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RESEARCH ARTICLE

Studying the emergence of a new social representation: Changes in thinking about nanotechnologies in early 21st-century Italy

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Abstract

We investigated the emergence of a new social representation (SR) of a techno-scientific innovation—nanotechnologies—among the Italian public. We reviewed how nanotechnologies entered parliamentary debates and the media agenda in the early third millennium. We conducted cross-sectional surveys in 2006 (N = 246) and 2011 (N = 486) to examine the emerging SR of nanotechnologies. We sought to observe processes of anchoring and objectification 'in action', by analyzing roles of (i) social groups, and (ii) neighboring SRs of science and of technology, over time. Several changes from 2006 to 2011 were identified: From a 'descriptive' to an 'evaluative' approach; from a 'neutral' to a 'controversial' issue; from a 'concrete' to an 'abstract' object; and from a 'technological' to a 'scientific' phenomenon. We conclude that nanotechnologies finally became 'relevant enough' by 2011 to be considered a proper object of SR, and an emerging SR can be observed.

The theory of social representations (SRs) (Moscovici, 1984) provides valuable insights for examining the common-sense understanding of new phenomena, like technological advances or scientific achievements (Kalampalikis, Bauer, & Apostolidis, 2013). Thanks to its heuristic potential and conceptual richness, this theory has proved to be a well-established framework able to articulate how new forms of knowledge circulate through society, and, even after more than 50 years, its foundational text, 'La psychanalyse, son image et son public' (Moscovici, 1961/1976), is still a guide to studying how societies respond to the techno-scientific challenges that they face (Bauer & Gaskell, 1999, 2008; Wagner & Hayes, 2005).

However, there is little research investigating what happens during the earliest stages, when the common-sense understanding of a new techno-scientific innovation begins to be developed (Jovchelovitch, 2008). When does a SR of a techno-scientific innovation emerge? What characteristics does it take on? Why does a new SR take the form it does, given all the other possibilities? Who develops a new SR? How does it change over time?

We offer a contribution in this direction, by studying the intra- and inter-representational processes involved in the emergence of SRs of techno-scientific innovations. In particular, we examine the case of nanotechnologies in Italy. Comparing two points in time (2006 and 2011), we investigate whether and how SR of nanotechnologies has emerged since the proliferation of the notion of nanotechnologies through Italian society. To this end, we explore the role played by the two generative processes of familiarization (i.e. objectification and anchoring) suggested by the theory of SRs, by analyzing similarities and differences across social groups and with neighboring, pre-existing SRs (of science and of technology) as well as by examining how these patterns of similarities and differences evolve over time.

Two clarifications about the object and context of the study are needed. First, nanotechnologies were selected as a paradigmatic case of techno-scientific innovation. As we will maintain in the following pages, they offer an interesting opportunity for a better understanding of the core processes underlying the emergence of a new SR because they are a recent and ongoing innovation that remains little known to the general public. Second, although our analysis focuses on the Italian context, our conclusions are likely to be relevant for other European countries, which are characterized by a view of scientific research as tied to economic competitiveness through ceaseless techno-scientific innovation and—at the same time—by a widely recognized problem of public unease with science, especially in relation to new science-based technologies (Felt & Wynne, 2007; see also Gaskell et al., 2010).

Before presenting the study, we will introduce some key premises. First, we will discuss some central concepts of the theory of SRs in relation to the emergence process of new SRs. Second, we will present how this

epistemological framework has been applied to techno-scientific innovations. Third, the background scenario to nanotechnologies in Italy will be established, by examining how this topic has entered political debates and the media agenda in the early 21st century.

Social Representations and their Emergence

Although SR has been defined in various ways by different authors, in this article we adopt a classic definition as a 'specific form of knowledge—common knowledge—*whose contents show the operation of generative processes* and socially marked functions' (Jodelet, 1984, p. 361; italics added). A key point of the theory of SRs is thus the crucial role of generative processes, which Moscovici (1984) identified as *anchoring* and *objectification*. Through these processes, the unfamiliar becomes familiar, and slippery concepts—such as those associated with techno-scientific innovations—are gradually transformed into SRs that can be put into question and modified. As they are traditionally conceived, anchoring is a process through which pre-existing and socially shared knowledge is applied to new social phenomena; objectification is a process through which new social phenomena are transformed into concrete and tangible objects, which are the product of collective processes (Wagner & Hayes, 2005; see also Kalampalikis, 2009).

Beyond these classic definitions, such processes have been widely debated and developed (e.g. rhetorically, Billig, 1988; narratively, Laszlo, 1997; dialogically, Markova, 2000; in relation to social identity, Breakwell, 2001; in relation to social positioning, Clémence, 2001; visually, Devine-Wright & Devine-Wright, 2009). However, there is still no consensus about their specific role in shaping an emerging SR, and the ambiguity is usually unsatisfactorily explained by claiming that the two processes are tightly interdependent. We aim here to contribute to this debate.

Conversely, it is agreed that 'anchors and objects are not fixed once and for all, they are transitional pointers in the evolution of meaning of an aspect of the world' (Bauer & Gaskell, 1999, p. 172). This means that new phenomena are subject to many social challenges, in that their SRs require continuous processes of familiarization. Thus, the dimension of time, although often overlooked in SR studies, becomes crucial to researching the ever-changing nature of representational processes (Bauer & Gaskell, 1999, 2008; Brondi, Sarrica, Cibin, Neresini, & Contarello, 2012; Salesses, 2005). In this regard, Moscovici (1984) emphasized that 'when studying a representation, we should always try to discover the unfamiliar feature which motivated it and which it has absorbed. But it is particularly important that the development of such a feature be observed *from the moment it emerges* in the social sphere' (p. 28, italics added).

Hence, attention must be focused on the processes of change in SRs from a diachronic perspective. Moliner (2001) identified three phases in the 'history' of an SR: *emergence*, *stability*, and *transformation*. While stability and transformation have been widely studied (e.g. Flament, 1994), emergence has been less explored in empirical studies (see Galli & Nigro, 1989; for one of the earliest examples). This phase, the understanding of which we aim here to deepen, precedes the appearance of broadly shared and stable SRs and is thought to be characterized by great variability and only weakly structured forms of knowledge (see the concept of 'SR-in-the-making' suggested by Moscovici, 1988).

During this phase, the underlying representational processes as well as the emerging shapes that SRs take are not randomly determined; they are profoundly related to social groups and serve a variety of socially marked functions (Bauer & Gaskell, 2008). The operation of anchoring and objectification is thus widely influenced by the social groups who co-produce the new SRs; specifically, 'the functions served should affect the prior systems of representation chosen to act as the anchor for anything new or any development of the old. They should shape the objects which will be chosen as the frame of reference or referent points for familiarisation which permits objectification' (Breakwell, 1993, p. 4).

Furthermore, anchoring and objectification imply that SRs are mutually related (Breakwell, 1993; Rouquette, 1994). Camargo and Wachelke (2010, p. 24.3) stated, 'if a representation is constructed through the interpretative resources contained in pre-existing knowledge, then the representations already shared by a group serve as a reference point for the new representation, and the old and new representations maintain a relationship among themselves'. Inter-representational relationships are thus particularly important when studying the emergence of new SRs. Indeed, the fact that SR is related to several neighboring SRs 'may accelerate the process by which the representation of a new object in social discourse emerges and gains structure' (Salesses & Romain, 2013, p. 186). Moreover, 'these familiar objects may, however, be associated with either positive or negative attitudes, i.e. with acceptance or rejection. This, in turn, will lead to the new representational field developing in different ways' (p. 186). Nevertheless, this issue remains insufficiently studied.

Social Representations and Techno-Scientific Innovations: Why Nanotechnologies?

The theory of SRs seems to provide useful tools for analyzing the emergence and development of the interpretative resources made available to laypeople by their social context, for coping with techno-scientific innovations (Kalampalikis et al., 2013). Research in this field—mainly focused on biotechnologies, genetic engineering, genetic modified foods, and stem cells—has offered relevant insights (e.g. Bauer & Gaskell,

1999, 2008; Castro & Gomes, 2005; Green & Clémence, 2008; Wagner & Hayes, 2005; Wagner & Kronberger, 2001; Wagner, Kronberger, & Seifert, 2002): On the one hand, laypeople feel the need to develop a primary form of knowledge—largely based on metaphors and iconic contents—which is functional for everyday life and communication as well as to maintain (or to change) the status quo. On the other hand, laypeople tend to create links among techno-scientific innovations and to anchor new innovations to previous ideas, knowledge, attitudes, and experiences, which thus play a crucial role in assessing novelties and in shaping new SRs (Kronberger, 2015).

Nanotechnologies are a recent research field, which has been acclaimed as the next strategic technology after biotechnologies and other new technologies (e.g. information technologies). For this reason, they have been receiving increasing attention from the social sciences. Focusing only on the European context, they have been studied in terms of experts' representations (e.g. Bertoldo, Mays, Poumadère, Schneider, & Svendsen, 2016); press coverage (e.g. Anderson, Allan, Petersen, & Wilkinson, 2005; Te Kulve, 2006; Veltri, 2013); public perception (e.g. Gaskell, Eyck, Jackson, & Veltri, 2005); and risk perception (e.g. Pidgeon, Harthorn, & Satterfield, 2011; Wiedemann, Schütz, Spangenberg, & Krug, 2011). However, nanotechnologies remain somewhat unknown for laypeople: according to recent European data from the survey questionnaire Eurobarometer 73.1 (Gaskell et al., 2010), only 46% of Europeans—and 37% of Italians—claimed to be aware of nanotechnologies (i.e. had ever heard of, spoken about, or searched for information on nanotechnologies).

