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The matter of complex anti-matter: the portrayal and framing of physics in Dutch newspapers

Sanne Willemijn Kristensen, Julia Cramer, Alix McCollam, W. Gudrun Reijnierse and Ionica Smeets

Abstract

Physics is often perceived as difficult, but there has been little research on how physics is reported in the media. In this two-stage content analysis, we examine the portrayal of physics in five major Dutch newspapers. Results show that astronomy and astrophysics is the most prominent field. Furthermore, newspaper articles are triggered almost equally by scientific and non-scientific events. Finally, the majority of described physics concepts are framed as difficult, but journalists do provide explanations for them.

Keywords Representations of science and technology; Science and media

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Introduction

Physics underlies many technological developments that support and impact our daily lives. For example, a smartphone is full of technologies that were discovered through physics research in the past decades. New developments in physics research can have a huge impact on society. According to Schäfer [2017, p. 51] "citizens and many decision-makers obtain their information about science mainly, or even exclusively, from news media and, increasingly, from online media". It is therefore important to know how physics is communicated to the general public.

In this study, we look at how physics is portrayed in the media. So far, research on science in the media has mainly focused on biosciences, medical sciences and climate science [Schäfer, 2012], and, in general, physics has not been widely studied as a topic in science communication [Gerber et al., 2020]. In order to broaden the field of science communication as a whole, experts interviewed by Gerber et al. [2020] suggest more research for under-represented fields such as physics.

Our study explores how physics is portrayed in Dutch newspapers, focusing on: 1) amount of attention for different fields; 2) triggers for including physics in newspapers; 3) framing of the subject as difficult or easy; and 4) explanations of physics concepts used in Dutch newspaper articles ($N = 698$).

Theoretical framework

There is a big variety of approaches in studies on the portrayal and representation of science in the media. We study the communication of physics in Dutch newspapers by researching *what type of physics is discussed*. We do this by checking which specific fields are reported, whether or not the articles are written because of a scientific trigger, and in which section of the newspaper the articles are printed. This study also analyses *how physics is discussed* in the newspaper articles by checking if physics is framed as difficult or easy, and if the physics concepts are explained. In this theoretical framework, we share the relevant literature on which we based our approaches and methods.

2.1 Science in the media

Several studies have looked at how the process of science is portrayed. An early Canadian study [Einsiedel, 1992], in which science news in Canadian newspapers was analysed, found that only a quarter of news articles reported on the background and methodological aspects of a study where this would have been appropriate. A later study, analysing reporting of the entire science domain in Dutch newspapers, also found a low amount of reporting of background and methodological aspects [Hijmans, Pleijter and Wester, 2003]. Furthermore, their analysis showed that quality newspapers did not report more or better information about methodological aspects than popular or regional newspapers. Interviews with science journalists revealed that information about research details was ignored to avoid complicated information.

In the same Dutch study [Hijmans, Pleijter and Wester, 2003], the majority of science news was published in the news section (67%), as opposed to the specialised science section (11%), although this distribution differed strongly between domains. Of all the science domains, the physical sciences were most often reported about in the science section (52%). Articles printed in the science section more often contained a direct reference to a scientific publication (70%) than articles in different sections of the newspaper (30%). No significant difference was observed between the reporting of methodological aspects in or outside the science section [Hijmans, Pleijter and Wester, 2003].

In this study, we will investigate the number of physics articles published in the science section of Dutch newspapers, and we will describe differences found in reporting between articles that are published in- and outside the science section.

2.2 The spread of media attention

One common aspect in studies that research the representation of science in the media is mapping the spread of media attention across different domains of science. This allows researchers to give a general overview of the science landscape in the media. Generally, studies found that the medical and social sciences get the most media attention [e.g. Einsiedel, 1992; Elmer, Badenschier and Wormer, 2008; Hansen and Dickinson, 1992; Hijmans, Pleijter and Wester, 2003; Summ and Volpers, 2016]. Hansen and Dickinson [1992], for instance, studied British newspaper articles and news broadcast items, and found that for all mass media channels, health & medicine and social sciences obtained most media attention. This preference towards medical and social sciences was also found by Summ and

Volpers [2016], who examined science coverage in German print media. A number of other studies found that either social sciences [e.g., Hijmans, Pleijter and Wester, 2003] or medical sciences [Einsiedel, 1992; Elmer, Badenschier and Wormer, 2008] were the most reported domains in newspaper articles about science. There thus seems to be a general tendency towards reporting on medical sciences and social sciences in the news.

In two German studies, physics was found to have a low contribution to science in the newspapers: 4.8% of the news articles [Elmer, Badenschier and Wormer, 2008] and 9% of the news articles [Summ and Volpers, 2016]. In studies on Dutch and Canadian science coverage, the portion of physics articles was so low that physics was coded as part of physical sciences, which was 13% of the total dataset [Hijmans, Pleijter and Wester, 2003], or as a part of the category other science domains, which was 3% of the total dataset [Einsiedel, 1992].

