers from all disciplines were also concerned about fake news and claimed that researchers' working conditions and research funding across all

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disciplines needed to be improved for future research to be capable of coping with current and future challenges.

Keywords: responsible research; COVID-19; pandemic; researchers; disciplines; RRI principles.

I. Introduction

Over the last decade, the concept of Responsible Research and Innovation (RRI) has gained visibility and traction in Europe, specifically in the European Commission (EC) policy context. RRI is a key action of the European Union's Science with and for Society (SwafS). It asks for a shift in research practices towards a new interdisciplinary, sustainable, ethical, and society-oriented research approach. RRI claims that, for research and innovation processes and outcomes to be relevant, they must align with society's values, needs and expectations. To that end, not only researchers but all societal actors (e.g., citizens, policymakers, professionals, and civil organisations) must be involved in all the phases of the research process, which means that their views are taken into account when designing and conducting research and that they can easily access the results and outcomes of such research (European Commission, n.d.).

RRI advocates for the development of inter/transdisciplinary and intersectoral projects, knowledge transference and governance commitment to research to generate innovation and changes in and for society. However, the degree of implementation of these principles is very disparate within the European Arena. Differences among countries in their RRI implementation are in line with the financial investment of the countries in research and development (Mejlgaard et al. 2019; OECD 2021). Specifically, Spain, with a domestic public and private expenditure in Research & Development (R&D) below the OECD average (European Commission 2020), has deficits in some of the RRI principles, such as public engagement, the use of technologies, interdisciplinarity, and internationalisation of research, among others (European Commission 2021; Mejlgaard et al. 2019). These principles are especially relevant to facing the consequences posed by COVID-19 in a post-pandemic scenario.

The COVID-19 pandemic is one of the most unexpected and far-reaching challenges facing researchers worldwide, not only in terms of health but also of its psychological, social, and economic effects. Crucial and new ethical scientific challenges emerged due to the pandemic regarding research objectives, priorities, methodologies, resources, and processes (Kara and Khoo 2020). The R&D ecosystem was also under scrutiny during COVID-19, and several gaps emerged. Coordinated and sustained research funding, an

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efficient end-to-end R&D ecosystem, and efficient research structures and policies are some of the most critical gaps faced by the R&D ecosystem, along with the need to ensure global equitable access to research-related outcomes and products (Lurie et al. 2021).

In this sense, the difficulties of communication between science and society, that is, effective communication of research results and research-based recommendations, have also been palpable during the COVID-19 pandemic. The 'infodemic' and rise of fake news have made it even more difficult for citizens to access, understand and use trustworthy research-based information (Hartley and Vu 2020; Lu et al. 2021; van Der Linden et al. 2020). Some studies found that citizens' views about science and researchers are significant predictors of the extent to which they engage and use scientific information and disease-preventing behaviours (Chu et al. 2021; Lu et al. 2021). The study of Post et al. (2021) suggested that citizens have different informational needs, which are related to their views of science, policymaking, and media. Their results also highlighted the importance of enhancing citizens' understanding of scientific knowledge as refutable and temporary and clarifying the connection and boundaries between scientific results and policymaking to avoid dogmatic views of science and the alienation of people seeking to construct their own opinions (Post et al. 2021).

The RRI principles of co-creation and responsible research constitute a unique opportunity to cope with all the challenges mentioned above (Kara and Khoo 2020). However, aside from the developments of the knowledge, treatment and prevention of the virus itself, the extent to which the COVID-19 pandemic has impacted research and, more specifically, the RRI processes globally and locally is unclear.

Researchers' perceptions of these changes are especially relevant, as they are both key informants of such impact and central actors in implementing the RRI principles. Studies exploring researchers' voices regarding the impact of the COVID-19 pandemic on their work are scarce. A notable exception is a study conducted by Frontiers (Rijs and Fenter 2020). A survey distributed among Frontiers editors, reviewers and authors in May and June 2020 obtained more than 25.000 responses from Health and Science researchers worldwide. Besides offering evidence of COVID-19 impact on participants' personal and institutional work, results show researchers' worries about the long-lasting effects of the pandemic on funding, the fake news and the need to promote research-based policies (Rijs and Fenter 2020). In line with the RRI principles, the study claims the need to improve society's science education -including political leaders- and to promote interdisciplinary research to enable research-based responses to current and future threats. The

authors also found that the pandemic resulted in an increased willingness to publish open-access articles, share data, and use preprint servers. Although not further explored, significant disciplinary and geographical differences appeared in almost all the variables (Rijs and Fenter 2020). These findings call for in-depth exploration of the differential impact of the COVID-19 pandemic among researchers of different backgrounds.