In this regard, a first issue that needs to be addressed is whether nanotechnologies are an innovation that is 'too new', or if they are already a 'relevant enough' object, to be considered in terms of SR. In other words, it is crucial to consider what characteristics a social phenomenon should have to become the object of an emerging SR. The debate on this point is ongoing and still intense (Wachelke, 2012). On the one hand, clearly not every object allows for the emergence of SR, since it must be relevant for a group; on the other hand, a wide range of more or less strict conditions has been proposed for a social phenomenon to be considered in terms of SR, without reaching a strong consensus (e.g. Flament & Rouquette, 2003; Garnier, 1999; Marchand, 2000; Moliner, 1993). For this reason, we suggest returning to three criteria initially proposed by Moscovici (1961/1976): that is, the social phenomenon should be ambiguously defined, different social groups should be more interested in some aspects of that phenomenon than others, and people should feel the pressure to infer about it. Moreover, the social phenomenon should be shared and contextualized in a given cultural framework (Farr & Moscovici, 1984).

On this basis, nanotechnologies may be a suitable object to study within the theory of SRs, because they represent a paradigmatic example of the way such a complex set of processes, which we call 'techno-scientific innovation', evolves and gets organized over time. Indeed, we agree with Bertoldo et al. (2016), who stated that 'considering the limited public awareness of nanotechnology (Eurobarometer, 2010; Satterfield et al., 2009) and the relatively modest attention devoted to the subject by the media, SRs theory suggests that it would be unlikely for the public to have already formed a unified or systematic representation of nanotechnology' (p. 6). However, for this reason, we believe that nanotechnologies offer a prime opportunity to examine how society arrives at a socially shared and negotiated understanding of a new techno-scientific innovation, focusing on the first steps of the representational process.

Several arguments regarding nanotechnologies in other European countries and regarding other techno-scientific innovations (i.e. biotechnologies) in Italy help support our choice. First, when nanotechnologies entered the public sphere at the beginning of the 21st century, they were accompanied by ambiguous assertions ranging from triumphant announcements of extraordinary (techno-scientific, economic and socio-cultural) outcomes to repeated warnings about possible (moral, ethical and safety) risks. Second, parallel to the institutional setting, the collective imagery revealed the emergence of ambivalent positions too. European data (Gaskell et al., 2010) have shown that more than six out of 10 EU citizens (61%) think nanotechnologies could have positive effects, whereas opponents declare themselves to be concerned about the safety of nanotechnologies and about the perceived absence of benefits. In Italy, the percentage of optimists is even lower (55%). Third, the temporal trend shows a very similar trajectory to the path taken by biotechnologies: while nanotechnologies and biotechnologies had enjoyed an upward trend since 2002, in 2010 a drastic decline in optimism was observed in Italy as elsewhere in Europe (Gaskell et al., 2010). Finally, Bucchi and Neresini (2004) suggested that contextual factors—such as trust in (scientific and political) institutions, good welfare systems, values and cultural roots—play a crucial role in fostering or hindering public support for biotechnologies and other innovations, more than the nature of the innovation itself (see also Bucchi & Neresini, 2002; Gaskell & Gottweis, 2011, on biobanks). In brief, the ambiguously defined field, the co-presence of contrasting and ambivalent positions, and the contextual and cultural specificities are all promising indicators of the likely (imminent or ongoing) emergence of an SR of nanotechnologies in Italy.

Background Scenario: Formal Communications about Nanotechnologies in Italy

The processes of anchoring and objectification, through which people cope with the novelty of

techno-scientific innovations, are driven by various forms of communication, including mass media and policy discourse (i.e. formal communication, Bauer & Gaskell, 1999). Indeed, the theory of SRs focuses on how language and communication reproduce and transform techno-scientific innovations, thereby producing new SRs (Bauer & Gaskell, 2008; Castro & Gomes, 2005; Moscovici, 1993; Wagner & Kronberger, 2001).

Especially in modern societies—'characterized by the mobility [...] the diversity of social groups, a high degree of reflexivity [...] the massive and widespread circulation of information through the development of the mass media [...] the liberal principles of equal access to, and full visibility in, the public sphere' (Jovchelovitch, 2001, p. 171)—the analysis of different *modes* of communication (i.e., formal and informal) becomes an imperative for the study of collective imagery (Bauer & Gaskell, 1999), since new social phenomena may capture the attention of a wide section of the public within a short time. The interconnected interests in different spheres of the modern public enable rapid shifts from common sense to scientific beliefs (and back). This provides an opportunity to deconstruct old SRs or, as in the current research, to construct new ones (Howarth, 2006; Joffe, 1995; Jovchelovitch, 1997).

Nevertheless, neither empirical research on formal communications about nanotechnologies, nor attempts to study the mutual relationships between formal and informal communications, have been frequent. In order to fill this gap and provide an adequate framework within which the present study could take place, we conducted a preliminary analysis of the background scenario regarding policymaking and media coverage. In particular, we took into account parliamentary debates (1 January 2000–31 December 2014) and national press coverage (1 January 2000–31 December 2015) that mentioned the term 'nanotechnologies' (Figure 1).

Parliamentary Debates

Regarding the parliamentary debates, we reviewed 92 verbatim reports and related official documents of sittings of the Italian Parliament (47 in the Chamber of Deputies and 45 in the Senate) (Figure 1). The term 'nanotechnologies' appeared for the first time in the Chamber of Deputies in 2002. In the following years, discussions about the topic ranged from a minimum of three to a maximum of 10 debates per year. Given the concurrently high level of attention paid in the international and European contexts (Nordmann, 2004; Roco & Bainbridge, 2002), these values can be interpreted as very low. This limited discussion about nanotechnologies did not allow us to identify real peaks in attention; they remained a marginal topic in the Italian Parliament during the whole timespan under consideration, from their appearance to the present day.

Nevertheless, given that limited discussion does not necessarily entail a lack of evaluation, we also looked at how politicians referred to nanotechnologies. Indeed, potential clashes of opinion are of interest for studying the emergence process of new SRs. Nanotechnologies were mostly evaluated positively (48 sentences, 52.2%); however, neutral evaluations were frequently present as well (39, 42.4%). No discussion gave a negative evaluation to nanotechnologies, but since 2008, some debates began to propose an ambivalent view of the topic (5, 5.4%). The criticisms mostly regard the potential long-term risks for health, the massive use in agriculture (in this case, it is worth noting the strong overlap between nanotechnologies and genetically modified organisms), the associated experimentation on animals in the medical field and related ethical issues, and their possibly dangerous application in the military sector. Interestingly, the general idea of nanotechnologies and the recent critical voices seem not to vary between political actors (i.e. in relation to their parties and orientations) (see Brondi, Sarrica, Caramis, Piccolo, & Mazzara, 2016, for a discussion of a similar pattern in Italian politicians in relation to energy sustainability).

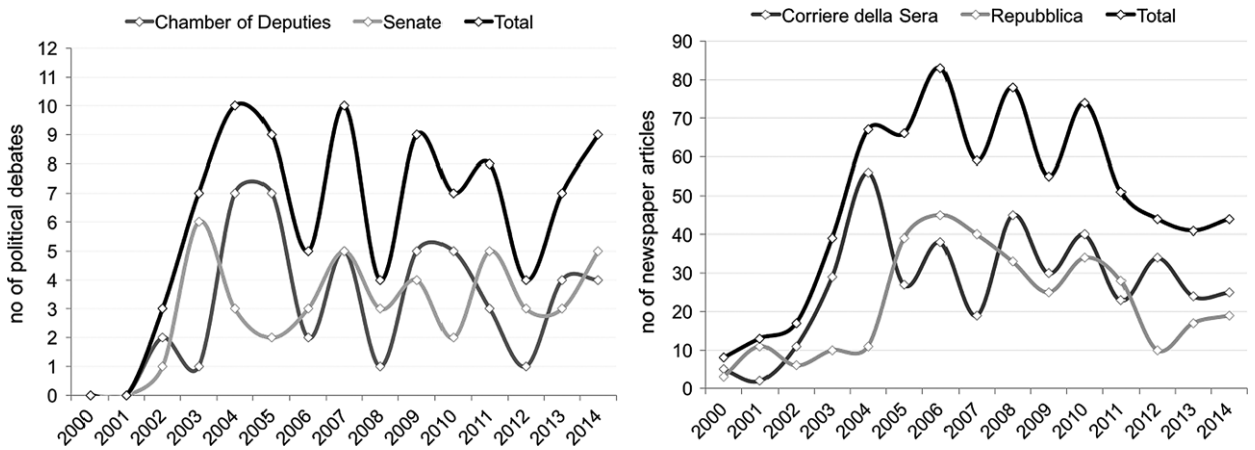

Fig. 1: Trends of parliamentary debates (left side) and press coverage (right side) about nanotechnologies over time

National Press

Regarding the national press, we reviewed 739 articles from the two most widely printed newspapers in Italy (331 from *La Repubblica* and 408 from *Il Corriere della Sera*) (Figure 1). Although these newspapers are not explicitly politically oriented, they cannot be considered totally independent either: *La Repubblica* is left-wing oriented, while *Il Corriere della Sera* is traditionally the newspaper of the bourgeois. However, differences between the two newspapers considered are not very clear.

The press coverage on nanotechnologies illustrates that the two newspapers began to address the topic for the first time in 2000 and continued to write about it —with a steady increase—until 2006, when nanotechnologies reached the maximum level of attention (83 newspaper articles, 45 in *La Repubblica* and 38 in *Il Corriere della Sera*). In subsequent years, the interest followed a fluctuating trend until 2010, when the press coverage began slowly and progressively to decrease. Looking at this general trend, similar to what was observed in the parliamentary debates, it is possible to state that nanotechnologies are still an underrepresented topic in the media, especially when compared with other issues (e.g. see Sarrica, Brondi, & Cottone, 2014, on energy sustainability).