The amount of science communication research about physics decreased between 1990 and 2000, from 21.6% of all science communication research in 1990 to 8.0% in 2000 [Schäfer, 2012]. In a more recent study, the amount of science communication research on the more broadly defined physical sciences was found to be stable between 1979 and 2016, but low (between 3 to 4%) [Gerber et al., 2020]. Gerber et al. found that more science communication studies shifted to research specific domains, but that the attention across these domains is mostly focused on biology and environmental sciences. He recommends science communication research to include more contributions from under-represented domains such as physical sciences.

In our study, we choose a similar approach as Einsiedel [1992], Elmer, Badenschier and Wormer [2008], Hansen and Dickinson [1992], Hijmans, Pleijter and Wester [2003] and Summ and Volpers [2016], by studying the media attention spread across different fields within the domain of physics. By doing so, we will gain a better insight into which topics of physics are discussed in the news.

2.3 *Triggers of media attention for physics: a classic or broad definition of science communication*

An approach to categorise types of science communication is to study what triggers the media to report on science. Wormer [2009] coined the definitions of classical and broad senses of science communication by differentiating between the types of events that trigger news articles. Science news in the classical sense of science communication is generated by an event that happened in the scientific world, such as a peer-reviewed publication [Wormer, 2009, p. 1]. Science news in a broad definition of science communication is triggered by a non-scientific event [Wormer, 2009, p. 1], for example, an event from daily life or the general news such as the scientific explanations behind a tsunami.

An analysis of German newspapers found a clear difference between how science sections and other sections reported on science. The majority of articles in the science section had a scientific trigger, while in the other sections of newspapers, the majority of articles were triggered by a non-scientific event [Elmer, Badenschier and Wormer, 2008]. Summ and Volpers [2016] differentiated between what they termed a “narrow” and “broad” definition of science communication by looking at whether a direct reference was made in the newspaper articles to research results or research projects (narrow), or not (broad). Results of their study showed that only 11% of the broadly defined science news was found in the science section, whilst 41% of the narrowly defined science news was found in the science section. In addition, the humanities and social sciences were more often written about in the broad definition, while the natural sciences were more often reported in the narrow definition of science communication.

In our study we use Wormer’s [2009] definitions of classical and broad to investigate by which events physics news is triggered in Dutch newspapers.

2.4 *Framing physics as difficult or easy*

Little is known about how the general public perceives physics as a topic in science news. From science-education literature, however, it is known that students from various ages view physics as difficult and uninteresting. In a questionnaire among year 10 school students (age 14 to 15) in the U.K., for instance, the most frequently found reasons for finding physics uninteresting are that it is seen as difficult and irrelevant [Williams et al., 2003]. This same relation between perceived difficulty of physics and interest of students in the topic was found by Havard [1996] with year 12 students (age 16 to 17) in the U.K.

When looking at the motivation of students for selecting a certain subject, the combination of the subject’s difficulty, enjoyableness and usefulness were found to be the three most important factors [Cuff, 2017]. This means that perceiving physics as difficult could influence whether or not students select it as a subject in school. It is unknown whether the same negative relationship between perceived difficulty level and motivation to learn more about a topic holds for the general public.

Consistently calling a topic difficult or easy can be seen as a form of framing. However, we could not find any research on this type of difficulty framing for physics, or any other science domain. There has been research into other types of frames used in communicating new technological developments that fall in the physics domain. For example, Claassen et al. [2012] researched risk framing in news articles found online and in Dutch newspapers about electromagnetic fields and health in Dutch media. In many articles (44%) the negative risk frame *precaution and concern* was present. Another example of research into framing of a new technology, is a Norwegian newspaper analysis focussing on nanoscience and nanotechnology [Lein Kjølberg, 2009]. This study found nanoscience and nanotechnology to be framed as *positive*, *important for the future* and *under control*.

Negative frames in physics were found to have more influence than positive frames [Achterberg, 2014; Cobb, 2005]. For example, the effect of risk framing on U.S. public opinions about nanotechnology was studied using surveys [Cobb, 2005]. Respondents that were presented with the risk frame had a decreased trust in industrial leaders and were less likely to expect benefits. The benefit frame did not increase the trust in industrial leaders, but did make the respondents less worried and angry about nanotechnology. The results showed that frames about the risks of nanotechnology had slightly more influence on the perception of nanotechnology than benefit frames. Interestingly, if both risk and benefit frames were presented, the framing did not have any effect on the public perception. Another example of a study into the influence of negative and positive frames on public perception of physics and technology is the work of Achterberg [2014], in which the influence of frames on the trust of the Dutch public in hydrogen technology was investigated. Negative frames were found to erode the trust of people who initially had a high trust in hydrogen techniques, while positive frames did not affect the trust of people with a low initial trust in hydrogen techniques. Providing positive information about hydrogen technology was found to have a negative effect on the trust of people with a low initial trust in science and technology.

We consider a "difficult" frame to be negative due to the negative relation found between difficulty level and interest in high school students [Havard, 1996; Williams et al., 2003]. As negative frames are found to have more influence than positive frames [Achterberg, 2014; Cobb, 2005], we study whether physics is framed more often as difficult or easy.