The present study aims at exploring researchers' perceptions about the impact of the COVID-19 pandemic on their disciplines, with an emphasis on RRI-based practices (i.e., interdisciplinary collaborations, knowledge transfer and dissemination, and engagement of non-academic actors) and on the perceptions of the main societal actors at the beginning of the COVID-19 pandemic. These were the aims of this study, guided by the following questions:

1. What are researchers' perceptions about the impact of the COVID-19 pandemic on RRI-based practices in their discipline?
2. What are the differences among disciplines in researchers' perceptions of the impact of the COVID-19 pandemic?
3. What are researchers' perceptions about the impact of the COVID-19 pandemic on citizens', politicians', media's, and professionals' perception of science?
4. What are the differences among disciplines in researchers' perceptions of the impact of the COVID-19 pandemic on citizens', politicians', media's, and professionals' perception of science?
5. What are the lessons learnt and future opportunities emerging from the COVID-19 pandemic from researchers' perspectives?

II. Method

II.1. Participants

1499 researchers from the three Catalan-speaking regions of Spain (Catalunya 57.4%; Valencia 36%, and the Balearic Islands 6.6%) participated in the study, 52.9% of which were female, 45.8% were male, and 1.3% identified with non-binary categories. The mean age of participants was 44.29 years old (age range = 23-79). Participants were distributed among disciplines: Sciences (27.4%), Social Sciences (25.6%), Humanities (17.3%), Health Sciences (16.4%) and Engineering and Architecture (13.3%). Most respondents were PhD holders (64.2%), 27.2% were pre-doctoral researchers, and 8.7% were other research staff (e.g., lab and research assistants).

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II.2. Instrument

Data were collected through an online survey developed as part of a larger project on researcher development. This survey focused on the impact of the COVID-19 pandemic on different aspects of the lives and work of researchers. The survey was available in Spanish and Catalan[1] and took 10 to 15 min to complete. The present study focused on two scales of the survey, one related to the changes researchers perceived in their discipline due to the pandemic (5 items), and the other focused on the impact they thought the pandemic had had on the perceptions of science of different societal actors (4 items) (see Table 1 for more detail on the items of each scale). All items were Likert Scale questions with five answer options (1 -very negative impact- to 5 -very positive impact-). The survey also included one open-ended question where they could extend their responses and reflect on what changes they thought should be maintained and why.

Table 1

Survey Items

Dimension	Item		Answer options
Discipline	Do you think that the COVID-19 pandemic has had an impact on the research of your discipline in relation to the following aspects?	• The prioritisation of knowledge transfer and dissemination • Interdisciplinary collaborations • Collaborations outside the academic field • The emergence of new research topics • Funding opportunities	1 = Very negative impact 2 = Negative impact 3 = No impact 4 = Positive impact 5 = Very positive
Social Science perception	What impact do you think the COVID-19 pandemic has had on these groups' interest in science and research?	• Citizens • Politicians • Media • Professionals	1 = Very negative impact 2 = Negative impact 3 = No impact 4 = Positive impact 5 = Very positive

[1] The full survey, as well as details on the aims and procedures of the project, can be accessed here: https://www.researcher-identity.com/impactocovid19.

Dimension	Item		Answer options
Changes to maintain	Which of these changes do you think will be relevant to maintain? Why?		Open-ended

II.3. Procedure

Responses were collected in May and June 2020. Institutional e-mail addresses of researchers from all the universities in the three regions were collected from universities' public websites. Potential participants were sent an e-mail with basic information about the project and a link to the project's website, where they could get further information about the aims and objectives, funding, risks, and advantages of participating, and they could download the complete questionnaire. Participants accessed the survey through this website. The link to the questionnaire was not included in the e-mail to ensure participants had full information about the project before answering. At the beginning of the questionnaire, participants gave their consent to participate according to the ethics clearance procedures. The study aims and procedures were approved by the ethics committee and the data protection delegate of our institution.

II.4. Data analysis

Descriptive analysis was conducted for all items of the two scales: changes in the discipline and changes in societal actors' perception of science. Rather than being interested in assessing the intensity of perceived impacts, we aimed at knowing and comparing the direction (or type) of impact researchers perceived: positive, negative or no impact. Therefore, answers were classified into three categories (1-negative impact-; 2-no impact-; 3- positive impact) by collapsing the two ends of the 5-point responses of the Likert scales ("very negative impact" and "negative impact" were merged into "negative impact" and "very positive impact" and "positive impact" were integrated into "positive impact"). With these categories, descriptive analysis was conducted for the two scales. Pearson's Chi-square test was used to analyse differences between disciplines for the two scales' questions. Corrected standardised residuals were calculated for all the cases to assess the strength and location of the association. Overall, this analysis allowed us to assess the frequency and distribution of the three types of

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impact (negative, positive and no impact) and compare disciplines regarding each type instead of comparing the intensity of the impact (e.g., mean scores) perceived by each discipline.