Nevertheless, considering the lexicon of the articles, it should be noted that nanotechnologies are increasingly becoming a controversial issue. We developed an indicator, which we named 'risk indicator', to measure to what extent specific terms from a list of words concerning the semantic field of risk were present in the articles.[1] Tracing the trend of this indicator across years, some interesting patterns emerge. Risk follows a rather discontinuous pattern, with a minimum value in 2007 (0.009) and two notable peaks in 2012 (0.022) and 2015 (0.032). However, starting from 2007, references to risk constantly increase within the articles about nanotechnologies (see Figure A1 in the Appendix S1).

To conclude, our review of formal communications, both parliamentary debates and national press, can be interpreted as initial evidence for debate and dispute about the topic. This may indicate a first step in the emergence process of an SR of nanotechnologies, by introducing some controversial elements that reveal light-and-shade aspects as well as the presence of different positions about them.

[1]The list of words was obtained by analyzing a sample of articles related to science and technology in which the dimension of risk was clearly explicit and by extracting the most discriminative 16 words using a widely used information retrieval measure based on term frequency (i.e. TF*IDF). The indicator counts the occurrences of a word in an article, normalised by the number of words in the list and the length of the article. More details about the indicator are available at the TIPS project website (a guest account is available upon request): http://purl.org/tips.

Aims of the Current Study

The overarching goal of this study is to investigate the core processes involved in shaping emerging SRs of techno-scientific innovations. Following Wagner et al. (2002), the guiding question is therefore 'how a country's public develops an everyday understanding of a new technology' (p. 323), by exploring the case of nanotechnologies in Italy. Specifically, a cross-sectional study comparing two points in time (2006 and 2011) examines the emerging SR fostered by the Italian public. This provides a means to observe the two generative processes of anchoring and objectification 'in action', addressing the following questions: What is the relationship between these two processes? Do they occur in parallel, or does one process become more salient than the other in specific conditions?

This overarching goal entails several specific research questions, which serve both theoretical and methodological aims, in addition to their societal importance:

Our first aim was to investigate the *intra-representational processes* involved in shaping the emerging SR of nanotechnologies. This implies examining changes over time and differences among social groups in the emergence process, to address the following research questions: When does a new SR emerge? And how does it develop over time? Who contributes to its emergence and development? We expected to identify different representational pathways across the two time-points as well as diverse ways of dealing with the object by different social groups. Consequently, we assumed that such different views—and the potential clashes among them—may provide valuable indicators of the emergence of an SR of nanotechnologies.

Our second aim was to investigate the *inter-representational processes* involved in shaping the emerging SR of nanotechnologies. This implies examining the role of neighboring pre-existing SRs in the emergence process, to address the following research question: Why does a new SR take precisely the form it does, from all the others possible? In other words, why do some elements become part of the SR while others are left out? We expected to detect ever-changing inter-representational relationships with two neighboring SRs—of science and of technology—which would orient the emerging content and structure of the new SR of nanotechnologies. Consequently, we assumed that such relationships—and their transformations over time—would provide valuable indicators of the shape assumed by the emerging SR of nanotechnologies.

Method

Two cross-sectional surveys were conducted in Italy in 2006 and 2011 (Brondi & Neresini, 2017). We conducted a second survey five years after the first one in consideration of the discontinuous background scenario described above (see also Gaskell et al., 2010).

Some substantial differences were observed in the way of dealing with nanotechnologies between these two points; we thus assumed that some relevant insights for the study of the emerging SR of nanotechnologies could be indicated.

Instrument

The questionnaire consisted of multiple response free association tasks, followed by closed-ended questions and social and personal information.

Free association tasks. First, participants responded to the word-stimuli NANOTECHNOLOGIES, SCIENCE, and/or TECHNOLOGY by answering questions in the form of 'what comes to your mind when you hear the word ...' and then reporting the first (up to 10) words that spontaneously emerged in their mind. The questionnaire in 2006 began with three word-stimuli in a fixed order (NANOTECHNOLOGIES, SCIENCE, and TECHNOLOGY), while the questionnaire in 2011 presented those three words in four combinations (NANOTECHNOLOGIES and SCIENCE, SCIENCE and NANOTECHNOLOGIES, NANOTECHNOLOGIES and TECHNOLOGY, and TECHNOLOGY and NANOTECHNOLOGIES) in order to check whether the presentation order of the word-stimuli had an effect. Since this had no statistically significant effects on participants' answers,[2] results will be presented together, without distinguishing between the four versions of the 2011 questionnaire.

Nanotechnologies awareness. In order to assess the relationship between levels of 'nanotechnologies awareness' and social perceptions, closed-ended questions inspired by Gaskell, Allum, and Stares (2003; see also Gaskell et al., 2010) were introduced. Two questions investigated the 'familiarity' with the topic: 'Have you ever talked about or discussed nanotechnologies with anyone?' and 'Have you ever heard or read anything about nanotechnologies?' (the possible answers were 'yes' or 'no'). Then, other questions investigated the 'engagement' in nanotechnologies, by examining the sources of information employed to acquire scientific knowledge about the topic: 'Do you usually read...' newspapers, newspapers' Science & Technology sections and popular science magazines, and 'Do you usually follow...' TV/radio newscasts and TV/radio scientific programmes (the possible answers were reported on a four-points frequency scale and then reduced to the categories 'yes' or 'no', where 'yes' corresponded to the answers 'often' and 'always' and 'no' corresponded to the answers 'rarely' and 'never').[3]

Demographics. Finally, in order to relate experiences and perceptions to structural and sociological variables, the last section of the questionnaire collected social and personal information about the participants' characteristics: gender, age and educational qualification.

Participants

The surveys involved a non-probability quota sample of 732 participants (246 in 2006 and 486 in 2011), balanced according to gender (male and female), age (four groups: 15–29, 30–44, 45–59, and over 60 years old), and educational qualification (three levels: compulsory school diploma, high school diploma, and university degree). In order to guarantee an equal geographical distribution of the sample, participants were recruited in five Italian cities (Turin for the Northwest, Padua for the Northeast, Rome for the Centre, Naples for the South, and Cagliari for the islands).

The survey in 2011 maintained the same quota sample, but participants were randomly assigned to four groups, who received the four versions of the questionnaire previously described.

Procedure

Participants were asked to complete the self-report questionnaire in the presence of a researcher, who had the task of providing information about the general purpose of the study and the compilation methods. A convenience sampling method was adopted to recruit the required number of participants from each stratum, both in 2006 and 2011. More precisely, a snowballing procedure was used: the researcher selected a few participants and asked whether they knew of anybody with the characteristics that were needed to fill each stratum. Participation was voluntary, and participants were guaranteed privacy protection according to the ethical standards currently in force in Italy with regard to social and psychological

[2]The analysis of specificities (Bolasco, 1999), aimed at identifying whether and how much a word is characteristic of certain partitions of the corpus, was carried out in order to check order effects. This analysis, based on the hypergeometric function, assumes an equal distribution of the words in the texts. The variances between expected and observed appearances of the words are tested probabilistically and test-values are computed. In this study, four partitions of the corpus, which correspond to the four combinations of the word-stimuli presented by the questionnaires, were taken into account for the analysis. No characteristic lexical form emerged, that is, each lexical form has a test-value lower than 1.96, in absolute value. Additionally, all the analyses presented in the article were replicated by restricting the 2011 sample to those participants who responded to the word-stimulus NANOTECHNOLOGIES first. The results were largely confirmed, with just a few very minor differences, which however would not change the interpretations provided in the text (see the online supplementary materials, Appendix S2, for further details).

[3]We adopted the notions of 'awareness', 'familiarity' and 'engagement' as proposed by Gaskell et al. (2003, 2010) for comparison reasons. However, it should be noted that such notions are similar to those of 'personal involvement' and 'practices' (e.g. Gruev-Vintila & Rouquette, 2007), which play a well-recognized role in the emergence process of new SRs.

research. In particular, informed consent was obtained from participants.

Results

Nanotechnologies Awareness

We determined nanotechnologies awareness by examining the responses to the closed-ended questions. In particular, we took into account the frequencies of familiarity with nanotechnologies and engagement in nanotechnologies, and their comparisons over time.

Self-reported familiarity with the topic remained unchanged between 2006 and 2011 (Table 1). When asked whether or not participants had ever talked of or discussed nanotechnologies with someone, less than a third of them answered in the affirmative. However, when asked whether or not they had ever heard or read something about nanotechnologies, more than half of the respondents answered 'yes'. These results are in line with the data and trends reported by Gaskell et al. (2003, 2010).

Concerning the engagement in the topic, results show an unexpected trend across time, which might be interpreted as a gradual waning of interest in techno-scientific topics (Table 1). When asked about the sources of information usually employed, on the one hand, the *generalist* sources (newspapers and TV/radio newscasts) maintained their priority role over the years with no statistically significant differences; on the other hand, the sources specifically focused on scientific and/or technological issues (*focused* from now on) (newspapers' Science & Technology sections, popular science magazines, TV/radio scientific programmes)—touched on in 2006—suffered a very sharp decline in 2011.

Considering the background scenario and the rather low coverage of nanotechnologies by the press, the public seems to be in a way left alone in the process of familiarization with this novelty. Thus, the public has to construct its own universe of meanings, drawing on the currently available interpretative resources.

