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Attitudes toward science among the European public: a methodological analysis

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Over the past decade, several influential papers examining the relationship between scientific knowledge and attitudes toward science have been published. The 1992 Eurobarometer has been the preferred source of data for analysis, and a number of suggestive conclusions regarding the extent and nature of the links between knowledge and attitudes have been proposed. Summated scales were built through principal component analysis of the attitudinal items and reliability analysis, but little attention has been paid to the content of the attitudinal items and to the metric and conceptual weaknesses of the scales. A more parsimonious revision of the data, carried out here, shows that the measures used are fuzzy and, as a consequence, the empirical support for some published results is very limited. We suggest that more theoretical effort should be devoted to the design of questionnaires and to the combined use of statistical exploratory techniques and qualitative analysis in the interpretation of the data.

1. Introduction

Over the last two decades, the public understanding of science has evolved into a dynamic, interdisciplinary field of study. The "scientific literacy" (SL) paradigm has been the most formalized and influential approach in this area, not only among researchers, but also among policy-makers. Since the mid-1990s, growing criticism of central assumptions and theses of the SL approach (especially of the so-called "deficit model" and the thesis of a linear dependence of attitudes toward science on knowledge) has opened up the field to a broader research perspective from which a number of suggestive conclusions regarding the extent and nature of the links between knowledge and attitudes have emerged. This more recent literature has also contributed to the creation of a climate in which the call for dialogue with the public on science policy decisions and the design of appropriate institutional arrangements for public participation have assumed central importance. In the current historical context of ever-increasing dependence on science and technology, combined with social unease over some scientific and technological areas, it is therefore all the more important that the results obtained in studies of the public understanding of science be based on a solid theoretical and methodological foundation. In this paper, we will present a detailed critique of the way in which specific statistical methods have been deployed in the study of public attitudes toward science, and the results that have been obtained through these methods. We will suggest in what way the methodological as well as the underlying theoretical apparatus of the field will have to be modified to yield more reliable results and richer interpretations.

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Section 1 will outline the important role that studies of the public understanding of science play in a context of fundamental historical change in the social functions of science and its relation with the public. An awareness of this role is a necessary prerequisite for fully understanding the implications of methodological and theoretical changes in the field itself. Section 2 will present a reconstruction of the path that has been followed in the measurement of attitudes toward science since the late fifties. Section 3 will review the main characteristics of the attitudinal measures included in the preferred database for comparative analysis of public perceptions of science, the so-called "Eurobarometer." Sections 4 and 5 will offer a detailed analysis and critique of methods used in constructing summated attitude scales, exposing their weak level of reliability. Finally, in section 6, we will point to alternative methods and outline a modified theoretical program for the study of the attitudinal dimension of public understanding of science.

2. Scientific knowledge and attitudes toward science

Attitudes toward science and scientific literacy

One of the most central topics in the emergent area of research known as "public understanding of science" is the assessment of the public's scientific knowledge; this issue is interesting in and of itself, but above all in terms of the role that is attributed to the variable of "knowledge" in attitudes toward science, as well as in policy-making about scientific and technological matters. In the tradition of scientific literacy—to date the most highly formalized line of research in this field—one crucial assumption is that a population's grasp of the scientific worldview has fundamental consequences for its attitudes toward science. More specifically, the generally unquestioned assumption has been that the public's positive attitude or consent to science, understood as a form of knowledge of the world, as a central social institution and profession, and as a particular type of approach to practical problems and social demands, depends on the extent of the public's familiarity with scientific content and method. The willingness to participate in public policies involving science, according to this view, is a function of individuals' perceptions of themselves as knowledgeable in certain scientific areas, and the quality of the public's input into the decision-making process depends on the attainment of a certain scientific knowledge threshold.

This assumption on the part of some influential researchers is shared by the scientific community, which, following a principle of "enlightened cognitivism," often attributes signs of social resistance to certain scientific advances to the public's or the decision-makers' lack of scientific knowledge and not, for example, to differences in values or in the assessment of the potential usefulness of the scientific application in question. Analysts of the public understanding of science, the scientific community, and policy-makers have tacitly or explicitly agreed that this "cognitive deficit" is undesirable, and this diagnosis has in turn served as a justification for developing programs to correct it. From the late 1950s to the late 1990s, such programs relied mostly on unidirectional communication from professionals to the lay public; only in the most recent phase have the so-called "3 Ds"—dialogue, discussion, and debate between the scientific community and the public—been given greater weight.[1]

The most influential analysis of attitudes toward science (and, less centrally, toward technology) took shape within the conceptual framework of the paradigm labeled "scientific literacy" in the United States and "public understanding of science" in Europe, which crystallized in the late 1980s, although its roots go back to a period almost thirty years earlier. In this paradigm, cognitive dimensions (knowledge of science) were emphasized over evaluative or axiological ones (links of attitudes toward science with other families of attitudes and values).

The seminal 1958 report on *The Public Impact of Science in the Mass Media* identified a poor understanding of what science is about and skepticism about which problems are amenable to scientific understanding and treatment as one of the main roots of a negative or "threat-oriented" vision of science.[2] Science information and, more formally, science education on the part of the public, were found to be inversely related to feelings of high threat by science.[3] Starting with the National Science Board's *Science Indicators 1980* in the United States, Jon D. Miller and collaborators introduced the notion of "attentiveness to science," a composite measure that captures mainly a cognitive dimension, namely the combination of declared interest, declared information, and a minimum of relevant media use to keep informed about science. Since 1980, this measure (obviously closely linked to scientific literacy, even though it is not restricted to knowledge) has been used to account for variations in attitudes to science and technology: the "attentive public" (estimated that year at $\sim 18\%$ of the general public) is more likely to take an active role in controversies and holds more positive general views of science (expectations of benefits and lack of fears) than the rest of the public.[4] John Durant, a leading European researcher of public understanding of science, and his collaborators, were the first to offer an even sharper formulation of the dependence of attitudes on knowledge; in the pages of *Nature*, they claimed that "preliminary analysis of results on these measures [of attitudes] indicates that there are important relationships between public understanding and public attitudes, with a tendency for better-informed respondents to have a more positive general attitude towards science and scientists."[5] Neither this paper nor a slightly more comprehensive presentation of the same evidence with a special section on attitudes offers an analysis of the claimed relationship between scientific knowledge and attitudes toward science.[6]

Generally speaking, the hypothesis that uneasiness about or resistance to science is mainly based on the public's low level of scientific literacy has been suggested in analyses of public understanding of science (particularly those published as *Reports* or preliminary analyses of available data) by juxtaposing empirical assessments of the public's (low) level of scientific knowledge and its (ambivalent or critical) attitudes toward science and technology, rather than by explicit claim and statistical proof. In policy-making circles, this assumption, stripped of the nuances and limitations that accompanied it in the actual statistical analyses, was taken to be a hard and proven fact and was, in turn, fed back to public-understanding researchers as well as to the scientific community at large. But a review of the literature of the 1980s and early 1990s shows that significant progress was made toward a richer and more complex understanding of public attitudes toward science even within the confines of the scientific literacy paradigm. Particularly, the classic problem known since Converse as "non-attitudes" or "lack of structure" (lack of interrelation, consistency, and stability) in the attitudes of large segments of the public, which was originally investigated in terms of political issues, began to be considered in relation to science, i.e., an object that is omnipresent in advanced societies but which generally operates in the background and poses considerable difficulties for understanding.[7] In the early 1980s, Miller *et al.* distinguished three subsets of the public in terms of science and technology, the "attentive," the "interested," and the rest of the public, and explored the differences between these segments.[8] They provided some empirical support for the thesis of a more congenial view of science on the part of the "attentive public" by analyzing the distribution of responses to a number of attitudinal items by degree of attentiveness, as well as by constructing two indexes (one of perceived benefits and the other of risks of science) and examining the corresponding contingency tables and measures of association by attentiveness. Other analyses targeting attitudes toward technology (instead of science and technology lumped together as a homogeneous entity) have addressed a related problem: They question not so much whether general attitudes toward technology exist or not, as what significance and function they might have for predicting attitudes toward particular technological applications.

Since technology today is an extraordinarily complex and varied formal object, the value of measuring general attitudes toward it is extremely limited, according to this line of research, which for the most part has evolved independently of the scientific literacy paradigm. These authors have attempted to find and measure an intermediate level between general attitudes (which are virtually universal but have limited predictive validity) and those concerning very specific technological applications, a level where it would be possible to measure and formalize attitudes toward clusters of technologies that are perceived by the public as sufficiently similar to elicit essentially homogeneous valorations.[9]

Since the mid-1990s, two new lines of work within the SL tradition have emerged. One of them offers a more nuanced vision of public understanding of science in both its cognitive and evaluative dimensions.[10] The other line of work questions some of SL's main assumptions.[11] The latter approach, of special interest in the context of this paper, critically revises the supposedly linear relationship between knowledge and attitudes and points to a more complex image by showing that this relationship is weak and manifests itself above all in effects on attitudinal consistency and discrimination.[12]

Moreover, some of these analysts have gone beyond a cursory exploration of the relationship between knowledge and attitudes vis-à-vis science to offer more substantial interpretations and even outlines of explanatory models such as that of a "postindustrial effect." According to this new interpretation, the relationship knowledge-attitudes takes a curvilinear shape when examined comparatively in several European societies at different levels of development: European countries that score lower on an industrialization index (such as Greece, Portugal, or Spain) exhibit less positive attitudes toward science than more industrialized countries (like Britain or France); but other highly developed countries manifest less positive attitudes that are apparently similar to those in societies with a lower level of industrial development, so that the linear relation turns into a curvilinear one.[13] This result can be explained, according to the authors, by quite different factors: In the case of less industrialized countries, the lack of positive attitudes would be a result of a low level of scientific information, whereas in the case of more industrialized nations, it would be the consequence of an active and critical stance that is based on a high degree of familiarity with science and its impacts.