Responses to the open-ended question (n = 494) were analysed using a consensual qualitative research approach (Hill 2012) by four researchers to ensure consistency around the overall themes. The aim was not to quantify participants' qualitative responses but to organise data to illustrate regularities in researchers' views. Thus, emerging themes were organised and grouped into categories related to the different dimensions of RRI, and representative examples of each category were selected to illustrate these categories.

III. Results and discussion

III.1. What are researchers' perceptions about the impact of the COVID-19 pandemic on the RRI- based practices of their discipline?

Regarding the first aim of the study, results across disciplines showed that, at the beginning of the pandemic, approximately half of the respondents perceived no impact of the COVID-19 pandemic on the RRI-based practices of their disciplines (see Figure 1), namely knowledge transfer and dissemination, interdisciplinary collaboration, and collaborations with non-

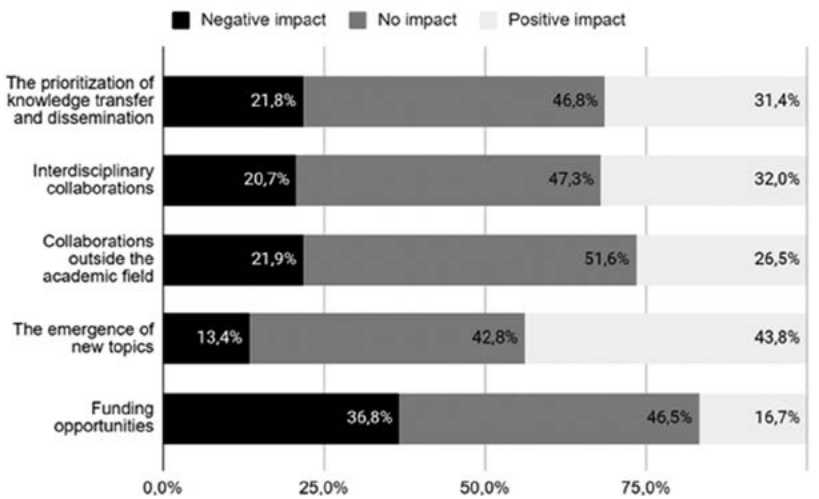

Figure 1

Impact of the COVID-19 pandemic on RRI-based practices

academic sectors. Researchers were slightly more positive about the impact of the pandemic on the emergence of new topics and more negative regarding the impact on funding, with more than one-third reporting negative effects. Given that the study was conducted during the first months of the COVID-19 pandemic, it is possible that non-traditional research collaborations were not yet put into place, although this aspect seems the best tool for fighting against COVID-19 (Lee and Haupt 2021). Future studies can analyse if this perception changed in the later stages of the pandemic, and researchers now perceive a higher impact of the RRI principles in their disciplines.

III.2. What are the differences among disciplines in researchers' perceptions of the impact of the COVID-19 pandemic on RRI-based practices?

Despite many researchers did not perceive any impact of the COVID-19 pandemic on the practices of their discipline, further results showed statistically significant differences among disciplines in all the items analysed (see Table 2): prioritization of knowledge transfer and dissemination (X^2 (8) = 35.910, $p < 0.001$); interdisciplinary collaborations (X^2 (8) = 38.807, $p < 0.001$); collaborations outside academia (X^2 (8) = 39.770 $p < 0.001$); emergence of new topics (X^2 (8) = 164.885, $p < 0.00$); and funding opportunities (X^2 (8) = 57.275, $p < 0.001$).

Table 2

Impact of the COVID-19 pandemic on the RRI-based practices of each discipline

	Science	Social Sciences	Humanities	Health Sciences	Engineering and Architecture
Knowledge transfer and dissemination					
Negative impact	89 (21.7%)	65 (16.9%) z = -2.7	63 (24.3%)	66 (26.8%) z = 2.1	44 (22.1%)
No impact	197 (47.9%)	165 (43%)	137 (52.9%) z = 2.2	96 (39%) z = -2.7	107 (53.8%) z = 2.1
Positive impact	125 (30.4%)	154 (40.1%) z = 4.3	59 (22.8%) z = -3.3	84 (34.1%)	48 (24.1%) z = -2.4
Interdisciplinary collaborations					
Negative impact	88 (21.4%)	61 (15.9%) z = -2.7	65 (25.1%)	54 (22%)	43 (21.6%)