Nanotechnologies Vocabulary

Intra- and inter-representational processes were explored by analyzing the responses to the free association tasks. Specifically, the content and field of the representation of nanotechnologies and their changes over time were considered. To this end, textual data were submitted to different analyses with the support of Spad (Lebart, Morineau, Becue, & Haeusler, 1989) and Evoc (Vergès, 1992) software.

Preliminarily, a vocabulary was created and diversity and rarity indexes (Flament & Rouquette, 2003) were calculated. Then, the vocabulary was processed to reduce data dispersion. Four independent judges (i.e. research team members, with a background in social psychology or in sociology, actively involved in the project and trained for the task) carried out a preliminary equivalence treatment of the texts aimed at merging synonyms. The reliability of this process was enhanced by discussing all mergers among the judges, so as to reach consensus.

Information about the original and resulting (after preliminary equivalence treatment of the texts) vocabularies about nanotechnologies in 2006 and 2011 is summarised in Table 2. This information indicates the suitability of both samples' and corpora's dimensions for carrying out the analyses mentioned below (see Wachelke & Wolter, 2011; for prototypical analysis, and Deschamps, 2003, for lexical correspondence analysis).

Table 1. NT awareness: Familiarity and engagement

	2006		2011	
NT awareness	Yes	No	Yes	No
Familiarity				
Talked of/Discussed NT ($\chi^2(1) = 2.95$, $p = .086$)	71 (28.9%)	175 (71.1%)	112 (23.0%)	374 (77.0%)
Heard/Read about NT ($\chi^2(1) = 0.67$, $p = .412$)	148 (60.2%)	98 (39.8%)	277 (57.0%)	209 (43.0%)
Engagement				
Generalist sources of information				
Newspapers ($\chi^2(1) = 0.01$, $p = .934$)	192 (78.0%)	54 (22.0%)	378 (77.8%)	108 (22.2%)
TV/Radio newscasts ($\chi^2(1) = 2.54$, $p = .111$)	226 (91.9%)	19 (7.7%)	429 (88.3%)	56 (11.5%)
Focused sources of information				
Newspapers' S&T sections* ($\chi^2(1) = 9.42$, $p = .002$)	162 (65.9%)	82 (33.3%)	265 (54.5%)	221 (45.5%)
Popular science magazines* ($\chi^2(1) = 11.95$, $p = .001$)	88 (35.8%)	158 (64.2%)	115 (23.7%)	371 (76.3%)
TV/radio scientific programmes* ($\chi^2(1) = 58.73$, $p < .001$)	135 (54.9%)	111 (45.1%)	127 (26.1%)	359 (73.9%)

Note: In cells the number of respondents and—in brackets—the percentage computed by row.
*χ^2 test is significant for $p < .005$, Bonferroni correction is applied for all the pairwise comparisons in relation to 'engagement' (i.e. $5 \times 4/2 = 10$).

Table 2. Corpora in 2006 and 2011

	2006	2011
Number of participants	246	486
Original vocabulary		
Number of occurrences (N)	1,234	1,859
Number of distinct words (Types) (T)	513	775
Number of single-occurrence words (Hapax) (H)	361	576
Diversity index (T/N)	0.416	0.417
Rarity index (H/T)	0.704	0.743
Resulting vocabulary		
Number of words (N)	1,234	1,859
Number of distinct words (Types) (T)	245	360
Number of single-occurrence words (Hapax) (H)	113	171

Note: Regarding the resulting vocabulary, diversity index is 0.198 in 2006 and 0.194 in 2011, and rarity index is 0.461 in 2006 and 0.475 in 2011. However, these indexes do not provide any useful information on the level of sharing and consensus about the object because they strongly depend on the preliminary equivalence treatment of the texts carried out by the researchers; therefore, they will not be commented in the text.

The original vocabularies about nanotechnologies in 2006 and 2011 have the same diversity values. Concerning rarity, in 2011 participants evoke single-occurrence lexical forms slightly more than in 2006. Note that, regarding both indexes, values close to 1 usually indicate the absence of an organized SR. Their quite high values thus may be interpreted as a preliminary indicator of an idea of nanotechnologies which is not broadly shared, stable or consensual, and remains so across time.

Intra-Representational Processes over Time

Our first main aim was to investigate the *intra-representational processes* involved in shaping the emerging SR of nanotechnologies. To this end, we adopted a temporal perspective, analyzing whether and how the content and field of the representation of nanotechnologies evolved and became organized over time.

Representational content. We used prototypical analysis, that is, the 'rank-frequency' method (Vergès, 1994), to define the content of the representation of nanotechnologies in 2006 and 2011 (Figure 2; see also Tables A1 and A2 in the Appendix S1 for further details about the frequencies and evocation rankings of each lexical form). This allows for the definition of four quadrants by considering the cross-tabulation of two criteria (frequency and the appearance evocation ranking of the associations), as illustrated in Table 3. Prototypical analysis was accompanied by formal statistical analyses comparing mean evocation rankings and frequencies of each element in 2006 and 2011 (i.e. *t*-tests and analysis of specificities, respectively).

Note that the 'rank-frequency' method allows for the proposal of hypotheses about the potential candidates for the central core, but it does not provide a precise assessment of the structure of the representation. Thus, results should be read with this caveat in mind. The evocation ranking and frequency distributions allow for the definition of the cut-offs, required to compose the four quadrants shown in Table 3. No norm, theoretically or methodologically driven, exists to define these cut-offs. Dany, Urdapilleta, and Lo Monaco (2014) discussed this issue extensively and highlighted that 'in practice, the descriptive analysis of the corpus guides the definition of this threshold. And so, this varies according to the studies, without mention of the elements which led to its definition. [...] in the majority of cases the threshold used is not justified' (p. 495). The authors supported their statements by referring to several works that adopted very different cut-off values (see also Wachelke & Wolter, 2011, on this issue).

In this study, we tried to overcome this criticism as follows. Given the comparative purpose of the study, identical cut-offs were defined for both corpora (i.e. 2006 and 2011). For doing so, first, the Kolmogorov–Smirnov (K-S) test was used to check whether the two corpora came from the same distribution and might be thus compared. Since they did not differ significantly ($D = 0.046$, $p = .085$),[4] we created a combined corpus by computing composite scores both for evocation ranking and frequency (weighted for the total number of participants, i.e. the proportion, expressed as a percentage, of participants who evoked each lexical form). Then, regarding evocation ranking, the mean of the combined corpus was used as the cut-off both in 2006 and 2011. This choice is in line with that most often adopted in the literature. Regarding frequency, the cumulative distribution of the combined corpus has been taken into account and the value that split the distribution into two equal parts used as the cut-off. This choice—among many others adopted in the literature (e.g. mean, tertiles, cut-offs based on Zipf's law)—is coherent with the aims of the study as well as with the hypothesis of an emerging SR that is only weakly structured, since it allows for a greater inclusion of elements within the quadrants and a more precise exploration of their mutual variability over time. These values were computed and assessed through a bootstrapping procedure (with 1,000 resamples). The resulting values were: regarding frequency, 27 (95% CI [25, 29]; $SE = 0.066$), which corresponds to 3.64% of participants (i.e. frequency = 9 in 2006 and 18 in 2011); regarding evocation rank, 3.22 (95% CI [3.18, 3.26]; $SE = 0.002$).

[4]Moreover, similarly, all the sub-corpora made up of the lexical forms in each of the 10 evocation rankings did not differ significantly either: sub-corpora of lexical forms first-evoked, $D = 0.103$, $p = .069$; second-evoked, $D = 0.091$, $p = .164$; third-evoked, $D = 0.067$, $p = .595$; fourth-evoked, $D = 0.060$, $p = .832$; fifth evoked, $D = 0.117$, $p = .239$, sixth evoked, $D = 0.149$, $p = .200$; seventh-evoked, $D = 0.099$, $p = .885$; eighth-evoked, $D = 0.136$, $p = .817$; ninth-evoked, $D = 0.288$, $p = .481$; tenth-evoked, $D = 0.240$, $p = .940$.