2.5 Physics explained in newspaper articles

Another aspect of representation of science in the media is if and how the science is explained. Even though research shows that explanation enhances people's ability to understand scientific concepts, the amount of explanation in newspaper science stories is low [Long, 1995]. In a content analysis of U.S. news articles, it was found that in the majority of news articles only 10% or less of the article comprised explanation [Long, 1995]. One can argue that because of the nature of physics, where many topics lie beyond the limits of what people can see, feel or hear, the need for explanation is essential, as described by Turney [2004, p. 335]:

> "Human beings have direct knowledge only of things of medium size — a few millimetres to a few hundred meters — and which last for a few seconds to a few decades. They can recover information directly (ignoring the mediation of the sensory organs) only through registering light of certain wavelengths, sound of a relatively narrow range of frequencies, and so on. Scientific observation transcends all these limitations at the price of more and more complex mediations between observer and observed."

In the science communication community, the definition of "an explanation" is still up for debate [Long, 1995; Pavitt, 2000]. There have been different suggestions made from a philosophy of science stance — a review of these can be found in, for example, Faye [2014] and Rowan [1988]. In this work we adopt the following definition: "Explanatory discourse, (. . .), is premised on the assumption that readers are aware of some phenomenon such as light or language dialects but do not fully understand that phenomenon's nature. Thus explanatory discourse tries to promote or create understanding for lay readers of some phenomenon." [Rowan, 1988, p. 16]. This view on explanation leaves room to include different explanatory tools in our analysis [Faye, 2014]. In our work we predefined four different theory-based explanatory tools: causal explanation, analogy, functional explanation, and giving a definition or description.

In physical science, causal explanations are a natural form of explaining [Faye, 2014]. Explaining a phenomenon using a causal mechanism will make the reader know “why”, as opposed to knowing “that”. This allows one to identify the causal factors responsible for the fact [Faye, 2014]. For example, instead of stating that an apple falls from a tree, a causal explanation would explain that it is the gravitational force between two objects with mass, the earth and the apple, that causes the apple to fall straight down on the earth.

According to Pavitt [2000], analogy and functional explanation are the two major types of scientific explanation. An analogy is a systematic mapping between two situations: the target (the novel situation) and the source (the familiar one) [Kapon, 2014]. An example of an analogy is explaining the movement of colliding molecules in terms of the motion of colliding billiard balls. A functional explanation, on the other hand, provides knowledge about what the function or application of a concept is [Faye, 2014]. An example of a functional explanation is how semiconductors are used to make small electronic components that are used in the chips in your phone and computer.

Finally, one can also explain a concept by giving a description of the concept, or its definition [Faye, 2014]. For example, in the sentence “The electron is a negatively charged particle.” one explains something about the electron, just by describing one of its properties.

In Summ and Volpers [2016], the types of explanatory tools differ between science domains and various types of science reporting. Articles that fell under the narrow definition of science communication contained more explanations and data, and fewer causal attributions, solutions, predictions, evaluations and risks than broadly defined articles.

In our analysis, we investigate if there is any explanation provided about concepts of physics in the selected Dutch newspaper articles, and we follow up on the approach of Summ and Volpers [2016] by performing a more in-depth analysis of the types of explanations used to explain physics.

Method

This study aims to answer the following research questions:

RQ1: Which fields of physics are covered in Dutch newspaper articles?

RQ2: Is physics reported in the classical or broad definition of science communication?

RQ3: Is physics framed as difficult or easy?

RQ4: Is the physics in the articles explained and, if so, how?

To answer these research questions, we conducted a content analysis of Dutch newspaper articles. Via research questions 1 and 2, we studied the type of physics news that is presented in the newspapers. By answering research questions 3 and 4, we investigated how physics is discussed in the Dutch newspapers.

3.1 Data selection

The dataset was obtained using online database Nexis Uni [Lexis Nexis, 2020]. We selected the five most-read Dutch national newspapers [Mediamonitor, 2020], including online versions of these newspapers: *De Volkskrant*, *NRC*, *Trouw*, *Algemeen Dagblad*, and *De Telegraaf*.

In order to gain an image of the recent portrayal of physics in the news, we set the search window from the 1st of January 2018 up to and including the 31st of December 2019. The following Dutch search string was used: "natuurkunde or natuurkundig* or sterrenkunde or sterrenkundig* or *fysica or fysic*", which are the Dutch terms for physics and astrophysics. We used the wildcard (*) to also find compound words, such as 'quantumfysica' (quantum physics), which are written as one word in Dutch.

This search yielded a total of 1,824 newspaper articles, also including articles such as columns, letters and opinion pieces. To ensure that all articles in our dataset covered physics, two independent coders assessed if there was actual physics content present in each of the articles by looking for physics terms and jargon. Here and for all other inter-rater reliability tests reported in this paper, we used Cohen's kappa [Cohen, 1960] to calculate inter-rater reliability scores, because our data are nominal, units and categories are independent, and there were two coders who coded the data independently. In addition, we refer to both the kappa statistic and percentage agreement because kappa, as a chance-corrected coefficient, is sensitive to agreement on rare categories. Percentage agreement might therefore be high, while kappa is relatively low. Especially in such cases, adding percentage agreement provides a bit more insight into the extent to which coders agreed on the analysis of the data.

Results of the data selection showed "Almost perfect" [Landis and Koch, 1977, p. 165; Wong, Paritosh and Aroyo, 2021, p. 1] agreement between the two coders: $\kappa = 0.91$, 95.3% agreement. After this selection, 766 articles remained (42.0% of the initial dataset). Finally, duplicate articles were removed and articles which contained multiple short stories about physics from different authors were split into multiple shorter articles. This resulted in a final dataset of 698 news articles about physics.