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	Science	Social Sciences	Humanities	Health Sciences	Engineering and Architecture
No impact	204 (49.6%)	163 (42.4%) z = -2.2	137 (52.9%) z = 2	101 (41.1%) z = -2.1	104 (52.3%)
Positive impact	119 (29%)	160 (41.7%) z = 4.7	57 (22%) z = -3.8	91 (37%)	52 (26.1%)
Collaborations outside academia					
Negative impact	84 (20.4%)	71 (18.5%)	73 (28.2%) z = 2.7	55 (22.4%)	45 (22.6%)
No impact	242 (58.9%) z = 3.5	180 (46.9%) z = -2.2	118 (45.6%) z = -2.2	116 (47.2%)	118 (59.3%) z = 2.3
Positive impact	85 (20.7%) z = -3.1	133 (34.6%) z = 4.2	68 (26.3%)	75 (30.5%)	36 (18.1%) z = -2.9
The emergence of new topics					
Negative impact	66 (16.1%)	32 (8.3%) z = -3.4	35 (13.5%)	40 (16.3%)	28 (14.1%)
No impact	221 (53.8%) z = 5.3	89 (23.2%) z = -9.0	142 (54.8%) z = 4.3	82 (33.3%) z = -3.3	107 (53.8%) z = 3.4
Positive impact	124 (30.2%) z = -6.6	263 (68.5%) z = 11.3	82 (31.7%) z = -4.3	124 (50.4%) z = 2.3	64 (32.2%) z = -3.6
Funding opportunities					
Negative impact	161 (39.2%)	116 (30.2%) z = -3.1	120 (46.3%) z = 3.5	79 (32.1%)	75 (37.7%)
No impact	172 (41.8%) z = -2.2	190 (49.5%)	126 (48.6%)	106 (43.1%)	103 (51.8%)
Positive impact	78 (19%)	78 (20.3%) z = 2.2	13 (5%) z = -5.6	61 (24.8%) z = 3.7	21 (10.6%) z = -2.5

z = Corrected adjusted residuals.

Results show that *Social Sciences researchers* were more likely to perceive a positive impact of the COVID-19 pandemic on the RRI-based practices of their discipline. Specifically, they were more likely to perceive a positive impact on the prioritisation of knowledge transfer and dissemination (40.1%) than their counterparts were in the Humanities (22.8%) and Engineering and Architecture (24.1%). Interestingly, Health Sciences

researchers were more likely to perceive a negative impact on this RRI-based practice than their counterparts were (26.8%). Differences between Social Scientists and Humanities researchers were also evident in regards to interdisciplinary collaborations (41.7% and 22%, respectively, perceived a positive impact) and in the collaborations outside academia, where social scientists tended to perceive a more positive impact (34.6%) and Humanities researchers were more likely to perceive a negative impact (28.2%). In this regard, Sciences and Engineering and Architecture researchers were more likely to perceive no impact than the other disciplines (58.9% and 59.3%, respectively).

The most significant differences among disciplines are observed in the emergence of new topics. Again, Social Scientists (68.5%), along with Health Scientists to a lesser extent (50.4%), were much more likely to report a positive impact on the emergence of new topics than their counterparts were (Science: 30.2%, Humanities: 31.7%, Engineering and Architecture: 32.2%). Finally, concerning funding opportunities, although, as explained above, most of the researchers perceived negative or no impact on their discipline, differences among disciplines follow a similar trend: researchers in Health (24.8%) and Social Sciences (20.3%) were more likely to report a positive impact than researchers in the Humanities (5%) and Engineering and Architecture (10.6%) were.

At the beginning of the COVID-19 outbreak, Health Sciences researchers, especially those in medical disciplines, were the first to be called upon to respond to the crisis, focusing on the study of the COVID-19 virus and, consequently, as expected, new topics and many new opportunities for funding emerged. However, at the early stage of the pandemic, they perceived a more significant negative impact on knowledge transfer and dissemination than researchers in the other disciplines.