In later analyses, however, some of these authors have postulated a "chaotic" relationship between knowledge and attitudes in postindustrial societies.[14] Other interpretations, initiated by Georges Gaskell and the same analysts, conclude that the variable of knowledge lacks explanatory power in relation to attitudes toward science and is poorly correlated with them, at least in specific and controversial areas such as biotechnology.[15] Instead, a vast array of factors involving culture, the institutional framework for regulating technologies, trust in the regulator, the intensity and type of media coverage of technological controversies, environmental values, and risk perceptions are postulated to have greater power to explain the different degrees of acceptance (or rejection) of biotechnologies in the United States and Europe.[16] But this alternative analytical perspective, which focuses on particular scientific and technological domains and relies on richer questionnaires, remains to date more a program than a reality. It has not yet evolved beyond a heuristic level that specific analyses will have to explore and implement by means of new and more complex measuring instruments.

Practical implications of studies of the public understanding of science

The degree of association between scientific knowledge and attitudes toward science is far from a mere academic question, but has crucial historical, social, and political implications. It is indeed one of the central questions of late modernity, considering that the public's manifestations of unease about some techno-scientific advances have emerged at a time of extreme dependence of global society on science, its "life-support system," in Burke's apt metaphor.[17] From the onset of modernity, it has been taken for granted that ignorance is the main barrier to the acceptance of social change and material, cognitive, and moral progress.[18] If at the turn of the twenty-first century, attitudes toward science—one of the crucial modern institutions—do not appear to be associated with knowledge, or if this association takes on very different forms depending on which subset of science or intersection of science and society we consider, then it would appear that the main option available to the scientific community and the policy-makers is dialogue with the public, without any prerequisites of scientific knowledge for its involvement in public policy. Techno-scientific expertise and viewpoints based on a mixture of values, "local knowledge," and common sense or background knowledge would then be given equal weight as inputs for decision-making processes.

First-generation analyses of the public understanding of science, even if they were not very sophisticated theoretically and methodologically, helped to reinforce the rationale for programs aimed at improving the public's "scientific literacy." If successful, it was assumed, such programs would yield a wide range of individual and collective benefits, from citizens' private empowerment and macroeconomic advantages all the way to aesthetic benefits (i.e., appreciation of the elegance and beauty of scientific representations of nature). These studies attributed enormously powerful consequences to the public's familiarity with scientific knowledge, which would have a democratizing effect, increasing not only the public's involvement in decision-making processes, but also the effectiveness of these processes themselves. All this would lead, if not to an automatic consensus, then at least to more informed decisions than those from a public without scientific knowledge.[19] But some authors have also foregrounded the enormous challenge to democracy that arises from the combination of a high dependence on science and technology and policy-making processes that increasingly rely on specialized scientific expertise with the participatory demands of a public that is unfamiliar with many dimensions of scientific issues.[20]

In Europe, where public distrust of regulators has recently been triggered by the BSE crisis ("mad cow disease"), the attempt to introduce genetically modified foods into the market, and the outbreak of foot-and-mouth disease, the most recent studies of the public understanding of science have contributed to a quite different mood among policy-makers. The promotion of public awareness and understanding of science has not disappeared as an objective, but a new dimension has emerged that is being given more weight, as is clear from the House of Lords' recent report on *Science and Society.*[21] The report describes the creation of a new, dialogue-based relationship between science and society that blurs the classical borderline between the scientific community and the public in the formulation and implementation of highly complex public policies. The new hypotheses about the absence of significant relations between knowledge and attitudes, stripped of their nuances, have found their way into reports such as this, where the keywords now are "participation," "dialogue," and "consensus." The search for institutional mechanisms and designs that successfully "engage the public" (the title of one chapter in the House of Lords' Report) has become the focal point for a large part of the analytical effort and, above all, for the concrete programs currently underway in various European countries, as well as for several European Commission initiatives. The overall climate appears to have changed, and this has led some analysts, who are otherwise sympathetic to the new mood, to issue warnings about the undesirable consequences of abandoning the traditional SL paradigm all at once.[22]

The "social contract" between science and society

Clearly, one reason why analyses of public attitudes toward science are received with so much interest has to do with a historical change of context for scientific practice and its application to practical problems. This change of context (obviously caused by multiple factors) is fundamental and has far-reaching consequences for the development of science itself as an institution, as well as for the definition and implementation of some central policies for the late-modern period: environment, health, nutrition, energy, transportation, and information technologies, to name only a few.

The relationship between science and the public could be represented by the two halves of a parabola. The first, rising one started with modernity and was propelled forward throughout the nineteenth century by the professionalization and institutionalization of science, which defined it as the exclusive activity of a minority group, clearly differentiating who could be considered a scientist and who was a lay person or, at best, an amateur.[23] This context was characterized by strong social consent to the scientific mission, limited regulation, and a high degree of legitimization that was granted due to the almost universal belief in both the inherent value and the material benefits of scientific progress. This belief was a crucial component of modernist mentality and culture, and it is in this context that the subculture of the scientific community evolved, which still exists today.

With the clear distinction between "scientific community" and "public," the question arose regarding what we might call the "implicit social contract" that determines the interaction between them. By virtue of this tacit contract, the scientific community obtained autonomy in its selection of goals and the development of research, along with an increasing volume of financial and human resources. In return, it contributed to the production of a flood of material goods and services that had been inconceivable only a short time earlier. Through its public decision makers, society accepted the assumption, for the most part without reservation, that material support and non-interference with the scientific community's procedures, no matter how esoteric or anti-natural they might seem, would sooner or later lead to a higher standard of living and a broader range of choices for the majority. The connection between abstract knowledge and the satisfaction of practical necessities always has been, and continues to be, indirect, with many obstacles and fairly significant time lags, as the history of innovation has shown; but during most of the modern period, the link between scientific research and material progress was accepted with unshakable trust.

The first signs of a descent in the parabolic trajectory of the relations between science and public became visible in the aftermath of World War II, but the decline began to manifest itself fully only in the late 1960s and has perpetuated itself into the new century. During this period of late modernity, a new context with two important dimensions has evolved: on one hand—a total dependence on science and technology to sustain economic growth and standards of living—and on the other hand, the emergence of side effects and significant risks that are amplified by the dynamics of public risk perception and the role of the media in technological controversies. In this dual framework, there is conditional consent to scientific goals and modes of operation, depending on the research objectives and in some cases also on the chosen methods (e.g., in the case of animal experimentation); regulatory pressure and external direction through public policies and business strategies have also increased to develop the benefits and control the side effects of so-called "organized innovation."[24] At the same time, cultural ambivalence (and sometimes disenchantment) about progress, rational control, and the epistemological status of science has emerged and has manifested itself in, among other things, a systematic criticism by the "postmodernist" segments of academia and the arts. The scientific community now faces strong pressure to deliver more useful results (less "blue-sky research"), as well as to reduce the risks and side effects of scientific advances ("zero-risk tolerance" in broad social segments of many of the most affluent countries). The selection of research areas, the application of knowledge to practical problems, and questions of research ethics have been opened up to public input.

There is a growing body of literature aimed at charting these radical changes in the characteristics of the scientific enterprise today.[25] Some analysts have even postulated that the "implicit contract" between science and the public is up for renegotiation.[26] But scientists concerned with the public status of science have argued in favor of maintaining or even reinforcing the borderline between the two by foregrounding the cognitive distance that arises as a consequence of the extended and demanding process of socialization in the "grammar of research."[27] According to them, the threshold of "scientific literacy" for grasping techno-scientific advances is so high that it could not in practice be achieved without formal scientific training. The alternative, in their view, would be to construct an institutional architecture of "independent, knowledgeable, and credible advisory groups that can gain the acceptance of the public, assist in the decision-making process, and form a new and productive alliance between the public and the science/technology community."[28] In this context of uncertainties, challenge, and polarization, the conclusions reached by analyses of public attitudes toward science take on a high degree of visibility and relevance.