To study if physics is framed as difficult or easy (RQ3), we searched for words that indicate a difficulty level. These words were selected by searching for synonyms of 'moeilijk' (difficult) and 'makkelijk' (easy) in the Cornetto database [Clarin, INL and VU Amsterdam, 2013]. We identified six synonyms for 'difficult': *moeilijk*, *ingewikkeld*, *complex*, *lastig*, *verwarr* and *verward* (difficult, complicated, complex, tricky, confusing). Three synonyms for 'easy' were identified: *makkelijk*, *eenvoudig* and *simpel* (easy, straightforward, simple). In this search we also used the wildcard (*) to find compound words. Using the concordance tool AntConc [Anthony, 2019], we identified all fragments from our dataset in which these difficulty level indicators were present, resulting in 839 text fragments, each consisting of a thousand characters. In the analysis, we only included text fragments in which the difficulty level indicator referred to a physics term ($N = 369$). This selection was made by two independent coders and resulted in "(Almost) perfect" [Landis and Koch, 1977, p. 165] agreement between the two coders: $\kappa = 1$, 100% agreement after discussion.

Table 1. Overview of the two different coding phases.

Coding phase	*Codebook*	*Main objectives*	*Dataset*
1	Codebook I (Supplementary material 1)	– Analysing the fields and topics present in the articles – Finding the trigger of the news article – Checking if there is any physics explained	All 698 articles
2	Codebook II (Supplementary material 2)	– Analysing cases where physics concepts were framed using a difficulty level indicator – Researching the explanation provided for these concepts	369 text fragments of 1,000 characters obtained from the main dataset by searching for difficulty level indicators

3.2 Coding

Coding of the final dataset was carried out by two independent coders in two consecutive stages (Phase 1, Phase 2). In Table 1, we summarise which codebook was used, what the main objective was, and which dataset was coded.

The coding schemes for these two stages were developed and improved by performing a pilot on a sample of Dutch newspaper articles about physics from 2017. The pilots and both coding stages were carried out by two independent coders (the first and second authors of this paper).

In Phase 1, the two independent coders read all articles in the dataset ($N = 698$) and coded each article for a number of descriptive characteristics (metadata), physics fields, news triggers (scientific/non-scientific), and whether there is any physics explanation present in the article. A detailed description of the coding scheme for Phase 1 can be found in Supplementary material 1.

In Phase 2, the two independent coders analysed whether physics concepts in the 369 fragments from the dataset that contained difficulty level indicators were framed as difficult or easy. For example, in "quantum physics is very complex to understand", quantum physics is framed as being difficult. In addition, the coders also determined in which context the difficulty level indicator was used (e.g., a concept is difficult/easy to measure, to explain, to understand). Finally, a quantitative open coding approach with some predefined explanatory tools based on the literature (e.g., analogy, causal relation, functional explanation [Faye, 2014; Kapon, 2014]) was used to code the types of explanation present in the text segment. During the open coding, we identified additional explanatory tools, which are reported in section 4.4. A detailed description of the coding scheme for Phase 2 can be found in Supplementary material 2.

3.3 Inter-rater reliability

To test the reliability of our coding schemes, coding of the final dataset was done with an overlap of 20% between the first and the second coder. In both coding phases, inter-rater reliability was calculated before and after discussion of the results.

The final agreement of questions in codebook I, ranged between "Substantial" and "Almost perfect" [Landis and Koch, 1977, p. 165], suggesting that the coding scheme can be applied to Dutch newspaper articles about physics in a reliable fashion.

The inter-rater reliability during Phase 2 remained low during the pilot phase. Therefore, it was agreed that the first and second coder would start the coding process by independently coding 20% of the dataset, followed by discussion to recalibrate, and finally only one of the coders would code the remaining dataset, keeping the discussion in mind. The agreement before discussion ranged between "Slight" and "Almost perfect" [Landis and Koch, 1977, p. 165] for the questions from codebook II. All codes were discussed and perfect agreement was reached after discussion of the 20% of overlapping dataset. The first coder subsequently coded the remaining articles.

Results

From the 698 articles in our dataset, 323 were published in 2018, and 375 were published in 2019. In Table 2, an overview of the number of news articles and cumulative words per newspaper is given. The *science section* had the biggest contribution with 245 articles (35.1%), followed by the section *online only*, which contained 94 articles (13.5%). We identified 242 different authors in our dataset. The top ten contributing authors together wrote 335 articles which made up 48.0% of our dataset.

Table 2. Overview of number of news articles and words per newspaper in our dataset.

Newspaper	*Number of articles*	*Number of words*
De Volkskrant	246	233,208
NRC	201	181,314
Trouw	118	114,316
Algemeen Dagblad	74	45,530
De Telegraaf	59	30,874
Total	698	605,242

4.1 The spread of media attention

Of the 698 articles, 341 (48.8%) concerned one field of physics. In 245 articles (35.1%), we identified two fields, and the remaining 112 articles (16.0%) were about more than two fields and thus categorised as *physics in general*. Table 3 displays the spread of media attention over the fields of physics. Note that the sum of the percentages exceeds 100%, due to the fact that there were two fields assigned for 245 articles.