In contrast, Social Sciences researchers were the ones that perceived a more positive impact of the COVID-19 pandemic in all the assessed areas, including knowledge transfer and interdisciplinary collaborations, showing that the COVID-19 pandemic has had a positive impact on promoting change toward the RRI principles in these disciplines. Interestingly, the immediate social consequences (e.g., economic, psychological, and educational effects) in the early stage of the pandemic and the lockdowns seem to have promoted interdisciplinary collaborations, collaborations with non-academic sectors and knowledge transfer to respond to the current social demands to a greater extent in the Social Sciences than in the other disciplines. In addition, Social Science researchers perceived that the COVID-19 pandemic provoked the emergence of new research topics and more funding opportunities. Thus, it

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seems the COVID-19 pandemic stimulated beyond Health Sciences. Social Scientists perceived more benefits for their discipline than researchers in the other disciplines. This is a surprising result, as the Health Sciences, especially medicine, seemed to dominate the interest and focus of the first strategies to deal with the crisis. However, these disciplines were already much better funded and publicly valued than others before the pandemic (European Commission 2020). In contrast, while still in the background of crisis management, Social Sciences researchers perceived a significant increase in funding, new research topics, and the public's interest and recognition of their disciplines.

On the other hand, Science, and Architecture and Engineering researchers were more likely to perceive no impact on the RRI-based practices and opportunities in their disciplines. It seems that, at the beginning of the pandemic, when this study took place, these disciplines were not summoned to face the pandemic and its consequences, despite calls for interdisciplinary collaborations and the omnipresence of technology in the way people coped with the situation (Kara and Khoo 2020; Vargo et al. 2021). It is unknown whether the role of these disciplines changed in later phases of the pandemic.

Finally, Humanities researchers were the least positive in their perception of the impact of the pandemic on their discipline. They were more likely to report a negative impact on the RRI-based practices (interdisciplinary collaborations, collaborations outside academia and knowledge transfer), the emergence of new topics, and funding opportunities. They also perceived a decrease in resources for research in the Humanities during the COVID-19 pandemic.

III.3. What are the researchers' perceptions about the impact of the COVID-19 pandemic on citizens', politicians', media's, and professionals' perception of science?

Regarding the third objective, analysing researchers' views about the impact on the perceptions that citizens, politicians, media, and professionals had about science (see Figure 2), overall, researchers reported a positive impact of the COVID-19 pandemic, especially on citizens' (78.3%) and media (70.9%) perceptions. They were less positive about the impact on the views of politicians (47.6%).

Although results show an overall positive impact of the COVID-19 pandemic on the perception of science in all societal sectors, according to researchers, they were more sceptical about the impact on politicians.

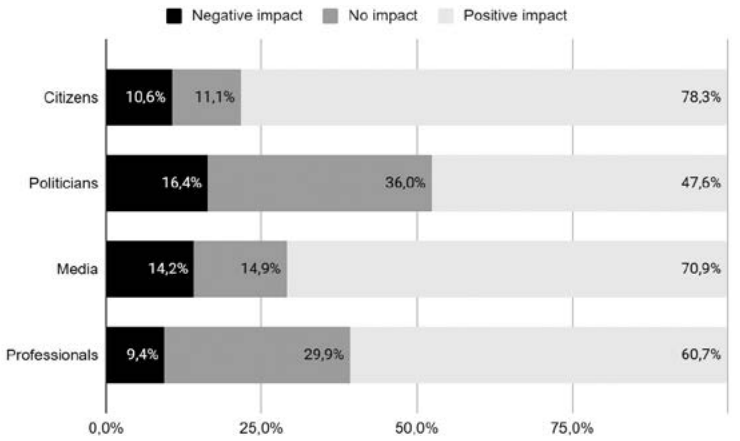

Figure 2

Impact of the COVID-19 pandemic on citizens, politicians, media, and professionals' perception of science

III.4. What are the differences among disciplines in researchers' perceptions of the impact of the COVID-19 pandemic on citizens', politicians', media, and professionals' perception of science?

Further analysis into researchers' perceptions of the impact on societal actors showed statistically significant differences among disciplines regarding changes in science perceptions of the four different agents: citizens (X^2 (8) = 30.373, $p < 0.001$), media (X^2 (8) = 29.126, $p < 0.001$), professionals (X^2 (8) = 33.990, $p < 0.001$), and politicians (X^2 (8) = 28.339, $p < 0.001$) (see Table 3).