The course of action that currently seems to have prevailed is unconditional dialogue between the public and the scientific community, and the creation of mechanisms whereby the public can participate in techno-scientific policies and controversies. The problem of insufficient familiarity with the technical aspects of such issues has received less emphasis; instead, a combination or equilibrium between "local knowledge" and scientific knowledge is being sought for.[29]

These experiments in giving "voice" to the public may have value for improving the relationship with scientific experts and building support for complex policies, thereby avoiding the "exit" course of action (in the elegant typology proposed by Hirschman in another context).[30] But it must be emphasized that the net effects of public participation in science policies through mechanisms that involve only a small number of participants remain to be assessed formally; this would require a more systematic effort (particularly to measure their reception by the public at large) than has been undertaken so far.[31] Even more importantly, some of the assumptions underlying the emergent theoretical framework for research on public understanding of science, which these proposals rely on, need to be evaluated. In particular, the links between cognitive and attitudinal variables, between general and specific attitudes, and the structure and stability of attitudes toward science need to be investigated. This will in turn require a reassessment of the measuring instruments as well as of the consistency and validity of the scales which support some of the new theses that have been proposed in public understanding of science in the late 1990s.

Studying attitudes toward science: a methodological critique

The lack of theory in studies of the public understanding of science is one of the major weaknesses that needs to be overcome, and every effort toward building conceptual schemes and testing them with appropriate data should be welcomed.[32] Analyses that have critically examined the supposedly linear dependence of attitudes on knowledge over the last few years are a clear step ahead in this program, and even more so are attempts to relate knowledge and attitudes to the characteristics of the late-modern socioeconomic and cultural context in various countries. Nevertheless, in our judgment, two principal problems remain in some influential analyses published to date. The first one is the attempt to answer empirically questions that were not taken into consideration in the design of the questionnaires that were used to obtain the data. The second and more important one is the application of a simple algorithm to the data analysis that relies on a style of theorizing whose empirical support is only apparent. In reality, it is based on conceptually fuzzy scales and indicators that fall short of the standards generally applied in other areas of social-scientific research. This algorithm for the creation of summated scales consists of the following steps: first, the application of exploratory factor analysis (principal components) to series of items measuring predispositions toward science so as to detect latent attitudinal dimensions; second, a reliability analysis of the items making up these dimensions (Cronbach's Alpha), which almost completely omits any analysis of the content of the items and their theoretical or conceptual commonality. Since there is no explicit theoretical framework to guide the selection of items that are actually included in the questionnaires from the overall range of possible ones, it comes as no surprise that the resulting metric properties of the scales are remarkably weak. Generally, the analyses have foregrounded some of the weaknesses of these scales (low level of "explained variance" of the dimensions extracted by principal component analysis, low-level Cronbach's Alpha coefficient), but this has not prevented them from being used for analytical tasks in the proof of hypotheses and modeling (basically, multiple regression analysis); this procedure has led to conceptually and statistically unclear results that, in our view, do not establish any firm ground for the theoretical strengthening of the field.[33]

Our proposal consists of two main points. The first one is not to abandon the objective of constructing scales of knowledge and attitudes, given the well-known advantages of a robust and multidimensional metric, which in most cases can be derived only from aggregated indicators. The design of these scales will require more theoretical work aligned with a more sophisticated methodology than has been used to date (in terms of questionnaire design, sampling, and fieldwork), with pilot studies and application of all the formal instruments of the psychometric and sociological traditions in the study of attitudes, as well as application of the measurement guidelines for multinational surveys and comparative analysis.[34] Future work should apply more rigorous standards in the documentation of steps and decisions taken in the process of building scales, and the implications of these decisions (treatment of missing values and "middle responses," selection and exclusions of items in the course of exploratory factor analysis, etc.), so that independent researchers can evaluate the quality of the measurements and the embedded assumptions about the data that were fed into the statistical analysis.

The second point is a parsimonious re-examination of the already available data that, though obtained with little theoretical work, constitute a sufficiently rich basis for the exploration of scientific culture in late-modern societies and may at the same time have heuristic value for the design of more robust scales. Analysis of the conceptually richest items in the Eurobarometers (individually and taken together) by means of exploratory statistical techniques will make it possible to illustrate various aspects of the value perception of science and technology. This procedure will prevent the aggregated measures of the "forest" (the scale) from hiding some particularly salient and not linearly related "trees" (items), which is especially useful when there are signs that the "forest" perhaps consists of entirely different species (low correlation among items, absence of "simple structure" in the principal component analysis, low reliability Cronbach's Alpha). The statistical techniques of choice for this re-examination of the available data are exploratory ones (in the tradition of Tukey *et al.*, Benzécri *et al.*, Breiman *et al.*) that enable insights into the statistical evidence without imposing too much structure on it (contingency tables, correspondence analysis, classification trees).[35] These techniques can also help researchers generate richer and more precise hypotheses that are able to guide the design of theoretically well-founded questionnaires. In addition, exploratory as well as confirmatory analyses must aim at the construction of conceptual schemas that can be connected to other segments of the more general social scientific literature (such as theories of late modernity and postmodernity, of political and environmental culture, and of risk analysis).

The following pages are an attempt to make some progress with this program. They re-examine the construction and formal characteristics of the attitude scales that have been used by several influential analysts in public understanding of science since the mid-1990s as a basis for formulating conceptual schemas and hypotheses. An exploratory analysis of some aspects of late-modern scientific culture, and of relations between knowledge and attitudes toward science using a different interpretive strategy will be presented elsewhere.

3. Measuring attitudes toward science

The canonical questionnaire that has been used for the empirical study of public understanding of science in a number of nations (European Union, United States, Canada, Japan, and others) over the past decade has its origin in the 1957 pioneering study sponsored by the National Association of Science Writers in the United States. This study, which represented a real "tour de force" for its time, was carried out by the Survey Research Center at the Institute for Social Research (University of Michigan) and was directed by Robert C. Davis. It helped to establish a conceptual framework and corresponding measurements for the study of public understanding and attitudes toward science (embodied in a questionnaire developed after a number of pretests and a pilot study).[36] It also anticipated some of the central variables implemented later on in surveys conducted on both sides of the Atlantic: "interest" in science, "information" about science, "sources of science information," "understanding of a number of scientific notions," "understanding of the meaning of studying something scientifically" (or understanding of the "methods" of science), "attitudes toward the effects and limits of science," and "images and predispositions toward professional scientists." Eight items measuring the attitudinal dimension were retained (most of them literally, the rest in new formulations) by the biennial series of surveys on public attitudes and understanding of science published since 1973 in the *Science Indicators* by the U.S. National Science Board.

The first three *Science Indicators* (1973, 1975, and 1977) included a chapter on public attitudes toward science, with a limited number of assessments of science impacts, appreciation of the scientific community, and public preferences regarding areas to be supported, but no measures of scientific literacy.[37] There were no formal references to the metric properties of the analyzed items, and the data analysis was limited to frequency tables of individual items and their breakdown by socioeconomic groups. The 1978 edition contained no chapter on public attitudes, stating that "the omission reflects recognition of the problems associated with developing accurate information" and announcing a more sophisticated analytical approach to be reported in the 1980 *Science Indicators*.[38] The 1980 edition marks a turning point by introducing a new conceptual schema for the study of public attitudes toward science: the policy-making and public-participation perspective revolving around the notion of "attentiveness," mentioned earlier. Questions tapping general attitudes were introduced in combination with others designed to capture attitudes toward specific and controversial areas, mainly technological ones (nuclear power plants, food additives, space exploration); at the same time, most of the questions in the 1957 study and previous Science Indicator surveys were retained so as to allow for the tracking of changes in public attitudes. The bulk of the effort until the late 1980s was devoted to refining and strengthening the concept of "attentiveness to science" and to exploring its sources through the measurement of a repertoire of individual indicators (including personality measures) and school and family variables, using logit and path analysis models. Less significant advances from this period that deserve mentioning here are the introduction of new specific attitudinal areas that reflect changing concerns (mainly the addition of recombinant DNA), the proposal of some typologies based on the analysis of attitudes ("neutrals," "doubters," "advocates," and "balancers"), and parallel studies of attitudes toward particular areas of science among the general public and science policy leaders.[39] Until the end of the decade, only limited effort was devoted to the actual process of building scales or aggregated measures of attitudes, and even less to assessing their formal properties of reliability and validity.[40] Generally, analyses did not go beyond an assessment of structure in the attitudinal items through exploratory factor analysis (principal components with oblique rotation). Actual measures of scientific literacy were virtually absent from the published analyses until the 1987 report, which was based on a 1985 survey (where literacy was measured with a subset of three actually understood items, out of seven items whose understanding was merely self-reported). Only in 1988, in a parallel British-US study, was a more complex measurement of scientific literacy introduced. A critical dimension of attitude measurement, the number of response options for attitudinal items (from agreement to disagreement), was, to the best of our knowledge, neither subjected to pilot studies or experimentation nor standardized. It oscillated between five in 1957 and two in 1972, 1974, and 1976, four in 1979, two in 1981, two plus "no opinion" in 1983, two in 1985 (with acceptance of "it depends" if volunteered by the respondent), and four in 1988 and the following years (as opposed to five categories, including a neutral one, "neither agree, nor disagree," in the UK and the European Union). This inconsistency compromised attempts to map changes in attitudes to science and to offer a rigorous comparative analysis of public perceptions of science in the United States and European countries (an important question to which we will return later).[41]