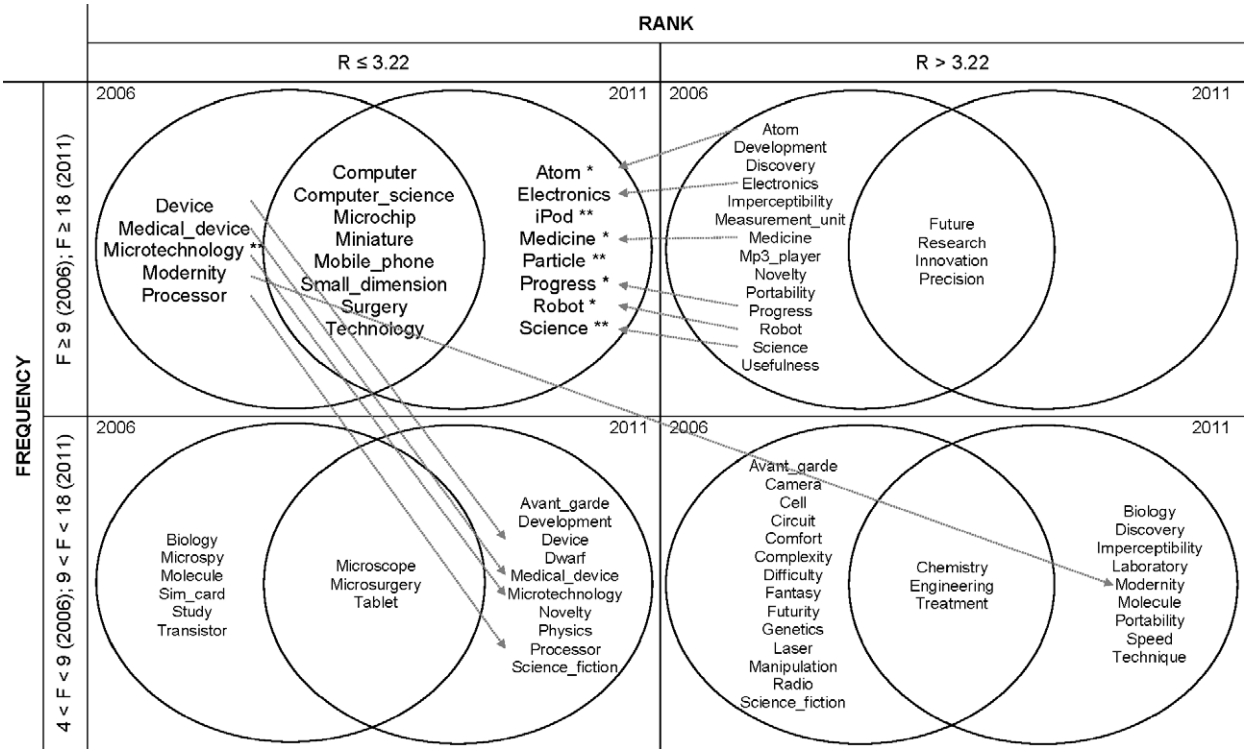

Fig. 2: Contents of the representation of nanotechnologies in 2006 (left circles) and 2011 (right circles)
Notes: * The difference between mean evocation ranking in 2006 and 2011 is statistically significant ($p < .05$). ** the difference between frequency in 2006 and 2011 is statistically significant ($p < .05$); for readability reasons the least frequent lexical forms (<4 in 2006 and <9 in 2011) are not reported.

Table 3. Example of prototypical analysis

	Appearance evocation ranking	
Frequency	Low—First-evoked associations	High—Late-evoked associations
High—Most frequent associations	Quadrant 1—Elements possibly belonging to the central core zone	Quadrant 2—Seemingly contradictory elements belonging to the potential change zone
Low—Least frequent associations	Quadrant 3—Seemingly contradictory elements belonging to the potential change zone	Quadrant 4—Elements belonging to the periphery

Observing Quadrant 1 (top left) in Figure 2, it may be noticed that the possible central core of the representation of nanotechnologies seems to become stronger over time, with the loss of just 5 out of 13 elements, and the acquisition of 8 new ones. The lexical forms within the intersection of the two circles represent the common elements of the central cores in the two years considered. The prefix 'nano' (more than the root 'technologies') seems to play a major role in shaping the idea of nanotechnologies. Indeed, associations related to their 'smallness' (*miniature* and *small_dimension*) are the most frequent and most often first-evoked words. Other lexical forms in this overlapping area include associations mainly referring to their fields of application (*computer_science* and *surgery*) and related devices (*computer*, *microchip*, *mobile_phone* and *technology*).

Instead, the lexical forms in the circles' marginal sections represent the elements of the central cores that differentiate each year. On the one hand, the elements *device* (test-value = −1.025, $p = .153$), *medical_device* (test-value = −0.277, $p = .391$), *processor* (test-value = −0.589, $p = .278$), and, in a statistically significant way, *microtechnology* (test-value = −2.184, $p = .014$)—candidates for the central core of the representation in 2006—move to the potential change zone in Quadrant 3 (bottom left) in 2011, by decreasing their frequency. Moreover, the element *modernity* (test-value = −0.481, $p = .315$; $t(22) = 1.892$, $p = .072$) moves directly to the periphery in Quadrant 4 (bottom right), by changing both frequency and evocation rank. On the other hand, into the central core of the representation in 2011 come six elements from the potential change zone in Quadrant 2 (top right) in 2006, by decreasing their evocation rank. In addition to *particle* (test-value = 3.465, $p < .001$) and *iPod* (test-value = 2.397, $p = .008$; note that the so-called iPod nano© was becoming very common in Italy at this

time), which significantly increase their frequency, such elements are: *Atom* ($t(37) = -2.156$, $p = .037$), *electronics* ($t(41) = -0.596$, $p = .554$), *medicine* ($t(101) = -3.139$, $p = .002$), *progress* ($t(90) = -3.363$, $p = .001$), *robot* ($t(38) = -2.586$, $p = .014$), and *science* ($t(65) = -1.935$, $p = .057$), which also significantly increases its frequency (test-value = 2.523, $p = .006$). The entry of the lexical form *science* among the elements that possibly belong to the central core in 2011 is worth noting for the subsequent analysis on inter-representational processes.

Figure 3 shows how the elements are displayed on the factorial plane, with a specific zoom on the possible central core zone and its changes over time. It is worth noting that most of the elements that have entered or left the central core between 2006 and 2011 are positioned quite distantly from the boundaries imposed by the cut-offs, giving some reassurance about the somewhat arbitrary definition of these values.

In short, the possible central core of the representation of nanotechnologies, rather than thoroughly changing, seems to become stronger by modifying only a few elements and introducing new ones. In 2006, the overall content includes possibly central elements mainly associated with small technological devices applied to different fields of engineering. In 2011, the content acquires some possibly central elements referring to natural and life sciences and to the idea of progress.

Representational field. We used lexical correspondence analysis (Lebart, Salem, & Berry, 1998) to map the representational field of nanotechnologies, illustrating some statistically significant variations in positioning by year (Figure 4; see also Table A3 and Table A4 in the Appendix S1 for further details of the dimensions' composition). This is a multivariate technique that applies correspondence analysis to textual data (Benzécri, 1973). It allows for a synthesis of the data on the factorial plane. The axes can be interpreted as semantic dimensions through which to read the corpus: In fact, proximity among lexical forms on the factorial plane refers to a combination of associations in the text, and exploring associations among lexical forms contributes to the description of the corpus. All the lexical forms (i.e. active variables) take part in determining factors, with different absolute contributions (i.e. the portion of the total inertia of the factor explained by a variable). The supplementary variables (i.e. the year, in this case) position themselves on the factorial planes as well. However, since they do not take part in explaining the inertia of factors, they do not have absolute contributions. Therefore, their statistical significance (i.e. the significance of their position on the factorial plane in terms of distance from the origin) is assessed by computing a test-value, factor by factor. Only those variables with a test-value higher than 1.96, in absolute value, are statistically significant.

The first dimension (x axis) is mainly determined by descriptive elements, which provide an overall neutral, or possibly positive, 'picture' of nanotechnologies. This opposes what we called 'technological devices and their components' on one pole to 'scientific fields and their potentialities' on the other. In particular, the 'technological devices and their components' pole (negative semi-axis)—which prevails in terms of absolute contribution if compared with the other—is mostly explained by concrete objects (*mobile_phone*, *iPod*, *computer*, *videogame*, *mp3_player*, *TV*, *tablet*, *household_appliance*, *radio*, *watch*, *microspy*, *camera*, *videocamera*) or parts of them (*microchip*, *electronic_card*, *memory_card*, *processor*, *transistor*), which can be

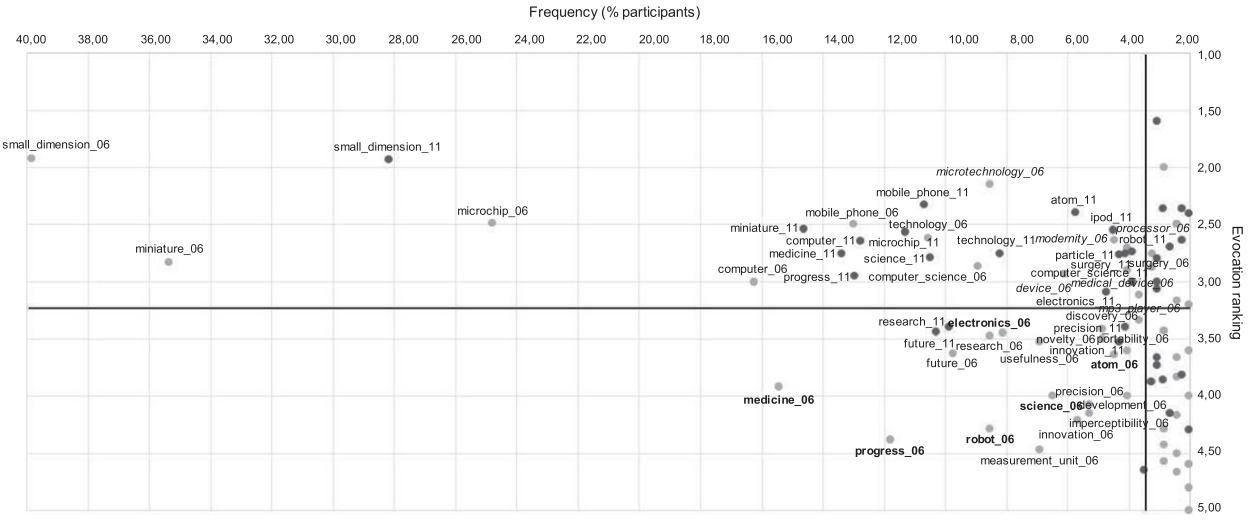

Fig. 3: Zoom on the possible central core zone and its changes over time

Notes: The light grey points refer to 2006; the dark grey points refer to 2011; the black lines trace the boundaries between the four quadrants in correspondence with the cut-off values; the lexical forms in bold type indicate the elements that have entered the possible central core zone over time; the lexical forms in italics type indicate the elements that have left the possible central core zone over time.