Table 3

Impact of the COVID-19 pandemic on citizens, politicians, media, and professionals' perception of science according to researchers in each discipline

	Science	Social Sciences	Humanities	Health	Engineering and Architecture
Citizens					
Negative impact	40 (9.7%)	40 (10.4%)	47 (18.1%) z = 4.3	15 (6.1%) z = -2.5	17 (8.5%)

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	Science	Social Sciences	Humanities	Health	Engineering and Architecture
No impact	40 (9.7%)	37 (9.6%)	34 (13.1%)	25 (10.2%)	31 (15.6%) z = 2.1
Positive impact	331 (80.5%)	307 (79.9%)	178 (68.7%) z = -4.1	206 (83.7%) z = 2.3	151 (75.9%)
Media					
Negative impact	58 (14.1%)	43 (11.2%) z = -2.0	62 (23.9%) z = 4.9	27 (11%)	23 (11.6%)
No impact	65 (15.8%)	60 (15.6%)	34 (13.1%)	30 (12.2%)	34 (17.1%)
Positive impact	288 (70.1%)	281 (73.2%)	163 (62.9%) z = -3.1	189 (76.8%) z = 2.2	142 (71.4%)
Professionals					
Negative impact	37 (9%)	32 (8.3%)	41 (15.8%) z = 3.9	17 (6.9%)	14 (7%)
No impact	131 (31.9%)	105 (27.3%)	821 (31.7%)	55 (22.4%) z = -2.8	75 (37.7%) z = 2.6
Positive impact	243 (59.1%)	247 (64.3%)	136 (52.5%) z = -3.0	174 (70.7%) z = 3.5	110 (55.3%)
Politicians					
Negative impact	61 (14.8%)	54 (14.1%)	69 (26.6%) z = 4.9	28 (11.4%) z = -2.3	34 (17.1%)
No impact	151 (36.7%)	136 (35.4%)	85 (32.8%)	91 (37.0%)	77 (44.2%)
Positive impact	199 (48.4%)	194 (50.5%)	105 (40.5%) z = -2.5	127 (51.6%)	88 (44.2%)

These most significant differences were between Health and Humanities researchers. Despite generally having positive views of the impact of the COVID-19 pandemic on societal actors' perception of science, researchers from *Health Sciences* were more likely to perceive a positive impact on citizens (83.7%), media (76.8%), and professionals (70.7%) and less likely to perceive a negative impact on politicians (11.4%). In contrast, researchers from the *Humanities* were less likely to perceive a positive impact on the four groups of societal actors: citizens (68.7%), media (62.9%), professionals

(52.5%) and politicians (40.5%) and were also more likely to report a negative impact on the views of these groups (18.1%, 23.9%, 15.8% and 26.6%, respectively) than researchers in the other disciplines.

Similar to the impact perceived on their disciplines, Humanities researchers were the most critical regarding the impact of the COVID-19 pandemic on societal actors' views of science, and, as expected, Health Sciences researchers perceived a more positive impact on the four social agents. This is not surprising as their disciplines were central in the COVID-19 pandemic and took the spotlight in debates everywhere.

III.5. What are the lessons learnt and future opportunities emerging from the COVID-19 pandemic from researchers' perspective?

Finally, regarding the fifth objective, we identified four topics regarding the lessons learnt and future opportunities emerging from the COVID-19 pandemic among researchers' responses to the open-ended question (n = 494). These topics were the following: the relevance of science for citizens and society, *fake news* and the role of media, the importance of improving the relationship between science and politics, and the need to improve research investment.

III.5.1. Relevance of science to citizens and society

In line with the main aim of the RRI principles, promoting societal actors' engagement with science, researchers highlighted the importance of the connection between science and citizens and society by making science more accessible to citizens. Comments included the need to promote citizens' interest and appreciation of the value of science and to open science to society.

III.5.1.1. Maintaining citizens' interest and appreciation of the value of science in improving society

Some respondents acknowledged an improvement in the awareness of the value of science due to the COVID-19 pandemic and highlighted the need to maintain and increase citizens' interest in science and their perception of science as a useful and necessary way to improve society ("Citizens' awareness of the need for science and research should be maintained", SS3846). In addition, many researchers also mentioned the need to recognise researchers' role in society ("Social recognition of science and scientists for their contribution to progress and improvement of social conditions", EA3749).

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III.5.1.2. Opening science to society

Secondly, researchers in our study perceived the COVID-19 pandemic as an opportunity to open science to society. Participants highlighted the need for science to be available and easily accessible for everyone to promote a better and more rigorous understanding of the world. The following two excerpts are illustrative examples of this theme: "All research should be interesting for the non-specialised public and should be available to everybody" (S905), and "I think it has been an opportunity for citizens to get closer to science and research than ever, but we need to keep working and making science accessible to everybody" (SS1374).

III.5.2. Fake news and the role of media

The second category was related to the media's mediation in the relationship between science and citizens during the pandemic. Despite researchers clearly valuing the role of media in disseminating scientific advancements during the COVID-19 pandemic, they were worried about the increase of *fake news*, a phenomenon that has been one of the most critical challenges during the crisis (Van Der Linden 2020). Many participants mentioned the importance of fake news in disseminating research during the COVID-19 pandemic and how this influenced citizens' trust in science. They also suggested ways to fight them back, mainly through scientific education and rigorous dissemination. Some respondents claimed for more rigorous dissemination of science, while others stressed the danger of fake news and how science education would help fight them back. Researchers in our study joined the claims of others (Lu et al. 2021; Post et al. 2021) in advocating for better science education to be able to understand and use science and rigorous dissemination of science in the media as the most effective means to fight *fake news*.