The field *astronomy and astrophysics* was written about the most. Of the 586 articles to which at least one specific field was assigned, this field was identified 307 times (52.4%). The field *plasma physics* received the lowest amount of media attention in our dataset (3 articles; 0.4%). The category *other* contained fields such as aerodynamics, and fields of physics that are no longer considered active research areas, but are seen as the foundation of many current research areas, such as classical mechanics, thermodynamics, and electromagnetism.

Table 3. Number of articles ($N = 698$) categorised by field. For 586 articles, one or two fields were assigned and 112 articles were considered to be about physics in general. Categories are based on the ArXiv repository [Cornell University, 2020].

Field	*N*	%
Astronomy and astrophysics	307	44.0%
Other	69	9.9%
General relativity and quantum cosmology	68	9.7%
High energy physics	62	8.9%
Quantum physics	53	7.6%
Biological and medical physics	52	7.4%
Condensed matter physics	46	6.6%
Nuclear physics	40	5.7%
Geophysics	30	4.3%
Optics	30	4.3%
History and philosophy of physics	26	3.7%
Fluid dynamics	20	2.9%
Mathematical physics	18	2.6%
Molecular physics	7	1.0%
Plasma physics	3	0.4%
Physics in general (more than two fields were identified)	112	16.0%
Total amount of fields assigned to 698 articles	*943*	*135.1%*

4.2 *Triggers of media attention for physics: a classic or broad definition of science communication*

In our dataset, we found an almost equal division between scientific ($n = 336$; 48.1%) and non-scientific triggers ($n = 329$; 47.1%). In 33 articles (4.7%), no clear trigger could be identified. Of the 336 articles with a scientific trigger, 151 were published in the science section (44.9%) and of the 329 articles with a non-scientific trigger, 88 were published in the science section (26.7%).

In the category *scientific triggers*, the most frequently used triggers were *research in progress* and *peer reviewed publication*. These categories were assigned if an article was about research that was carried out, the process of doing research in general, or scientific results either before or after peer-reviewed publication.

In the category *non-scientific triggers*, the most frequently used trigger was *science communication*. This category was assigned to articles about science communication activities, for example the opening of an exhibition in a science museum or the publication of a popular scientific book. Another frequently assigned category within *non-scientific triggers* was *recurring item*. This code was used for articles that were part of a regularly occurring series of articles. For instance, there were 16 columns in our dataset that were part of the weekly series “Jan asks Daan” in which a mathematician (Jan Beuving) and a physicist (Daan van Eijk) asked each other questions about mathematics and physics. Here the recurring nature of the column itself was considered as the trigger for publishing the article. Table 4 displays an overview of all triggers identified in the dataset.

Table 4. Scientific and non-scientific triggers. The data also included 33 articles for which no trigger could be identified, which are excluded from this table.

Scientific triggers (classical)	$N = 336$ (100%)	*Non-scientific triggers (broad)*	$N = 329$ (100%)
Research in progress	$n = 128$ (38.1%)	Science communication	$n = 128$ (38.9%)
Peer-reviewed publication	$n = 122$ (36.3%)	Recurring item	$n = 70$ (21.3%)
Scientist wins award	$n = 47$ (14.0%)	Personal life of a scientist	$n = 37$ (11.2%)
Scientific conference or lecture	$n = 11$ (3.3%)	Physics was used as an example or metaphor	$n = 20$ (6.1%)
Research facility is built, or opened	$n = 8$ (2.3%)	Political	$n = 19$ (5.8%)
Other	$n = 20$ (6.0%)	Natural phenomena	$n = 18$ (5.5%)
		Other	$n = 37$ (11.2%)