Although as early as 1979 there was an independent European Community survey on public attitudes toward science and technology, which tapped a number of interesting areas, its influence on later studies sponsored by the European Community remained negligible.[42] The parallel and joint effort by Miller in the United States and Durant and collaborators in the United Kingdom in 1988, linked to previous work in the United States, set the standard for the measurement of scientific literacy and public attitudes toward science, influencing the 1989, the 1992, and even the most recent 2001 EU study. The 1987 and particularly the 1989 Science & Engineering Report, as well as the publications of Durant and colleagues at the end of the decade, formalized the SL model in both its cognitive and evaluative dimensions. The structure of the 89 Indicators Report and Durant's papers reflects the new approach (which was already visible in less developed form in the 1982 *Science Indicators*). Public scientific literacy, assumed to operate as an explanatory variable, precedes the section on attitudes, which were measured through an expanded battery of items that also included the ones from the 1957 study. Curiously, as mentioned earlier, no attempt was made in this literature to present the distribution of attitudes by level of scientific literacy. The 1993 US Indicators Report reverted to the earlier sequence, presenting the scientific literacy assessment after the section on attitudes, but reversed the order once again in the 1996 edition, with literacy preceding attitudes.[43]

To sum up, studies of public understanding of science in Europe, sponsored by the European Commission, have been heavily dependent on former research developed in the United States, and particularly on Miller and Durant's joint work in 1988. Recognition of the many advances made in conceptualizing and measuring public understanding and attitudes toward science both in the United States and Britain should not prevent us from noting the scant attention that was paid to the methodological component of the research program, particularly to the attitudinal dimension and its significance for theory-building. Very little formal reporting is available on the way in which the attitudinal items were selected (although there are some cursory references regarding the British 1988 survey), why some of them were retained for inclusion in summated scales while others were discarded, on their differential levels of salience in people's perceptions of the effects of science, and on the reasons for the adopted metric (number of response options) and its frequent changes.[44] The analysis of attitudes toward science carried out over the last four decades has evolved from a rather basic examination of the distribution of responses to individual items to the construction of two aggregated indexes (capturing different dimensions of the public's evaluation of science effects, benefits and risks).[45] It then became a construction of a scale measuring a single continuum from negative to positive attitudes labeled ATOSS (Attitude Toward Organized Science Scale) through the aggregation of four items that were already present in the 1957 study.[46] Most recently, it has involved construction of two attitudinal schemas, one measuring "promises of science," the other "reservations toward science" (converted to a zero to 100 metric to facilitate comparative analysis between countries).[47]

It is surprising that the non-trivial difficulties encountered in building aggregated attitudinal measures never led to a thorough examination of their theoretical and methodological foundations. Instead, they were only considered as a sort of "noise" in the course of the analysis to be overcome by means of operational strategies that are themselves not exempt from problems (a point to which we will return shortly). Apart from the effort to use previous measures to permit tracking of attitude changes, perhaps the main explanation for these limitations is that the bulk of the research has been devoted to conceptualizing and measuring the cognitive dimension of public perceptions of science. This effort to measure the understanding of scientific concepts, principles, and methods has been sustained, up to the present, partly in response to mounting criticism of the notion of "scientific literacy" and the so-called "deficit model" from a number of researchers of different orientations (from John Ziman and Jean-Marc Lévy-Leblond to Bruce V. Lewenstein and Brian Wynne).[48] Recent critiques of core elements of the canonical public perceptions of science program (the "deficit model" and the assumption of a linear dependence of attitudes on knowledge) have created a favorable climate for taking a second look at their underlying assumptions, theoretical framework, and methodological dimension. Although methodological criticism of this program has included some observations on the limitations of the measuring instruments, these comments have been aimed mainly at the construction of new theoretical interpretations. In our view, such interpretations continue to be based on weak constructs and fuzzy indexes and may delay a much-needed revision of the methodological foundations of a research program initiated almost half a century ago. In the next sections, we will turn our attention to the analysis of some of these methodological problems.

4. The Eurobarometer and public attitudes toward science in Europe

Over the past decade, the Eurobarometer has been the main instrument for the comparative study of public perceptions of science.[49] Interpretations of Eurobarometer data have served as the basis for some of the most influential analyses in this research area, with regard to perceptions of science in general as well as of specific areas such as biotechnology. The four principal Eurobarometers for the study of general public knowledge and attitudes toward science and technology are those of 1978, 1989, 1992, and 2001. As mentioned earlier, the questions included in the 1989 Eurobarometer and those of the following years reproduced most of the items that already formed part of the pioneering study of 1957, as well as those of some national studies, most importantly in the U.K. (1988) and in the U.S. (the Biennial Science & Engineering Indicators).

In the rest of this paper, we will limit ourselves to data from Eurobarometer 38.1 (1992).[50] We use the 1992 file not only because it is the most recent one whose data are publicly available, but also because it is the one that has been used by the principal analysts in public understanding of science.[51] To measure the public's valuations and predispositions toward science, the questionnaire included two non-consecutive questions (Q62 and Q66) whose content is shown in Table 1.

Table 1. Attitude items: Eurobarometer 38.1 (1992).

1	"Science and technology are making our lives healthier, easier and more **comfortable**."
2	"Thanks to scientific and technological advances, the Earth's natural **resources** will be inexhaustible."
3	"We depend too much on **science** and not enough on faith."
4	"Scientific and technological research cannot play an important role in protecting the **environment** and repairing it."
5	"Scientists should be allowed to do research that causes pain and injury to **animals** like dogs and chimpanzees if it can produce new information about serious human health problems."
6	"Technological **progress** will make possible higher levels of consumption and, at the same time, an unpolluted environment."
7	"Because of their knowledge, scientific **researchers** have a power that makes them dangerous."
8	"The application of science and new technology will make **work** more interesting."
9	"For me, in my **daily life**, it is not important to know about science."
10	"Most scientists want to work on things that will make life better for the **average person**."
11	"Science makes our **way of life** change too fast."
12	"Thanks to science and technology, there will be more opportunities for **future** generations."
13	"**New technology** does not depend on basic scientific research."
14	"On balance, computers and factory automation will create more **jobs** than they will eliminate."
15	"Even if it brings no immediate benefits, scientific research is necessary and should be supported by the **government**."
16	"Scientific and technological research do not play an important role in **industrial** development."
17	"Some numbers are especially **lucky** for some people."
18	"New **inventions** will always be found to counteract any harmful consequences of scientific and technological development."
19	"Scientific research does not make industrial **products** cheaper."
20	"Only by applying the most modern technology can our **economy** become more competitive."
21	"**Computers** have made the use of bank services more complicated."
22	"Scientific and technological progress will help to cure **illnesses** such as AIDS, cancer...."
23	"The **benefits** of science are greater than any harmful effects it may have."

These 23 items refer to a wide range of topics.[52] Some statements are intended to capture general assessments of science; others aim at the effects of science in the increase of complexity, dangers, the erosion of religious faith, the environment, health, the economy, work, and other aspects of the interactions between science and society (Table 2; words in boldface will be used as labels for the corresponding items throughout the rest of this paper).

The first impression Table 2 conveys is that of a set of statements with differing levels of abstraction, ranging from general evaluations of science (as in the case of "Life comfort" and "Government") to very specific statements about the impact of a particular technology on the execution of a task (as in the case of "Computers"). Some items measure abstract questions (dangers, complexity), while others refer to the interaction of science and technology with some concrete domains (environment, health, economy, work). With some statements, it is difficult to know what exactly they aim to capture, or they refer to questions that are topics of debate among specialists (as in the case of "New technology"). Even though the items cover a fairly broad spectrum, there are clear omissions and imbalances. Some dimensions receive significant attention (e.g., the environment), whereas others that are at least equally important to the public (e.g., health) are represented by more limited formulations. Other dimensions that are known to have conditioned the perception of science for some generational cohorts are missing completely, especially the connections between scientific knowledge and military technology. There are hardly any references to risks, and the only technology that is clearly

Table 2. Themes in the 23 attitudinal items.

General Attitudes	"Science and technology are making our lives healthier, easier and more **comfortable."** "Even if it brings no immediate benefits, scientific research is necessary and should be supported by the **government**." "The **benefits** of science are greater than any harmful effects it may have." "Most scientists want to work on things that will make life better for the **average person**."
Complexity	"Science makes our **way of life** change too fast." "**Computers** have made the use of bank services more complicated."
Dangers	"Because of their knowledge, scientific **researchers** have a power that makes them dangerous." "New **inventions** will always be found to counteract any harmful consequences of scientific and technological development."
Religion	"We depend too much **on science** and not enough on faith."
Environment	"Thanks to scientific and technological advances, the Earth's natural **resources** will be inexhaustible." "Scientific and technological research cannot play an important role in protecting the **environment** and repairing it." "Technological **progress** will make possible higher levels of consumption and at the same time, an unpolluted environment."
Health	"Scientific and technological progress will help to cure **illnesses** such as AIDS, cancer." "Scientists should be allowed to do research that causes pain and injury to **animals** like dogs and chimpanzees if it can produce new information about serious human health problems."
Economy	"Scientific and technological research do not play an important role in **industrial** development." "Scientific research does not make industrial **products** cheaper." "Only by applying the most modern technology can our **economy** become more competitive."
Work	"On balance, computers and factory automation will create more **jobs** than they will eliminate." "The application of science and new technology will make **work** more interesting." "Thanks to science and technology, there will be more opportunities for **future** generations."
Other	"For me, in my **daily life**, it is not important to know about science." "**New technology** does not depend on basic scientific research." "Some numbers are especially **lucky** for some people."

represented is computers; in contrast, biotechnology and nuclear energy, for example, do not appear, even though they have a high level of coverage by the media and possibly great salience for the public. The selection, therefore, clearly bears the marks of the time when the items were originally formulated and shows the lack of theory in their formulation and selection.