III.5.2.1. Rigorous media dissemination of scientific advancement

Researchers stressed the need to maintain and increase the presence and interest of rigorous science and scientists in media, not only during the pandemic, to disseminate scientific advancements adequately and thus, again, to fight misinformation ("[what should be maintained is] the presence of rigorous scientific content in media", SS1168).

Moreover, researchers claimed that media should not only disseminate research knowledge directly connected to the COVID-19 pandemic but also those advances related to the other social, environmental, and economic

challenges that affect our society. The following is an illustrative example of these claims: "Evidently, I'd like scientists to replace talk show guests who want to talk about everything; this would improve the information citizens receive. However, the debate should not only focus on the pandemic but also on other social and economic issues that need to be treated by experts" (SS3996).

III.5.2.2. Fighting fake news through the improvement of scientific education

Researchers acknowledged the harm of these phenomena and stressed the need to fight against them to ensure rigorous scientific knowledge reaches society: "There is a general lack not only of interest but also of basic scientific knowledge. We have seen the worst misinformation situations. There is a terrifying amount of *fake news* that only increases mistrust of research" (S3359).

Better scientific education was considered a crucial element to fighting fake news and citizens' misinformation; for example: "Regarding citizens, a basic scientific education is crucial in moments like the one we are living now, and in our country, it doesn't exist" (SS912).

III.5.3. Importance of improving the relationship between science and politics

Another group of answers mentioned that one of the most important lessons learnt from the COVID-19 pandemic was the need to improve the relationship between science and politics by developing research-based policies and incorporating scientists into political bodies. They stress the importance of strengthening citizens' appreciation of science to promote the development of research-based policies and increase research funding (Rijs and Fenter 2020).

III.5.3.1. Developing policies based on scientific evidence

Some researchers claimed that politicians need to trust and collaborate with researchers to develop policies based on scientific evidence: *"Scientific evidence has to be the basis of the development of policies and media discourses"* (SS1278). The following excerpt also discusses the role that the public's interest in science can play in developing research-based policies ("it's good that public trust that politicians use scientific experts because this may lead to developing more research-based policies", SS957).

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III.5.3.2. Increasing the presence of scientists in political bodies

Other participants stressed the need to listen to scientists to develop policies and to increase the means of collaboration ("Channels between politicians and scientists have been created, and they should think how to resize and maintain them in the future", H4029) and to incorporate scientists into political bodies to influence the day-to-day of politics ("give more importance to scientists as counsellors of the government and citizens", S3630).

III.5.4. Need for more public research investment and funding

Finally, a large group of researchers mentioned that the COVID-19 pandemic emphasised the need for more research investment in their context. These results resonate with the low R&D investment in Spain, below the EU average (European Commission 2020; Mejlgaard et al. 2019), which indicates problems in research conditions are not new, but participants in our study claimed the COVID-19 pandemic stressed even more the importance of solving this problem.

III.5.4.1. Investment for all scientific disciplines and improvement of researchers' work conditions

Many researchers acknowledged the increase in research funding to face the COVID-19 pandemic. However, they claimed that one lesson learnt from this crisis was the importance of maintaining and further increasing research funding to prevent future crises (social, economic, energetical, climatic, etc.): "the increase in R&D investment needs to be very significant" (H886). Some demanded that these raises be applied to all disciplines and research topics relevant to society, not only those connected to the COVID-19 pandemic. These comments were more frequent among researchers in disciplines other than Health Sciences, and especially from those in the Humanities and Social Sciences: "In general, society has noticed the importance of research in health fields. However, I think research in all knowledge areas is necessary for societal progress. This conception, though, I think was absent from the media" (H2988).

Connected to this, many researchers claimed the COVID-19 pandemic stressed even more the precarious work conditions of researchers in Spain and the difficulties of obtaining research funding, despite their high-level training and constant efforts to be at the forefront. Thus, they highlighted the need to develop public policies aimed at improving research conditions

(research projects funds and research staff): "The interest of citizens and politicians in science should be maintained so researchers' work would not be so precarious, and their work conditions would improve" (2893).