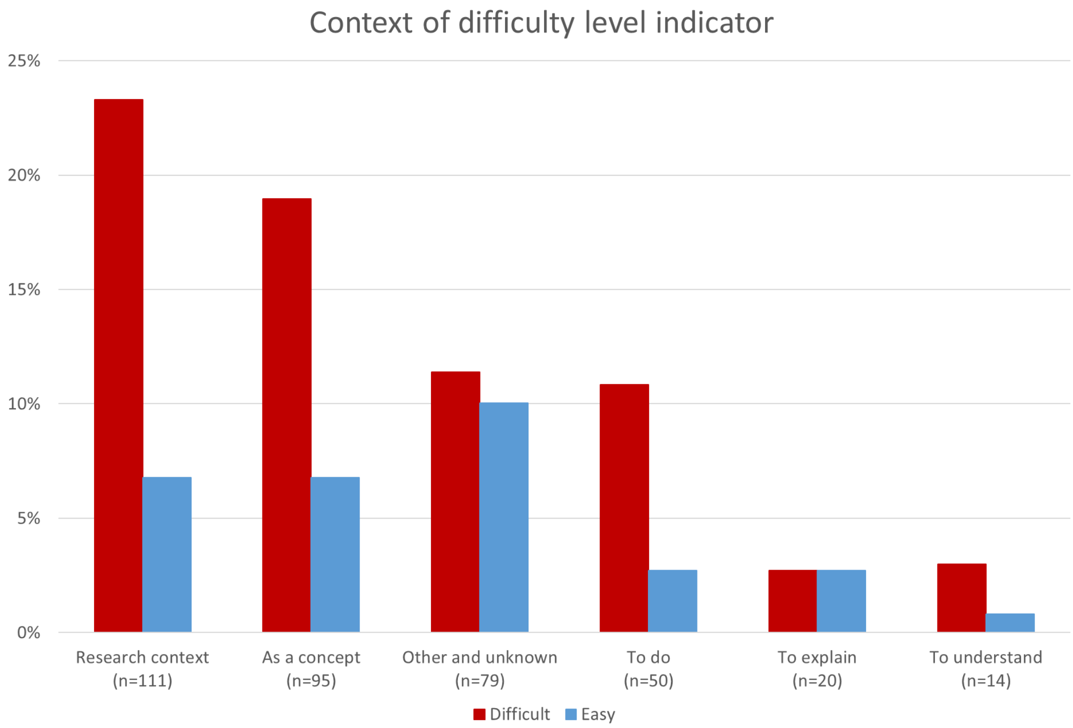

Figure 1. Context in which the physics concepts were framed to be difficult (red) and easy (blue). The contexts are given in percentages of the total number of text fragments in which framing of physics concepts was present ($N = 369$).

4.3 *Framing physics as difficult or easy*

Of the 369 text fragments in which a difficulty level indicator was used to describe physics concepts, the majority was framed as being difficult ($n = 259$; 70.2%). Figure 1 shows the different contexts in which the physics was being framed as difficult (red) or easy (blue).

Difficulty level indicators were most frequently used in the *research context* ($n = 111$; 30.1%). This category contains research activities, for example measuring, calculating, modelling, etc. The contexts *to explain* and *to understand* had a small contribution compared to the other contexts. In the category *to do*, we bundled all physics concepts that were described as difficult/easy to do, or to get done. For example, the space shuttle mission to repair the Hubble telescope was described as a difficult mission to do. The category *as a concept* was used if the physics concept itself was being described as difficult or easy, like "general relativity is easy". In the category *other and unknown* there were many different and small contributions.

4.4 Physics explained in newspaper articles

During coding Phase 1, we checked every article for any explanation about physics. In 559 out of the 698 articles (80%) there was some explanation present about at least one physics concept. The articles that were published in the science section contained an explanation in 93.1% of the cases, while the articles that were found outside the science section contained an explanation in 73.1% of the cases. Of the 336 articles that were written in the classical sense of science communication, 325 (96.7%) contained at least one explanation of a physics concept, while from the 329 broadly defined physics articles, 214 (65.0%) contained a physics explanation.

During coding Phase 2, we also checked if the physics concepts that were being framed as difficult or easy were explained. In 300 out of the 369 text fragments that contained a difficulty level indicator, some explanation about the physics concepts was given (81.3%). We identified the different types of explanation present. A total of 695 types of explanation were identified in the 300 different text fragments. Often multiple types of explanation could be identified for one text fragment. Figure 2 displays the distribution of each type of explanation in the 300 fragments containing an explanation. The categories *causal explanation* and *definition,*

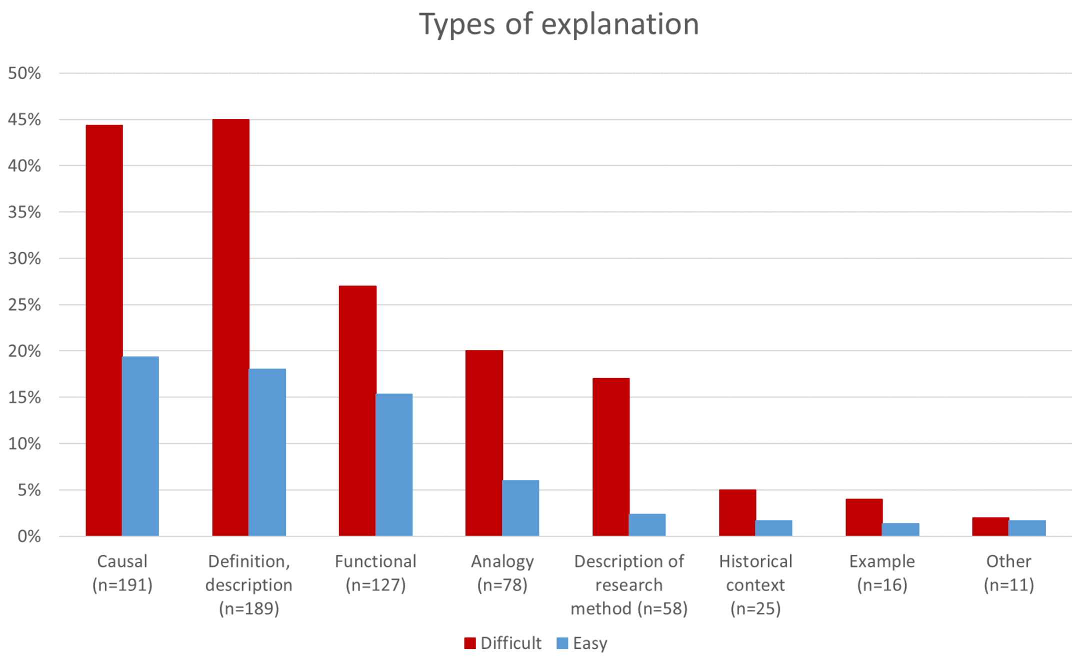

Figure 2. Different types of explanation used to explain physics. Multiple types of explanation could be coded for every text fragment. The types of explanation are given in percentages of the total number of text fragments in which framing of physics concepts was present ($N = 369$).