It is worth asking to what extent the scores that were obtained by collapsing some of these items into a summated scale (the favorite technique of most researchers who have analyzed these data over the last few years) would have been altered if items regarding weapons technologies or risks or statements about nuclear energy, instead of or in addition to, computers (technologies which, as we know from other studies, elicit opposed valorizations) had been included. The items in the questionnaires were apparently not subjected to prior analysis regarding their level of salience in the public's cognitive map of science; that is to say, one of the fundamental steps in the development of an attitude scale seems to have been skipped here.[53] Even before we analyze this battery of items in terms of its formal properties (correlations, dimensionality, and reliability), the conceptual review suggests that the best it can achieve is a tentative and non-systematic exploration of attitudes, an extremely general profile of the value dimensions of scientific culture in late-modern societies. But it would be difficult, on the basis of these items, to construct scales with the reliability and validity standards that are usual in other areas of social science research. With the Eurobarometer, we do not even know which facets the public of late-modern societies considers relevant when evaluating the contributions of science and technology, how these facets differ among nations, if at all, and how they have changed over time, questions that a new series of studies will have to examine. With these limitations in mind, the following pages will discuss systematically the methodological difficulties that arise in the construction of summated scales; these difficulties imply that some of the recent interpretations are based on an extremely weak empirical foundation.

5. The "split ballot" and the non-response in the analysis of attitudinal items

The 1992 Eurobarometer used the "split-ballot" formula for the attitude-related items (see Table 3) and, as is common in all surveys, various percentages of "don't know" responses were obtained for the different items. To address the undesired effects that result from the combination of split-ballot and non-response, some analysts have simply homogenized the percentages of "don't know" and the intermediate category of the five-point option ("neither agree nor disagree"), using a method that will be discussed later.[54] However, we believe that before one opts for one of the various methods for circumventing adverse effects, one must know what information is lost and what assumptions are embedded in the analysis as a consequence of these decisions. The variations in the responses, depending on which metric is used, as well as on the non-response percentages, reveal some of the weaknesses of the items for the construction of a robust scale and the difficulties some segments of the public encounter in making value judgments about science. Before we examine the possibilities for constructing a summated scale with some subset of the 23 items, it is important to review the behavior of each one of them in terms of the distribution of answers over four or five categories, as well as in terms of the percentage of non-responses.

Table 3. Response categories in split A and split B.

Split A: Response Options	Split B: Response Options
1 = Strongly agree	1 = Strongly agree
2 = Agree to some extent	2 = Agree to some extent
3 = Neither agree nor disagree	3 = Disagree to some extent
4 = Disagree to some extent	4 = Strongly disagree
5 = Strongly disagree	5 = DK (Don't know)
6 = DK (Don't know)	0 = No answer
0 = No answer	

The non-response

The mean percentage of "don't know" responses was in general relatively low at 9.1% for the twelve European countries that were included in the 1992 Eurobarometer, which in principle makes the use of these items in the construction of a summated scale plausible.[55] But as Table 4 shows, the distribution of "don't know" responses was significantly uneven among the different items.

Not all the aspects of science that were presented to the interviewees had the same level of familiarity, salience, or power to elicit valuations. Either because of the question content, its formulation, or a combination of both, the variability is significant. The statement concerning "Life comfort" yields the smallest percentage of "don't knows" (3.3% in split A, 3.8% in

Table 4. Percentages of "don't know" responses in split A and split B.

Items	Split A	Split B	Items	Split A	Split B
"Life comfort"	3.3	3.8	"Government"	8.0	9.5
"Daily life"	4.2	5.0	"Industry"	8.1	9.9
"Animals"	4.3	6.4	"Work"	8.1	10.4
"Way of life"	5.2	7.1	"Resources"	8.2	10.1
"Illness"	5.3	6.2	"Lucky number"	8.8	12.9
"Science"	5.6	8.7	"Benefits"	10.4	15.3
"Jobs"	6.0	7.6	"Economy"	10.5	12.7
"Average person"	6.3	8.8	"Progress"	10.8	14.8
"Researchers"	6.9	8.3	"Products"	11.5	14.7
"Environment"	7.1	9.0	"Inventions"	12.3	15.9
"Future"	7.2	9.8	"New technology"	17.5	20.3
"Computers"	7.3	8.4			

split B), whereas the item "New technology," which is very abstract and under debate even among experts, lies well above the 10% threshold of non-responses for both splits (17.5% and 20.3%, respectively). This medium variability becomes even more pronounced when one examines the "don't know" responses in terms of the variable of nation (Table 5), which points to the difficulties in understanding and the cognitive distance that some attitude items give rise to in less developed societies.

Table 5. Mean percentages of "don't know" responses, by nation.

	Split A	Split B
West Germany	4.7%	7.9%
France	4.7%	8.1%
Denmark	5.0%	4.9%
Belgium	6.0%	9.9%
East Germany	6.1%	10.5%
Netherlands	6.3%	7.0%
UK[a]	7.8%	9.8%
Italy	9.9%	12.8%
Ireland	13.0%	15.8%
Spain	13.9%	15.7%
Greece	15.3%	16.4%
Portugal	19.6%	17.0%

[a] UK includes Great Britain and Northern Ireland (each with its corresponding weight).

When one considers the "don't know" responses to each item by nation, the differences between the group of more developed and that of less developed countries emerge clearly and point to the difficulties involved in constructing an attitude scale that is usable for comparative analysis. These differences are illustrated for some specific items in Table 6.

The greatest variation in the medium percentage of "don't know" responses, however, emerges when it is analyzed in terms of the variable of the interviewees' "years of education" (see Table 7, which shows the percentages of "don't know" responses in split B for all the items; a similar pattern in a selection of items in split A is shown in Table 8). If one carries out the same analysis for other canonical sociodemographic variables, such as income, subjective social class, leadership, degree of declared information about science, and level of scientific knowledge, the same pattern of differences repeats itself, albeit in a less pronounced fashion.

Table 6. Percentage of "don't know" responses in split A and split B.

	Portugal	Greece	Ireland	Denmark	UK	France
Split A						
"Resources"	20.8	21.0	17.2	3.5	9.2	2.8
"Environment"	20.5	15.8	13.8	2.4	8.7	4.8
"Work"	19.2	15.4	14.3	4.5	9.1	3.8
"Industry"	21.8	16.6	13.2	5.2	9.4	4.3
"New technology"	36.7	32.8	20.5	7.1	12.3	13.6
"Benefits"	22.9	14.0	18.1	8.4	10.2	5.6
Split B						
"Resources"	18.4	24.9	21.9	3.5	11.3	5.2
"Environment"	22.3	16.1	15.6	3.3	9.5	6.7
"Work"	14.9	16.8	13.7	4.0	10.1	9.7
"Industry"	18.5	17.9	16.4	3.3	12.6	8.2
"New technology"	32.1	32.9	22.8	6.9	14.0	17.9
"Benefits"	19.6	19.9	20.7	8.2	14.4	10.8

It emerges clearly that the content and/or the formulation of the items appears more distant and has less power to elicit valuations among the segments of the European population with the lowest social and cultural level.

Table 7. Percentage of "Don't know" responses in Split B by education.

	Total	15 years of education or less	20 years of education or more
"New technology"	20.4	34.4	8.8
"Inventions"	15.9	25.0	7.7
"Benefits"	15.3	22.7	8.7
"Progress"	14.8	23.9	5.4
"Products"	14.7	23.2	7.5
"Lucky number"	12.9	16.0	11.5
"Economy"	12.7	20.3	5.5
"Work"	10.4	18.2	5.7
"Resources"	10.1	18.0	3.3
"Futures"	9.9	14.2	6.3
"Industry"	9.9	18.0	2.7
"Government"	9.5	17.5	2.6
"Environment"	9.0	17.5	1.5
"Science"	8.8	12.5	4.9
"Average person"	8.8	13.7	6.2
"Computers"	8.4	14.2	3.8
"Researchers"	8.3	14.6	4.2
"Jobs"	7.6	12.6	3.6
“”Way of life"	7.1	11.6	3.2
"Animals"	6.4	10.8	3.1
"Illness"	6.2	10.3	2.4
"Daily Life"	5.0	9.0	1.6
"Life comfort"	3.8	7.0	1.0

Table 8. Percentage of "Don't know" responses in split A and split B by education.