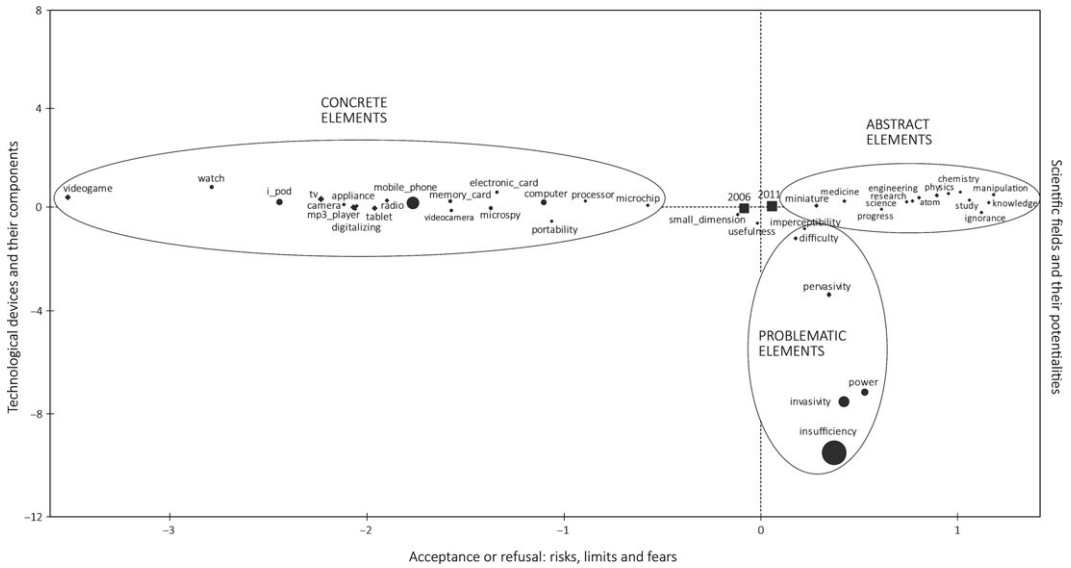

Fig. 4: Representational field of nanotechnologies by year: First (*x* axis) and second (*y* axis) dimensions
Notes: The points represent the active variables (i.e. the lexical forms) and the points' size is proportional to the value of the absolute contribution (A.C.); only those active variables with A.C. >100/T (Types, number of distinct words) are displayed; the squares represent the positioning of the supplementary variables on the factorial plane; only those supplementary variables with a test-value higher than 1.96, in absolute value, are displayed.

referred to together as 'portable digital devices' (*portability*, *digitalizing*). This idea of nanotechnologies is significantly ascribable to 2006 (test-value = −3.6). Contrarily, the 'scientific fields and their potentialities' pole (positive semi-axis) is especially characterized by abstract features, including areas of application (*research*, *science*, *chemistry*, *medicine*, *study*, *physics*, *engineering*) or related subjects (*atom*, *molecule*, *laboratory*) and their potentialities (*progress*, *innovation*, *knowledge*). This idea of nanotechnologies is significantly ascribable to 2011 (test-value = 3.6).

The second dimension (*y* axis) is mainly constituted by evaluative elements, which give a more controversial 'picture' of nanotechnologies. It is a unipolar dimension, characterized by a single pole that we called 'acceptance or refusal: risks, limits and fears'. In particular, some problematic elements, which include perceived limits (*insufficiency*, *difficulty*) and implicitly underlie scepticism and caution (*invasive*, *power*, *pervasive*, *imperceptibility*) take part in determining the pole (negative semi-axis). The word *usefulness* is the opposite counterpart, and—along with the other elements—contributes to making nanotechnologies a 'hot' object of debate. This view of nanotechnologies is significantly attributable to 2011 (test-value = −2.3).

Thus, the representation of nanotechnologies progressively evolves and gets organized across the years. In 2006, the representational field is constituted by a mere description of the notion composed of concrete objects ascribable to portable digital devices or parts of them. In 2011, the representational field is more focused on abstract features attributable to scientific areas of application and potentialities of nanotechnologies, with the introduction of some controversial elements of evaluation.

Intra-Representational Processes across Social Groups

We have described how the representation of nanotechnologies evolves over time, becoming a more controversial object of debate in 2011. However, to achieve the first aim of the study fully, we also explored who has fostered that change. We used lexical correspondence analysis and we examined the different ways of dealing with the object by the social groups, observing their positioning in the representational field of nanotechnologies. We focused the analysis on 2011 because the preceding analyses showed that only recently nanotechnologies have started to become a contested site for conflicting meanings and, thus, a phenomenon which can be considered a proper object of SR.[5]

We identified social groups (i.e. the supplementary variables) in terms of nanotechnologies awareness, as well as social and personal information. Regarding nanotechnologies awareness, familiarity and

[5]However, a brief account of the results concerning 2006 follows (further details are described in the Appendix S1). The representational field of nanotechnologies is composed by the intersection of two dimensions, which are mainly determined by descriptive elements. The first dimension replicates the opposition between 'technological devices and their components' (participants with lower nanotechnologies awareness, those with only a compulsory school diploma and young adults) and 'scientific fields and their potentialities' (participants with higher nanotechnologies awareness, those with a degree, young and elderly people). The second dimension opposes what we named 'supports for everyday life' (participants with higher nanotechnologies awareness, those with a degree, women and young adults) to 'assets for strategic sectors' (participants with lower nanotechnologies awareness, those with only a compulsory school diploma, men and adults).

engagement with nanotechnologies were considered. Familiarity (or not) includes answers to the questions 'Have you ever talked of or discussed nanotechnologies with anyone?' (abbreviations [TD] or [NOTD] in Figure 5), and 'Have you ever heard or read anything about nanotechnologies?' ([HR] or [NOHR]). Engagement (or not) with nanotechnologies includes answers to the questions about sources of information. Since *focused* (i.e. Science & Technology sections of newspapers [STS] or [NOSTS], popular science magazines [PSM] or [NOPSM], scientific TV or radio programmes [STVP] or [NOSTVP]) and *generalist* (i.e. newspapers [NP] or [NONP] and TV or radio news [TVR] or [NOTVR]) sources of information occasionally provide different positionings, their use (or not) will be discussed separately. Regarding social and personal information, gender (men [MAN] and women [WOM]), age (young people/15–29 years old [YOU], young adults/30–44 years old [YAD], adults/45–59 years old [OAD], and elderly people/60 onwards [OLD]) and educational qualification (compulsory school diploma [CSC], high school diploma [HSC] and degree [DEG]) were included in the analysis.

In 2011, the representational field of nanotechnologies is composed by the intersection of a dimension that is mainly determined by descriptive elements with a dimension mainly constituted by evaluative elements, similar to the combined field reported earlier (Figure 5; see also Tables A5 and A6 in the Appendix S1). The first dimension (*x* axis) opposes 'technological devices and their components' on one pole (negative semi-axis) to 'scientific fields and their potentialities' on the other (positive semi-axis). In particular, participants with lower nanotechnologies awareness—that is, those who are less familiar with nanotechnologies [NOHR] (test-value = −6.2) and less engaged with them [NOSTS] (−5.5) [NOPSM] (−5.9) [NOSTVP] (−5.5)—were more likely to mention concrete objects. Women [WOM] (−2.1), participants with only a compulsory school diploma [CSC] (−8.4) and those who usually use *generalist* sources of information [TVR] (−2.6) significantly share this view also. On the contrary, participants with higher nanotechnologies awareness—that is, more familiar with nanotechnologies [HR] (6.2) and more engaged with them [STS] (5.5) [PSM] (5.9) [STVP] (5.5)—significantly referred to more abstract aspects. This idea is also significantly attributable to men [MAN] (2.1), graduate participants [DEG] (7.3), elderly people [OLD] (3.1) and those who do not usually use *generalist* sources of information [NOTVR] (2.5).

The second dimension (*y* axis) is mainly characterized by evaluative elements, which show a more controversial representation of nanotechnologies, coherently with what emerged from the analysis by year. It is a unipolar dimension, characterized by the pole 'acceptance or refusal: risks, limits and fears'. In particular, participants with higher nanotechnologies awareness—that is, those more familiar with nanotechnologies [TD] (−2.3)—significantly perceive some problematic elements. Participants with a high school diploma [HSC] (−2.2), elderly people [OLD] (−3.2) and those who do not usually use *generalist* sources of information [NOTVR] (−2.1) significantly share this idea too.