III.5.4.2. Maintain citizens' and media interest to pressure politicians to invest in research

Finally, some researchers also highlighted the recently gained interest in science, this time as a way to increase research funding through the increased reputation and recognition of the value of science. The following are two illustrative examples of these claims: "Changes in the perception of citizens and media should be maintained to put pressure on politicians, so research and science are more recognised" (HS3384) and "Citizens must see research as an investment, not as an expense. I think citizens now have a better vision of research, which is important, especially so finally everybody is aware of the need to increase investment in research" (S3882).

IV. Conclusions

This study aimed to analyse researchers' perceptions about the impact of the COVID-19 pandemic on the RRI-based practices of their discipline and the impact on citizens', politicians', media's and professionals' perception of science at the beginning of the COVID-19 pandemic. Differences between disciplines were analysed to understand researchers' perceptions better. In addition, the study aimed to identify the lessons learnt and future opportunities that emerged during the COVID-19 pandemic from the researchers' point of view.

Regarding the first and second aims, although nearly half of the respondents did not perceive an impact on the RRI-based practices in their discipline. This proportion was slightly smaller for the emergence of new topics and bigger for collaborations outside the academic field and interdisciplinary collaborations. More importantly, there were significant differences among disciplines. As expected, Health Sciences researchers had more positive views of the impact of the COVID-19 pandemic on the practices of their disciplines. This is not surprising given the nature of the crisis and its critical consequences on people's health. In Spain and elsewhere, great economic investments were made from the beginning of the pandemic to cope with the crisis. However, Health Sciences researchers perceived a negative impact on the transfer and dissemination of knowledge. These findings might be explained by the qualitative findings that showed

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participants' concerns about misinformation, a problem particularly acute for these disciplines, as most pieces of fake news were directly connected to the virus and the pandemic (Hartley and Vu 2020; Van Der Linden et al. 2020).

Comparison among disciplines also provided some unexpected findings, namely the positive impact perceived by Social Sciences researchers in all the areas. It seems that researchers in these disciplines were well aware of the social consequences right from the beginning of the crisis and felt more compelled to take action than their counterparts. In contrast, researchers in the Humanities, Science, and Engineering and Architecture perceived no impact on the RRI-based practices and opportunities in their disciplines in the early reaction to the pandemic, despite it being the most global and critical crisis of recent years. Moreover, despite calls for addressing the consequences from all angles, this study shows that in Spain, at the beginning of the pandemic, the response to the COVID-19 pandemic focused on the health and social consequences. Future studies might explore whether the observed changes in RRI-based practices were maintained and whether other disciplines were involved in managing the crisis.

Regarding the third and fourth aims, results showed an overall positive perception of the impact that the COVID-19 pandemic had on the perception of science in the four actors, although researchers were slightly more sceptical about the impact on politicians' views. This scepticism might be explained by the qualitative findings on researchers' frequent claims for evidence-based policies and improving work conditions and funding in the different disciplinary areas. Researchers in the Humanities were again the most critical about the impact on societal actors' views of science, partly due to the lack of involvement of their disciplines in debating historical and philosophical implications of the pandemic.

Regarding the last objective concerning the lessons learnt and opportunities, results indicate that although RRI principles in science are not yet commonplace in Spanish research practices (European Commission 2021; Mejlgaard et al. 2019) and that researchers are aware of the need to promote them in order to address global challenges. Among RRI principles, researchers in our study stressed the importance of establishing stronger ties between science and other societal actors by making science more accessible to citizens, ensuring rigorous dissemination of scientific knowledge to fight *fake news*, and improving the connection between politics and science. Moreover, there is a great need for collaboration among all societal actors to advance scientific knowledge and especially to be able to cope with and overcome these and future crises (European Commission, n.d.; Hartley and Vu 2020; Kara and Khoo 2020; Lurie et al. 2021).

Finally, although researchers generally perceived increased funding opportunities in their field, through their answers, many participants demanded this improvement be extended to research conditions, including researchers' precarious work conditions and funding opportunities in all the disciplines, to enhance multi- and interdisciplinary approaches and to prevent future crises.

This study has some limitations. The results are based on a single questionnaire administered in the first months of the COVID-19 pandemic. Further research is needed to explore if researchers' perceptions about the pandemic's impact on their discipline have changed and how these changes are perceived in each discipline. Qualitative follow-ups, through interviews with key informants, would also help deepen the understanding of the effect of the COVID-19 pandemic on changes towards RRI-based practices, and especially on the consequences of these changes. Despite these limitations, this study offers interesting insights into the impact of the COVID-19 pandemic on research in Spain and how this impact may differ among disciplines. Results can guide further steps towards implementing the RRI principles in all the disciplines in the R&D ecosystem in Spain and elsewhere.

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