	Split A		Split B	
	15 years of education or less	20 years of education or more	15 years of education or less	20 years of education or more
"Resources"	14.9	3.0	18.0	3.3
"Environment"	14.0	1.9	17.5	1.5
"Work"	14.3	3.1	18.2	5.6
"Industry"	16.1	1.9	18.0	2.7
"New technology"	31.1	5.0	34.4	8.8
"Benefits"	17.0	4.0	22.6	8.6
"Government"	14.1	2.5	17.5	2.6
"Economy"	18.8	3.6	20.3	5.5

The "split-ballot" and the instability of the distribution

In the responses to the 23 items, the sample was divided into two halves, split A and split B, to ensure comparability of the Eurobarometer, which has traditionally used a five-point option, with the data of the *Science & Engineering Indicators* in the United States, which has relied on a four-point scale since 1987.[56] But the main reason for carrying out split-ballot experiments in public opinion research is to estimate the impact that the choice of different question forms and metrics (in this case, the presence of an intermediate category) has on the distribution of responses. Split A offered five categories (in addition to "don't know" and "no answer": completely disagree, disagree, neither agree nor disagree, agree, and agree completely); split B, on the contrary, included no intermediate category, and so the effect of forcing the interviewees toward a position either for or against each item could in principle be assessed (Table 3).

A question that emerges from the analysis of the results that were obtained through the split-ballot technique concerns statistically different score distributions in split A and split B. This difference arises not so much because of the medium percentage of "don't know" responses (8% in split A compared with 10.3% in split B), but fundamentally because of the

Table 9. Percentages of "agreement" and "disagreement" in splits A and B in selected items[a].

	Split A			Split B	
	Agree	Neither agree nor disagree	Disagree	Agree	Disagree
"Resources"	24.7	17.7	57.6	28.8 (+4.1)	71.2 (+13.6)
"Science"	44.4	23.2	32.4	52.5 (+8.1)	47.5 (+15.1)
"Progress"	34.8	24.5	40.8	43.5 (+8.7)	56.5 (+15.7)
"Daily life"	34.6	16.1	49.4	40.6 (+6.0)	59.4 (+10.0)
"Way of life"	57.5	20.1	22.4	63.4 (+5.9)	36.6 (+14.2)
"New technology"	22.5	15.8	61.7	27.9 (+5.4)	72.1 (+10.4)
"Industry"	14.7	10.3	75.0	18.0 (+3.3)	82.0 (+7.0)
"Benefits"	58.2	26.8	15.0	72.4 (+14.2)	27.6 (+12.6)
Total 23 items	48.4	17.1	34.5	55.9 (+7.5)	44.1 (+9.6)
13 positive items	58.4	16.6	25.0	66.5 (+8.1)	33.5 (+8.5)
10 negative items	35.5	17.6	46.9	42.0 (+6.5)	58.0 (+11.1)

[a] Valid responses ("Don't know" responses were excluded from the computation of percentages).

different distribution of agreement and disagreement in each of the splits. When one compares the response percentages that were obtained in each of the three big groups in split A—"agreement" (48.4%, including the categories "strongly agree" and "agree"), "disagreement" (34.5%, including "strongly disagree" and "disagree"), and the intermediate option "neither agree nor disagree" (17.1%)—with those of the two big groups in split B—"agreement" (55.9%, "strongly agree" and "agree") and "disagreement" (44.1%,"strongly disagree" and "disagree")—one discovers that the percentage distributions of agreement and disagreement differ significantly in the two splits (Table 9). This difference, which is clearly visible even in an informal inspection of Table 9, is corroborated by the result of a *Z-Test* for comparing non-correlated proportions.†

The consequences of changing the metric by eliminating one category or altering the scope of the response options are well known and have been discussed in the literature on methodology and scale construction.[57] Perhaps the most plausible working hypothesis is that the differences observed here derive from the group of subjects in split B who would have chosen the "indifferent" option but were obligated to select agreement or disagreement in its absence. But not all of respondents made the same selection, since out of the 17.1% of "indifferent" responses for the 23 items all together, 56.1% opted for "disagreement" (so that the 34.5% of disagreement in split A increases to 44.1% in split B), while 43.9% opted for "agreement" (so that the 48.4% in split A turns into 55.9% in split B) (Table 9).

Table 9 (which excludes "don't know" responses) shows further that the majority tends toward disagreement positions whether the items have positive content (where *agreement* implies a favorable attitude toward science) or negative content (where *disagreement* with the statement suggests a favorable attitude toward science). The 46.9% of disagreement with items with negative content in split A turn into 58.0% in split B; that is an increase of 11.1%, whereas the percentage of agreement rises only by 6.5%, going from 35.5% to 42.0%. Responses to items with positive content also show a greater tendency toward disagreement, although it is a minimal one in this case, going from 25% in split A to 33.5% in split B, an increase of 8.5%;

† According to the formula

$$z = \frac{p_1 - p_2}{\sqrt{\overline{p_e}\,\overline{q_e}\left(\frac{N_1 + N_2}{N_1 N_2}\right)}}$$

with

$$\overline{p_e} = \frac{N_1 p_1 + N_2 p_2}{N_1 + N_2} \qquad \text{and} \qquad \overline{q_e} = 1 - \overline{p_e}$$

the mean percentage of "agreement," estimating N_1 as the size of split A = 5,871 (6,382 minus 511, approximately 8%, adding the "don't know" and "no answer" categories) and N_2 as the size of split B = 5,757 (i.e., 6,418 minus 661, approximately 10.3%, also adding "don't know" and "no answer"), is

$$\overline{p_{\text{agreement}}} = \frac{5{,}871 \times 0.484 + 5{,}757 \times 0.559}{5{,}871 + 5{,}757} = 0.5211 \qquad \text{and} \qquad \overline{q_{\text{agreement}}} = 1 - 0.5211 = 0.4789.$$

This yields a *Z-Test* value for the differences in proportion of agreement in splits A and B of

$$z = \frac{0.484 - 0.559}{\sqrt{0.5211 \times 0.4789\left(\frac{5{,}871+5{,}757}{5{,}871\times 5{,}757}\right)}}$$

and a *Z-Test* value for the differences in proportion of disagreement in splits A and B of

$$z = \frac{0.345 - 0.441}{\sqrt{0.3925 \times 0.6075\left(\frac{5{,}871+5{,}757}{5{,}871\times 5{,}757}\right)}} = -10.60$$

both *Z-test* values with a significance < 0.001.

the increase in agreement is 8.1%. In fact, the tendencies that manifest themselves in the 13 positive items are quite varied: for 6 of them, there is a slightly stronger tendency toward agreement (e.g., in the case of “Benefits,” included in Table 9), for 4 of them the tendencies are equal, and for 3 the tendency toward disagreement is significantly stronger than that toward agreement.

When one examines the variations of “disagreement” between the two splits by nation and item, it becomes obvious that the differences between the two metrics appear between nations (considering all 23 items together), but also between different items in the same nation and, finally, in the same item according to nation (Table 10).

Table 10. Percentages of “disagreement” in split A and split B in selected items, by nation.

		Split A		Split B
		Indifferent	Disagree	Disagree
“Science”	Total	23.2	32.4	47.5 (+15.1)
	Greece	20.7	16.4	30.6 (+14.2)
	Spain	21.2	27.9	39.3 (+11.4)
	Portugal	23.4	18.6	28.8 (+10.2)
	Denmark	20.4	38.2	51.1 (+12.9)
	Netherlands	22.3	39.7	52.8 (+13.1)
“Way of Life”	Total	20.1	22.4	36.6 (+14.2)
	Greece	4.2	1.7	2.8 (+1.1)
	Spain	15.3	15.1	23.6 (+8.5)
	Portugal	15.4	8.4	15.7 (+7.3)
	Denmark	14.5	21.0	32.0 (+11.0)
	Netherlands	18.6	21.1	31.7 (+10.6)
“Environment”	Total	13.1	64.1	71.3 (+7.2)
	Greece	18.2	51.9	59.3 (+7.6)
	Spain	13.2	61.4	66.7 (+5.3)
	Portugal	22.1	48.0	63.6 (+15.6)
	Denmark	6.6	76.9	84.3 (+7.4)
	Netherlands	7.6	66.8	71.6 (+4.8)
“Progress”	Total	24.5	40.8	56.5 (+15.7)
	Greece	26.1	36.0	62.1 (+26.1)
	Spain	18.8	47.2	58.2 (+11.0)
	Portugal	20.5	40.0	43.4 (+3.4)
	Denmark	18.7	36.4	51.7 (+15.3)
	Netherlands	17.0	42.0	47.0 (+5.0)

All of these variations, some of which are extremely low or, on the contrary, extraordinarily high, exhibit the differential behavior of items with five versus items with four response options (split A vs. split B). In other words, splits A and B do not add up to a single measuring system. It would be worth discussing technically the objective degree of this dissimilarity overall, as well as item by item. But what seems unquestionable and important to emphasize here is the weak robustness of both: They generate responses that are difficult to explain since they arise from simply changing the response options for the same question. The discrepancies between the two metrics tend to increase with weak item construction, imprecise item content, and distance from the subjects’ perceptions.