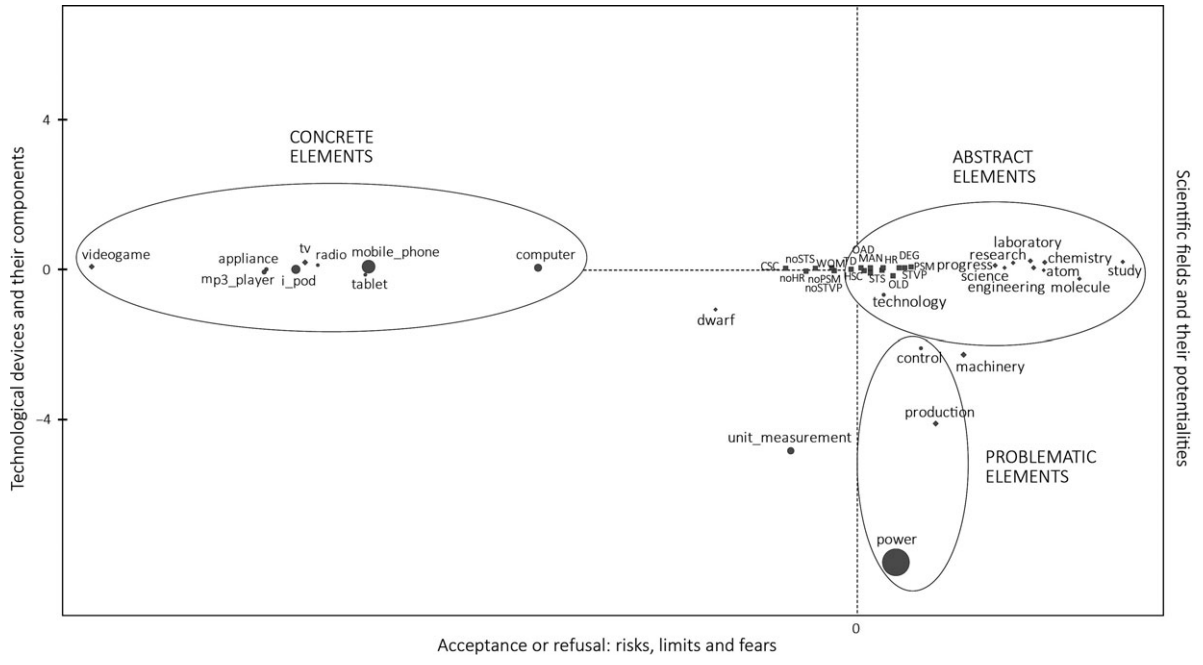

Fig. 5: Representational field of nanotechnologies in 2011: First (*x* axis) and second (*y* axis) dimensions

Notes: The points represent the active variables (i.e. the lexical forms) and the points' size is proportional to the value of the absolute contribution (A.C.); only those active variables with A.C. >100/T (Types, number of distinct words) are displayed; the squares represent the positioning of the supplementary variables on the factorial plane; only those supplementary variables with a test-value higher than 1.96, in absolute value, are displayed.

To sum up, on the one hand, the public less familiar with nanotechnologies and less engaged with them mainly refers to neutral descriptions composed of concrete objects ascribable to the technological domain. People with a lower educational qualification share this representation also. On the other hand, the public more aware of nanotechnologies tends to focus on abstract features attributable to their scientific areas of application and potentialities. People with a higher educational qualification contribute to promoting this representation too. Moreover, such social groups seem also to foster the emergence of controversial evaluations of the notion. Both *focused* and *generalist* sources of information play a role in this process; gender and age are instead not so crucial.

Inter-Representational Processes: Science and Technology

Our second main aim was to investigate the *inter-representational processes* involved in shaping the emerging SR of nanotechnologies. To this end, we used prototypical analysis and we explored similarities and differences among the elements that possibly belong to the central cores of the representation of nanotechnologies and neighboring pre-existing representations (i.e. SR of SCIENCE and SR of TECHNOLOGY), and whether and how they evolve over time. In this regard, it has already been noted that the notions of science and technology may play a role in the emerging process of the representation of nanotechnologies because they become possibly central core elements at different points in time and with varying relevance.

Inter-representational relationships between the possible central core of the representation of nanotechnologies and those of SRs of SCIENCE and TECHNOLOGY remain fairly stable over time and show some interesting features. Figure 6 portrays the overlaps among elements potentially belonging to the central cores of the representations of nanotechnologies, SCIENCE and TECHNOLOGY in 2006 and 2011. While in 2006 the three possible central cores do not share any elements, in 2011 they have in common the idea of *progress*, which was part of the overlapping area between the central cores of SRs of SCIENCE and TECHNOLOGY five years earlier. Contrarily, it should be noted that other (similar) perceived potentialities, which are present in the overlapping area between the central cores of SRs of SCIENCE and TECHNOLOGY in 2006 (i.e. *development*, *discovery*, *future*, *innovation*) or in 2011 (i.e. *development*, *future*, *innovation*, *research*), do not move toward the central core of nanotechnologies.

In 2006 as well as 2011, the central cores of the representations of SCIENCE and nanotechnologies share the reference to *technology*. In addition, the element *medicine* is present in their central cores in 2011. Over time, the SR of SCIENCE thus seems to orient the form of the emerging SR of nanotechnologies toward the field of the life sciences. In the two years considered, the central cores of the representations of TECHNOLOGY and nanotechnologies include the associations with *computer* and *computer_science*, in addition to the elements *device* and *modernity*, which are only present in 2006, and to the elements *mobile_phone* and *science*, which are only present in 2011. It is worth noting that while in 2006 the reference to *science* is part of the central core of the representation of TECHNOLOGY, in 2011 it becomes a central core element of the representation of nanotechnologies, suggesting a change in the way of dealing with this techno-scientific innovation.

This consideration is supported by the Kendall's tau correlations among corpora. Indeed, based on the results, although the coefficients of correlation are

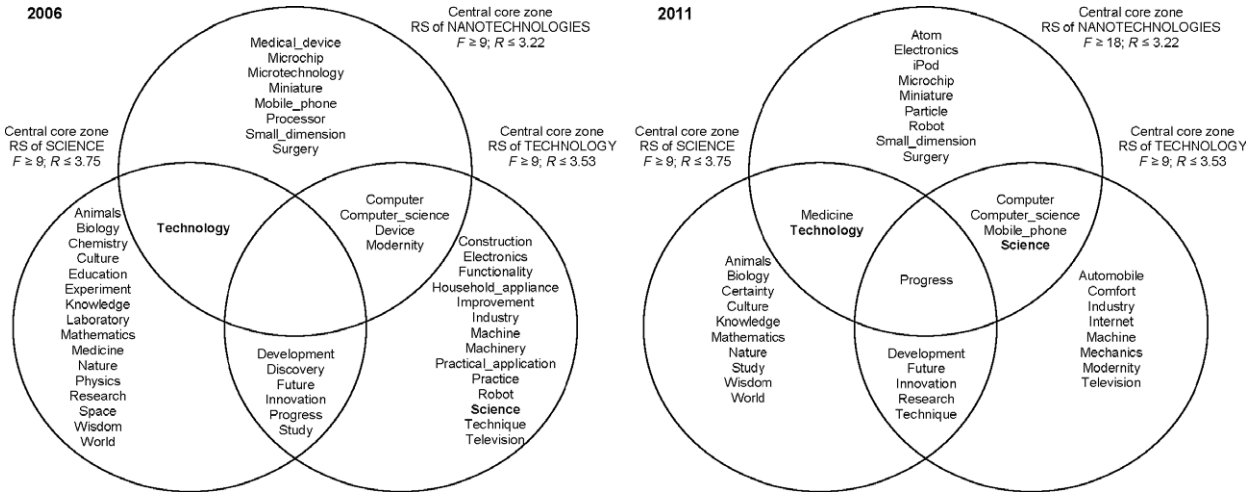

Fig. 6: Relationships among possible central cores of the representations of SCIENCE (bottom left circles), TECHNOLOGY (bottom right circles) and NANOTECHNOLOGIES (top centre circles) in 2006 and 2011

Notes: Cut-off values for SCIENCE and TECHNOLOGY were defined by following the same procedure adopted for NT. Regarding evocation rank, the mean of the combined corpus was used; regarding frequency, the value that corresponds to 3.64% of participants was used for comparative purposes.

rather weak (or weakly moderate), some interesting trends can be observed. On the one hand, the correlation between the lexicon associated with nanotechnologies and that associated with technology remains almost stable across the years (rt = .304, $p < .001$ in 2006 and rt = .302, $p < .001$ in 2011). On the other hand, the correlation between the lexicon associated with nanotechnologies and that associated with science notably increases over time (rt = .206, $p < .001$ in 2006 and rt = .319, $p < .001$ in 2011).

Summing up, the results highlight the important role played by neighboring, pre-existing SRs (i.e. those of SCIENCE and TECHNOLOGY) in the emergence process of the SR of nanotechnologies. On the one hand, the overlaps between the elements that possibly belong to the central core of the representation of nanotechnologies and those of the SR of TECHNOLOGY were to be expected, at least for the similarity between the two words; on the other hand, the increasing importance acquired by the universe of meanings underlying the SR of SCIENCE within the central core of the representation of nanotechnologies is worth noting. Thus, the emerging SR of nanotechnologies, albeit remaining largely autonomous, seems to be increasingly oriented by the SR of SCIENCE and, especially, toward the field of the natural and life sciences.

Discussion

The overarching goal of this study was to investigate the intra- and inter-representational processes involved in shaping the emerging SR of nanotechnologies in Italy. To this end, a cross-sectional study comparing two points in time (i.e. 2006 and 2011) examined the emerging SR fostered by the Italian public over time, also considering the potential roles of 'nanotechnologies awareness' (Gaskell et al., 2003, 2010) expressed by the participants (i.e. familiarity and engagement), their social and personal characteristics (i.e. gender, age and educational qualification), and other, neighboring, pre-existing SRs (i.e. those of science and technology).

Overall, the results of the study point to several movements across the years, which we believe should not be understood as abrupt and radical shifts from one state to another, but rather as progressive and gradual changes within a slow emergence process: From a 'descriptive' to an 'evaluative' approach; from a 'neutral' to a 'controversial' issue; from a 'concrete' to an 'abstract' object; and from a 'technological' to a 'scientific' phenomenon.

Theoretical Remarks: Intra-Representational Processes

Concerning intra-representational processes, our analysis of the emerging SR of nanotechnologies revealed overall changes over time, as well as different ways of dealing with the topic across social groups defined according to their nanotechnologies awareness and sources of information.