description were found most often. The last four categories in Figure 2 were found through open coding during the analysis. *Description of research method* was coded if it was explained in the text how the physics concept was being researched. For example, if, for the physics concept "the Higgs particle", the process of finding new elementary particles at Cern was explained. *Historical context* was coded if, for example, the story of the discovery of the physics concept was told. The category *example* was used if an example of the physics concept was given. For example, if the physics concept was "elementary particles" and it was stated that the electron is an elementary particle.

Discussion

Before we discuss our research questions, we would first like to reflect on the number of physics articles found in the science section. We saw that 35.1% of articles about physics were published in the science section. Compared to earlier results of Hijmans, Pleijter and Wester [2003], in which 52% of the physical science articles were reported in the science section, we found a relatively high amount of physics in other sections of the newspaper. It could be that this is related to the fact that almost half of the articles in our dataset were written because of a non-scientific trigger.

5.1 The spread of media attention

Almost half of the articles in our dataset concern the field *astronomy and astrophysics*. One possible explanation for the high number of *astronomy and astrophysics* articles could be that this field has a higher scientific output than other fields of physics. A search for publications about physics in the ArXiv repository for the same timeframe as our dataset (2018–2019), however, showed that publications about *astronomy and astrophysics* were about as frequent (17.6% of all 184.965 publications on physics in the time frame) as publications about *condensed matter physics* (20.4%) and *high energy physics* (18.4%) [Cornell University, 2020]. From this we can conclude that the scientific output of *astronomy and astrophysics* is not higher than that of other fields. One limitation of comparing the output per field between the ArXiv repository and our dataset, is that the ArXiv repository is an international database. Even though Dutch newspapers also report on international science news, it could be that certain fields gain more media attention in Dutch newspapers because these fields have a relatively active scene in the Netherlands compared to other countries. Furthermore, the number of publications in ArXiv does not take into account the scientific or societal impact of publications, which could also be an important factor for journalists in choosing to report about a topic.

We know that journalists mainly choose topics i) based on their own interest, ii) by assessing the relevance to the readers' daily life, and iii) by assessing whether the topic is something that the reader can relate to [Hansen, 1994]. It is therefore also possible that, because many topics in *astronomy and astrophysics* are about something that the public can relate to, such as the stars and the night sky, journalists feel this is more relevant to the reader than, for example, quantum physics, which might be considered to not be directly visible in our daily life. It would be interesting to test this theory by interviewing journalists about their motives to write about certain topics in physics.

During our analysis, it became clear that a few authors wrote a large portion of our dataset. The top ten authors in our dataset wrote 48.0% of all the articles. This suggests that these authors might have a big influence on how physics is presented in Dutch newspapers, and that our dataset might be influenced by their personal preferences and interests. The Netherlands is a small country, so this effect might be smaller in countries with a larger pool of science journalists. It would be interesting to perform a comparable study in such a country.

5.2 Triggers of media attention for physics: a classic or broad definition of science communication

Similar to the results of Summ and Volpers [2016], we found that articles with a scientific trigger are published more often in the science section than articles with a non-scientific trigger.

Based on earlier research, we know that for the entire science domain, the contribution from scientific and non-scientific triggers is distributed equally [Elmer, Badenschier and Wormer, 2008]. When looking at differences between science domains, however, the natural sciences are more often covered in the narrow definition of science communication, that is, triggered by scientific events [Summ and Volpers, 2016]. Building on this, our finding of an almost equal distribution between scientific and non-scientific triggers for articles about physics was unexpected.

The fact that almost half of the articles about physics have a non-scientific trigger seems to indicate that physics and society are strongly connected and intertwined in Dutch society. The biggest contribution of non-scientific triggers came from science communication. An international study comparing science communication activity by research institutes from different countries shows that Dutch institutes are active in communicating to the general public through events, traditional media channels and new media channels [Entradas et al., 2020]. Therefore, it could be that the large portion of *science communication* triggers is due to an active effort in physics communication in the Netherlands.

5.3 Framing physics as difficult or easy

The vast majority of physics concepts that are referred to with a difficulty level indicator are framed as difficult (70%). The fact that physics is associated with being difficult is shown for students in an educational setting [Havard, 1996; Williams et al., 2003], but this had not previously been shown in a science communication setting. We believe that further research is needed to test if the relation between perceived difficulty of topics and decrease in interest, which was found in an educational setting [Cuff, 2017; Havard, 1996; Williams et al., 2003], also holds for readers of newspapers, and how this is affected by difficulty framing in the news. If these relationships are translatable to how the public perceives physics in the news, then the framing of physics as difficult could have strong negative effects on the interest of the general public, as it is found that negative frames have more effect than positive frames [Achterberg, 2014; Cobb, 2005].