Another result from the split technique that needs to be mentioned here concerns only split A, which has been the preferred metric for the Eurobarometer analysts. For 11 out of the 23 items, the sum of those who opted for the intermediate option ("neither agree, nor disagree") and those who chose the "don't know" option is above 24%, and in 7 cases is above 29%. Clearly, there is a fairly large group of individuals who are unable to decide between agreement or disagreement, and choose instead the easier solution of indecision. Undoubtedly, there are a variety of reasons for this high level of "non-substantive responses" (NSR). But, apart from certain characteristics of the respondents, an aspect to which we will return below, one of the principal problems is, once again, the weak formulation of some of the indicators or their low level of salience, which does not give rise to well-defined valuations from a large number of individuals. This finding, it should be pointed out, is consistent with the literature on the salience and structure of attitudes.

"Split-ballot", "don't know" responses and strategies for homogenizing responses

Analysts who have used the Eurobarometer data to study public perceptions of science have had the option of either using only half of the sample (split A or split B) or coming up with some method of homogenizing the distribution of the responses. We will here focus on the scale construction procedure used by John Durant's research team.[58] Durant *et al.* used the following method to obtain five response categories regardless of whether split A or split B was applied: in split A options 1–5 are not modified, but the "don't know" responses are added to those in category 3 ("neither agree, nor disagree"); in split B, the intermediate category of "neither agree, nor disagree" is created by assigning the "don't know" responses to it, and recoding the original scores in category 3 ("disagree") as 4 and those in category 4 ("strongly disagree") as 5. Through these operations, the 23-item battery is given the same metric, with five response options that range from "strongly agree" to "strongly disagree."

The identification of the "don't know" with the "neither agree, nor disagree" response can be justified by arguing that both of them show an absence of evaluative attitude and the same degree of indeterminacy. But this argument omits a possible difference between the two: those who answer "don't know" ("expressed public ignorance or indifference") may feel remote from the object of the question not only in terms of valuation but also of cognition, while it is possible that a significant subset of those who choose the neutral category "neither agree, nor disagree" recognize the object to be evaluated, but adopt a position of genuine ambivalence because the proposed statement does not offer enough nuances or is too general, or because the response options are perceived as inappropriate or too restrictive, etc. The literature dealing with this topic is complex and based on limited evidence (specific surveys, both regarding content and form), which makes it difficult to generalize its conclusions to other cases. But a number of "heuristic guidelines" have been formulated that could be helpful for the analysis at hand. It is customary to investigate "non-substantive responses" both in terms of the characteristics of the questions that generate a disproportionate number of such responses and the profile of respondents prone to giving NSRs, and to distinguish between "non-opinion" (don't know) and "no opinion" (ambivalent). Apart from the education variable (the group of the uninformed in surveys is inversely related to level of education), among the three variables of "difficulty of the task" presented to the respondent, "question form," and "question content," it is the last one that seems to play the most important role in explaining "don't know" responses in a number of different surveys (although not necessarily in all or most of them).[59] Items that generate low personal involvement or interest, or that raise serious cognitive barriers for the respondent, seem to elicit a "no opinion" response. In the case of the Eurobarometer discussed here, four items obtain 30% or higher NSRs for half the sample in split A (see Table 11), and it could be argued that these items (“Benefits,” “Progress,” “New technology,” and “Inventions”) require evaluations that are too complex—to the point where some of them are even controversial among experts. Obviously, the level of NSRs is markedly higher among the segment of the population with 15 or fewer years of formal education (see Table 11), and the same relation holds true for the segment of low income and low scientific knowledge and interest (among other variables not shown here.) In addition, some authors have found that the two groups of respondents (“truly undecided” and “no opinion”) differ significantly from each other (as well as from those who hold substantive opinions): Individuals who express ambivalent opinions have higher education, greater mass media usage, and more issue awareness than those who select “don’t know” answers.[60] The Eurobarometer data show that the distribution of NSRs between “don’t know” and “neither agree, nor disagree” differs clearly by education of the respondent (and other associated socioeconomic characteristics): The tendency of the group of those with 20 or more years of education (17.2% of the sample) to give a “neither agree, nor disagree” response is much higher than among those who choose the “don’t know” option (with a mean percentage of 14.19 vs. 2.87%, respectively), while in the group with 15 or fewer years of education, the tendency to select either form of NSR is almost equal (with a mean percentage of 14.95 vs. 13.94%, respectively) (see Table 12). It is therefore not self-evident that the “non-existent” (don’t know) and “ambivalent” (neither agree, nor disagree) opinion categories are equivalent, and the question would merit further exploration.

Table 11. Percentage of “neither agree nor disagree” + “don’t know” responses in split A, by education.

	Total	15 years of education or less	20 years of education or more
“Benefits”	34.4	40.2	28.1
“Progress”	32.6	39.3	21.9
“New technology”	30.6	45.5	14.2
“Inventions”	30.4	39.5	21.1
“Work”	29.2	37.2	24.0
“Products”	28.5	34.2	23.7
“Lucky number”	28.0	29.0	26.2
“Science”	27.5	26.8	24.9
“Resources”	24.4	31.8	15.4
“Futures”	24.3	28.9	19.7
“Way of life”	24.2	24.1	19.5
“Average person”	23.3	27.7	19.6
“Economy”	23.0	31.5	13.9
“Researchers”	21.2	25.2	14.9
“Jobs”	20.2	22.8	18.1
“Government”	20.1	28.4	10.1
“Daily life”	19.6	23.5	14.1
“Environment”	19.3	28.2	10.8
“Computers”	19.0	24.2	13.4
“Animals”	17.8	20.8	13.6
“Industry”	17.5	27.9	7.4
“Life comfort”	15.8	19.1	12.0
“Illnesses”	12.0	18.7	5.8

With this reservation in mind, we can examine what occurs statistically when the responses are homogenized into five categories with the procedure outlined above. Table 13 shows the

Table 12. Percentage of "Neither agree nor disagree" and "Don't know" responses in split A by education.

	"Resources"		"Work"		"Industry"		"Benefits"	
	Neither ... nor	Don't know	Neither ... nor	Don't know	Neither ... nor	Don't know	Neither ... nor	Don't know
15 years of education or less	16.9	14.9	23.0	14.3	11.7	16.1	23.2	17.0
20 years of education or more	12.4	3.0	20.9	3.1	5.5	1.9	24.1	4.0
Low income	17.7	15.1	23.8	14.2	10.9	17.0	24.6	15.4
High income	13.5	2.2	17.9	2.8	6.0	2.5	19.2	4.7
Low level of scientific knowledge	18.8	21.7	21.3	22.1	14.4	22.2	23.4	24.6
High level of scientific knowledge	11.2	1.6	21.1	2.4	6.0	1.0	21.4	3.1

differences in percentage between the original and the homogenized data for some items (understood here as examples that are representative of the entire set).

In split A, the major differences occur between the original metric that includes a "neither agree nor disagree" category and treats "don't know" responses as missing cases in the calculation, and the adjusted metric that adds up the neutral and "don't know" answers without any missing cases. In the other categories, the differences are minor. In split B, the differences between the two metrics show up in various categories of agreement and disagreement. These differences increase along with the percentage of "don't know" answers that were transformed into "indifferent" ones. For the "Science" and "Way of life" items, with 8.8% and 7.1% "don't know" responses converted into neutral ones, respectively, the differences between the two metrics amount to about 2–3%, whereas for "Benefits" and "New technology," with 15.3% and 20.4% "don't know" responses converted into "indifferent" ones, respectively, the differences are considerable, amounting in some cases to more than 7% (46.0% vs. 39.0% of "agreement" for "Benefits," 37.4% vs. 29.8% for "New technology" in the "strong disagreement" category).

Table 13 also clearly shows the percentage differences between the homogenized data of split A and split B. These differences are, as one would expect, very significant in the "neither agree, nor disagree" category, in which split A always scores higher than split B, with differences as high as 10.2 points for the "New technology" and 18.7 points for the "Science" item. In the other categories, however, split B always scores higher than split A, with less pronounced but nevertheless significant differences: for example, 7.7 in the category "strongly disagree" for the item "Resources," 8.1 in the category "disagree" for the item "Benefits," and 9.4 in the category "disagree" for "Way of life."

When one compares the original and the converted metrics by nation or by sociodemographic variables (age, education), the differences generally increase significantly and in some cases very strongly.

The homogenization of response options highlights and even reinforces the two technically different types of measurement, split A and split B, which yield different percentages when they are applied to attitudinal objects that for significant population segments do not seem to have great power to generate value judgments.

When we move from the examination of differences in percentage to differences in parametric measurements (in this case, mean values) in the two splits and analyze original and converted data, the differences do not seem equally striking at first sight. This logically occurs for two arithmetical reasons. First, the number of subjects in each split is 6,000, and therefore

Table 13. Response percentages in split A and split B.