The movement from 'neutral descriptions' to 'controversial evaluations' of the notion may indicate that nanotechnologies were initially a 'quiet thing' (Howarth, 2006) and only after many years did nanotechnologies start to become a contested site for conflicting meanings: Thus, clashes among different positions appear, generating a potential SR. The appearance of some controversial elements may be interpreted as an indicator of on-going processes toward the development of SR of nanotechnologies, which finally become 'relevant enough' to be considered a proper object of SR. If not right away—that is, immediately after the first appearance of nanotechnologies in the different spheres of Italian society—yet after some years, an emerging SR can be observed. In this regard, we hypothesize that—although minority—this controversial view may acquire more and more importance in the future; the forthcoming SR thus may be characterized by a more balanced opposition between a neutral description and a critical light-and-shade evaluation of nanotechnologies. This may have potential long-term implications for the entire perception of this techno-scientific innovation, which may become an increasingly controversial matter even many years after its first appearance in Italian society.

This is especially true if we consider that the most 'active' social groups, as those actors who declared themselves to have talked of or discussed nanotechnologies fostered the more critical view. Therefore, given the absence of a stable and broadly shared representation, this can be interpreted as an emerging SR, or a 'representation-in-the-making' (Moscovici, 1988). In this regard, Augoustinos and Penny (2001) suggest that, with time as well as increasing familiarization, engagement and public debate, a contested 'representation-in-the-making' may 'become more centralized and consensualised, solidifying its status as a SR' (p. 16). For this reason, we hypothesize that this more critical view may acquire increasing importance because the most 'active' actors foster it; the forthcoming SR thus may be characterized by a more widespread critical evaluation of their positive and negative nuances. As a result of a process of minority influence, this 'niche' view may clash with other views more broadly shared, contributing to an orientation of the emerging SR towards becoming a highly controversial issue, with potential long-term implications for the overall perception of nanotechnologies.

Formal and informal communications seem to follow parallel representational paths, though with distinctive specificities. Indeed, both modes of communication take some time to start dealing with nanotechnologies. Then, after nanotechnologies have entered the various spheres of Italian society, they are described initially as a neutral, or at most a positive, phenomenon. Finally, during the last few years—similarly to what was highlighted regarding the evaluations of nanotechnologies in formal communications

—in the public's representation too some ambivalent views have begun to emerge with the introduction of some controversial elements, which reveal light-and-shade aspects and suggest discussion and dispute about the topic. Such paths are diachronic within each type of communication examined, but seem to be synchronic between them. Therefore, although the task of defining the specific role of each form of communication is challenging, some mutual influences can be certainly identified.

The movement from 'concrete technologies' to 'abstract sciences' may be interpreted by considering the two generative processes of familiarization (i.e. objectification and anchoring). The longitudinal nature of the study offers an unusual opportunity to observe these processes 'in action''. When people deal with the novelty for the first time, they mainly make references to concrete objects (objectification); on the contrary, when nanotechnologies begin to enter common-sense views, people seem to be able to anchor them to forms of knowledge that were acquired earlier (e.g. SRs of science and technology) (anchoring). In other words, while certainly recognizing the iterative nature through which these processes operate, this movement suggests that objectification becomes more salient than anchoring in the first steps of the emergence of new SRs, at least in the case of techno-scientific innovations.

This hypothesis is further supported by considering the positioning of the different social groups. Indeed, people less aware of the innovation or with lower educational qualifications mainly refer to concrete objects (objectification); instead people more familiar and engaged with nanotechnologies and people with higher educational qualifications seem to be able to anchor them to pre-existing and more abstract forms of knowledge (anchoring). This shift may also indicate that objectification intervenes with greater salience than anchoring at the beginning of the emergence process of SRs, when people are not able to draw on the interpretative resources contained in pre-existing knowledge and made currently available by the social context.

This movement also anticipates the important role played by the neighboring, pre-existing SRs in the emergence process, suggesting a change in the way of dealing with this new form of techno-scientific innovation. This will be explored more broadly below in the discussion of the inter-representational processes involved in shaping the emerging SR of nanotechnologies.

Moreover, the results suggest that frequency may precede accessibility as, from 2006 to 2011, most of the new elements enter from the potential change zone in Quadrant 2 and most of the old elements move to the other potential change zone in Quadrant 3. This means that if an issue is widely raised in the discourse (i.e. mentioned frequently), then it may become more accessible for individuals (i.e. come to mind early). In this regard, we hypothesise that a similar tendency may occur in the future. The forthcoming possible central core of the representation thus may become stronger with abstract elements (e.g. future, innovation, precision, research); in parallel, it may move further its focus toward the scientific domain (e.g. natural and life sciences).

Theoretical Remarks: Inter-Representational Processes

Concerning inter-representational processes, both SR of SCIENCE and SR of TECHNOLOGY—considered here as potentially significant neighboring, pre-existing representations—contribute to developing and orienting the emerging SR of nanotechnologies. Observations above about the process of anchoring have shown that the notions of science and technology play a role in the emergence process of the representation of nanotechnologies. Nevertheless, how explicitly SRs of TECHNOLOGY and SCIENCE orient the shape of the emerging SR of nanotechnologies (and back) is not so clear.

Across the years, SR of SCIENCE especially seems to move the representation of nanotechnologies towards the field of the natural and life sciences, that is, towards an idea of 'good' science, which is in opposition to the controversial emerging representation described above. The idea of progress—which is not, however, necessarily loaded with positive connotations—seems somehow to hide the potential risks and limits of nanotechnologies. This may be understood theoretically in terms of the concept of 'themata', that is, fundamental oppositional categories which have generative and normative power (Moscovici & Vignaux, 1994; see also Markova, 2000). Since themata encompass the idea that laypeople think and communicate by combining conflicting arguments (Castro & Gomes, 2005), the thematic opposition between 'good' and 'evil', in relation to science, may provide a valuable interpretative key for this polarity. The 'good–evil' thema thus evokes the universe of meanings underlying the 'dark side of science' and this is even more interesting because it emerges when the references to natural and life sciences (with their consequences for ethics, health and safety) become more salient.

In this regard, we hypothesise that the forthcoming central core of the representation of nanotechnologies, though maintaining a certain autonomy, may increasingly acquire elements from the universe of meanings underlying the SR of SCIENCE, with a specific focus on the natural and life sciences. We also expect that potential sudden shifts in the SRs of SCIENCE and TECHNOLOGY may substantially modify the overall perception of nanotechnologies, with a potential strong impact on the emerging representation.

Methodological Remarks

At the methodological level, the combined analysis of both content and field of SR of nanotechnologies over time provides relevant insights (Brondi et al., 2012). In particular, the prototypical analysis of the content

has proved to be very effective for investigating the inter-representational processes as well as for making hypotheses about the forthcoming representation; the lexical correspondence analysis of the representational field has shown itself to be very useful for examining intra-representational processes, together with considering the positions of sub-groups.

The results also confirm the value of adopting a comparative and mixed-method (Morgan, 2007) longitudinal approach. Although a five-year timespan may be insufficient to show the progressive organization of the representation (Guimelli, 1989, 1998; Moscovici, 1997; Rouquette & Rateau, 1998), the high degree of variability of the vocabularies in 2006 and 2011 may indicate that the dynamic process underlying the shaping of SR is currently under way, since an emerging SR is characterized precisely by a weak structure (Moliner, 2001). However, further developments of the study are needed to examine the complete organization and evolution of SR. A longer timespan would also allow for the observation of nanotechnologies when they are more dialogized—that is, when the number of people aware of them has increased.

Regarding intra-representational processes, a reflection about the sources of information should be mentioned. The annual reports by the two main Italian research institutes, ISTAT and CENSIS, show that 'digital' sources of information have become increasingly important in the last few years (i.e. since 2012). However, Italy represents a peculiar case, as the digital divide for a wide range of the population still remains considerable: The recent Digital News Report 2015 by the Reuters Institute shows that the ratio between the consumption of 'traditional' and 'digital' news in Italy is 4:1, whereas in other countries it is 2:1 (or even less). Although we can assume that in previous years the ratios were even less balanced, we cannot exclude the possibility that a shift toward digital sources might have occurred from 2006 to 2011. Thus, while carrying out further comparisons may be challenging, on the other hand these 'new' ways of producing and transmitting information cannot be ignored in the future.

Regarding inter-representational processes, a further development of the research may include investigating the relationships between SR of nanotechnologies and other SRs of neighboring, controversial objects (e.g. biotechnologies, genetic modified organisms). As the results suggest, such an expansion of the research would provide a stronger and more explicit contribution to understanding the reasons why some elements enter SR while others are left outside, and to exploring the directions SR may take when oriented by pre-existing problematic knowledge.

Societal Consequences

Finally, although more studies are needed, some practical implications of the study may be suggested. Our study of intra-representational processes highlights the possibility of monitoring the (potential) escalation of problematic and controversial views in the representation of a techno-scientific innovation. Indeed, as this study has shown, these do not necessarily appear when the novelty enters the society, because different social groups cope with it differently. In this regard, such 'niche' views may acquire increased importance over time or by being fostered by the most 'active' actors—becoming a highly controversial object even many years after the novelty's first appearance in the society.

Additionally, the inter-representational processes highlight the possibility of understanding and, if necessary, managing concerns and fears about a techno-scientific innovation before they transform into highly controversial issues, which are not so easy to deal with. Indeed, as this study has shown, pre-existing knowledge plays a crucial role in shaping the representations of new techno-scientific innovations. In this regard, neighboring objects may either foster or hinder ways of dealing with them, by orienting the universe of meanings underlying the novelties. Both possibilities may have potential long-term implications for the overall perception of techno-scientific innovations, with significant consequences for their public acceptance.

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Conflict of Interest

The authors confirm they have no conflict of interest to declare. Authors also confirm that this article adheres to ethical guidelines specified in the APA Code of Conduct as well as the authors' national ethics guidelines.

Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web-site.

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