5.4 Physics explained in newspaper articles

We performed two different measurements of explanation. In coding Phase 1, we checked if there was any physics explained in the entire article, and in coding Phase 2, we checked if the physics that was framed with a difficulty level indicator was explained. Both checks resulted in a similar high number of explanations found in the analysed texts of 80% and 81%, respectively.

When we checked if difficult framed physics concepts were explained more often than easy framed physics concepts we found that they are both explained in 81% of the cases. So the frame appears to have no influence on whether or not an explanation is provided.

Similar to Summ and Volpers [2016], we found the amount of explanations to be higher for scientifically triggered news articles than for non-scientifically triggered news articles.

In our work, we studied explanations by checking if there are explanations provided in articles about physics, and what types of explanations these are. Another approach to study explanations in science news is to analyse how much of the article consists of an explanation [Long, 1995]. This approach of Long showed that, for the majority of the articles, only ten percent or less of the article was comprised of explanation, which was categorised as "little explanation provided". Comparing our result to the results of Long [1995] is difficult, since the method by which we checked for explanation is different. Still, we do not have the same pessimistic view as Long on the amount of explanation provided, since we do find that the number of articles in which an effort was made to explain physics to the general audience is high.

The causal explanation was the most used type of explanation in our dataset. According to Faye [2014], the causal explanation is a very natural type of explanation in physical sciences.

Through open coding, we found the category *description of research method* as a type of explanation. This type of explanation was found in 58 of the 369 text fragments (15.7%), which means that the amount of description and background information of research methods is even lower in our results than in the work of Einsiedel [1992], in which a quarter of their set contained this type of explanation. Interviews with journalists showed that the description of research methods was often seen as a complicating factor [Hijmans, Pleijter and Wester, 2003]. This aligns with our result that physics concepts that were explained with a description of research methods were more often framed as difficult (87.9%) compared to the average of the dataset (70%).

Conclusion

We explored the portrayal of physics in Dutch newspapers. We specifically studied the spread of media attention over the different fields in physics, whether physics was reported in the classical or broad sense of science communication, whether physics concepts were being framed as either difficult or easy, and whether the physics concepts referred to in newspaper articles were explained. Based on a content analysis of 698 newspaper articles from five Dutch national newspapers, we conclude that there is a high amount of media attention towards the field of *astronomy and astrophysics* in Dutch newspapers, while other fields (*plasma physics* and *molecular and atomic physics*) receive barely any media attention. We found that Dutch newspapers report almost equally on physics in the classical and broad definition of science communication. Lastly, the majority of the physics reported in Dutch newspaper articles was framed as difficult (70%), but, also, the majority of the physics is explained (81%).

Many highly debated technological advancements in society, such as, for example, quantum computing, the 5G network and nuclear energy, are based on diverse types of physics concepts. Since news media and online media are the main source of information about science for citizens [Schäfer, 2017], a balanced representation of physics topics in newspapers is essential to create awareness of the origin of technological innovations in society. This could potentially increase the public's ability to form an informed opinion about these technologies and to engage in public debate. Also, considering that the public reading these articles about physics, consists of a very diverse group, we can only assume that they have very diverse interests. Offering a more balanced selection of topics could therefore potentially increase the enjoyment of the public in physics. The high effort for providing explanations is very positive and could potentially increase the understanding and trust in physics by the public. We would like to encourage journalists to withhold the difficulty framing of physics as it could potentially have a negative effect on the interest of the reader.

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Authors

Sanne Kristensen works as a Ph.D. student on a combined project which contains both experimental condensed matter physics research at the High Field Magnet Laboratory at the Radboud University and science communication research at Leiden University. During her Ph.D. project she spent one year as science communication scholar researching the communication of physics in Dutch newspapers. E-mail: sanne.kristensen@ru.nl.

Julia Cramer is assistant professor of science communication at Leiden University, the Netherlands. After obtaining her Ph.D. in quantum physics, Julia refocussed her research efforts to science communication. Julia is interested in how quantum physics is communicated to the general public and how this influences the acceptance of new quantum techniques in society.
E-mail: j.cramer@biology.leidenuniv.nl.

Alix McCollam is assistant professor in experimental condensed matter physics at the High Field Magnet Laboratory, Radboud University, the Netherlands. Her research focuses on understanding novel phases of matter driven by strong electronic correlations, particularly properties related to magnetism and superconductivity. She is also interested in understanding the most effective ways to communicate physics research to a wide, non-specialist audience.
E-mail: a.mccollam@ru.nl.

W. Gudrun Reijnierse is an assistant professor of language use and persuasive communication at the Centre for Language Studies at Radboud University, the Netherlands. In her research, she uses corpus-linguistic and experimental methods to study the use and effects of (deliberate) metaphor across genres, with a special interest in science journalism. Twitter: @GReijnierse.
E-mail: gudrun.reijnierse@ru.nl.

Ionica Smeets is professor of science communication at Leiden University, the Netherlands. Her main research interest is bridging the gap between experts and the general public. She enjoys working in interdisciplinary projects that focus on effective science communication about a specific topic, ranging from statistics to biodiversity and from hydrology to health research. Twitter: @ionicasmeets.
E-mail: i.smeets@biology.leidenuniv.nl.

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