		Original metric Split A ("Don't know" excluded)[a]	Adjusted metric Split A ("Neither agree, nor disagree" + "Don't know")	Original metric Split B ("Don't know" excluded)[a]	Adjusted metric Split B ("Don't know" = "Neither agree, nor disagree")
"Resources"	Strongly agree	6.3	5.7	7.3	6.6
	Agree	18.4	16.9	21.5	19.3
	Indifferent	17.7	24.4		10.1
	Disagree	28.3	26.0	32.7	29.4
	Strongly disagree	29.3	26.9	38.5	34.6
"Science"	Strongly agree	17.1	16.2	18.2	16.6
	Agree	27.2	25.7	34.3	31.3
	Indifferent	23.2	27.5		8.8
	Disagree	17.5	16.5	26.3	24.0
	Strongly disagree	14.9	14.0	21.2	19.3
"Way of life"	Strongly agree	20.9	19.8	23.0	21.4
	Agree	36.6	34.7	40.4	37.5
	Indifferent	20.1	24.2		7.1
	Disagree	16.3	15.5	26.8	24.9
	Strongly disagree	6.1	5.8	9.9	9.2
"New technology"	Strongly agree	5.3	4.4	6.5	5.2
	Agree	17.2	14.2	21.5	17.1
	Indifferent	15.8	30.6		20.4
	Disagree	31.4	25.9	34.6	27.6
	Strongly disagree	30.3	25.0	37.4	29.8
"Progress"	Strongly agree	7.9	7.0	9.8	8.3
	Agree	26.9	24.0	33.7	28.7
	Indifferent	24.5	32.6		14.8
	Disagree	23.6	21.1	33.2	28.3
	Strongly disagree	17.1	15.3	23.3	19.8
"Benefits"	Strongly agree	21.4	19.2	26.4	22.4
	Agree	36.8	33.0	46.0	39.0
	Indifferent	26.8	34.4		15.3
	Disagree	10.5	9.4	20.7	17.5
	Strongly disagree	4.5	4.0	6.9	5.9

[a] Valid percentages ("don't know" responses excluded).

a difference of 0.1 points between one mean value and another is equivalent to a difference of 600 cases. This very large quantity can indicate that 600 subjects go from responding with category 4 (disagreement) to 5 (strong disagreement), or from answering with category 2 (agreement) to 1 (strong agreement), or that 300 subjects change from response option 2 (agreement) to 4 (disagreement), or other possible combinations. The second reason why the parametric differences between the original and recoded values for each split do not appear very striking lies in the homogenization itself. When the original responses for certain items are biased toward either agreement or disagreement, the introduction of the intermediate option 3 tends to center the mean values to a higher degree the greater the number of "don't know" responses that are recoded into "indifferents," thereby mitigating the differences between the mean values for some items.

Table 14. Mean values for selected items in splits A and B.

	Split A			Split B
	"Indifferent" and "don't know" responses excluded	"Indifferent" = 3 "Don't know" responses excluded	"Indifferent" and "don't know" responses = 3	"Don't know" responses = 3
"Resources"	3.68	3.56	3.51	3.66
"Environment"	3.79	3.68	3.63	3.68
"Work"	2.32	2.47	2.52	2.52
"Way of life"	2.38	2.50	2.53	2.63
"Future"	2.08	2.25	2.30	2.32
"New technology"	3.76	3.64	3.53	3.60
"Industry"	4.08	3.97	3.89	3.97
"Benefits"	2.18	2.40	2.46	2.46

Table 14 clearly shows the differences in split A when one compares the results of the original data excluding "indifferent" and "don't know" responses with the results obtained when both are included: For "Future," the mean value rises from 2.08 to 2.30, for "Industry" it falls from 4.08 to 3.89. The differences decrease, sometimes even to the point of equality (for the items "Work" and "Benefits"), when one compares the homogenized results of split A with those of split B, because mean values tend to approximate the central value. For the item "Work," the mean value goes from 2.32 to 2.52 in split A and attains the same value, 2.52, in split B; for the item "Benefits," it goes from 2.18 to 2.46 in split A, with the same value of 2.46 in split B.

But when the mean values for the homogenized items in split A and split B are calculated by nation, the difference in measurement between the two splits resurfaces. Even though the differences tend to decrease, there are a significant number of countries (Italy, France, Greece, Great Britain, and West Germany) that show high degrees of relative difference between mean values (see Table 15 for some of them); in other countries (Greece, Ireland, and Spain), the differences also increase significantly for some specific items.

Table 15. Mean values for selected items, by nation, in split A and split B[a].

	Italy		France		Belgium		Denmark		West Germany	
	Split A	Split B	Split A	Split B	Split A	Split B	Split A	Split B	Split A	Split B
"Resources"	3.40	3.58	3.84	4.06	3.63	3.76	3.92	4.10	3.27	3.47
"Science"	2.84	3.08	2.96	3.11	3.02	3.27	3.02	3.09	2.74	2.88
"Environment"	3.76	3.67	3.78	3.88	3.59	3.83	4.02	4.24	3.57	3.74
"Way of life"	2.55	2.66	2.74	2.86	2.67	2.80	2.41	2.51	2.49	2.63
"Industry"	3.92	3.92	3.89	3.96	3.70	3.85	4.28	4.26	3.80	3.96

[a] All mean values are calculated by adding "don't know" responses in both splits to category 3 ("indifferent").

When the comparison is carried out in terms of subject variables, such as income, leadership, age and education, by contrast, the earlier conclusion is confirmed. The differences, even when they are small, increase slightly because the number of "indifferent" plus "don't know" responses (category 3) in split A is much higher than the number of "don't know" responses (also category 3) in split B. Subjects with lower income in split A make up 27.9% for "Resources" compared to 15.2% in split B. Those with 20 or more years of education in split A make up 15.4% for "Environment" compared to 3.3% in split B, and practically the same is true of the rest of the group for most items.

Our objective in this section has been to point out the wealth of information that is hidden in the "don't know" responses and in the neutral category ("neither…nor"), and to show the different effects that result from opting for either split A or split B. In spite of these differences, the general data matrix that emerges from the homogenization of both splits will be used in the following sections so as to re-examine the formal properties of an attitude scale that is constructed by means of a subset of these items, as has been proposed in the literature mentioned above. It must be kept in mind that when mean values and percentages are calculated on the basis of this entire data set, the results will lie in between those obtained for split A and B; this fact can be interpreted as a compensation for possible biases and therefore as a more objective grasp of reality. By contrast, the calculation of other statistical coefficients such as correlations, factor analysis, analysis of variance and reliability, which are based on the degree of covariation between items, might be more significantly affected by the randomness that is generated through data homogenization.

6. The construction of an attitude scale

In this section, we will examine the possibilities of constructing a scale of attitudes toward science on the basis of the homogenized data obtained from the 23-item battery of Eurobarometer 38.1 (1992), which was, as was indicated earlier, designed to measure general valuations and predispositions toward science. To reiterate, this must be done by opportunistically using data that were obtained with little theoretical base work and without following all the required steps for constructing a scale with satisfactory formal properties. We will particularly focus on those items that were used by some influential researchers in the field of "public understanding of science" to construct a suitable scale for formulating some of the most recent and influential hypotheses concerning the value dimension of scientific culture in Europe.[61] The main steps that were taken in building a scale of attitudes toward science in Europe empirically—i.e., through statistical data analysis with very little theoretical guidance—will be reviewed here, and the quality of the scale (mainly its reliability) will be assessed. Some of the most serious difficulties encountered in this process and the weak robustness of the resulting scale will be documented and taken as an indication that a new research program for the attitudinal dimension of public understanding of science is needed. The conceptual flow diagram to replicate the building process of the scale is as follows: an analysis of the (Pearson) correlation between items, review of the factor analysis results (principal components with varimax rotation), and estimation of reliability through Cronbach's Alpha Coefficient.

Correlations between items

Analysis of the correlation matrix of the 23 items reveals the weak relations between them. Pearson's r is close to zero for many items and does not rise above 0.25 except in isolated cases. This is unsurprising considering the aspects mentioned above: the content of the items, the two splits, and the homogenization method. One representative example of this weakness is the correlation matrix of the seven items that have the highest correlation coefficients (Table 16). Using the coefficient of determination r^2 it is clear that the percentage of interrelation between any two items lies below 10% (with the exception of "Work" and "Future," where there is a 13.98% interrelation, with $r = 0.37$). This is definitely a matrix in which items are highly independent of each other; their relation is 90% due to random factors.

Two additional reasons for this low level of interrelation are, unquestionably, the statistical limitations that accompany a narrow range of response options (1 to 5) and the very large

Table 16. Matrix of correlations between seven items.

	"Life comfort"	"Work"	"Average person"	"Future"	"Government"	"Economy"	"Benefits"
"Life comfort"	1.00						
"Work"	0.243	1.00					
"Average person"	0.216	0.269	1.00				
"Future"	0.283	0.374	0.278	1.00			
"Government"	0.252	0.169	0.185	0.221	1.00		
"Economy"	0.233	0.227	0.176	0.239	0.265	1.00	
"Benefits"	0.252	0.221	0.244	0.288	0.266	0.241	1.00

weighted sample size (12,800). With a range from 1 to 5, every small change in the responses to one or the other item leads to a noticeable decrease in correlation between them. And obviously, since

$$r = \frac{\sum Z_X Z_Y}{N}$$

r tends to decrease due to the very large N, although the modest quality of the items (both in terms of content and linguistic form) plays a more important role, contributing to a decrease of the covariance.

An additional aspect that merits comment here is the metric attributes of the data on attitudes as measured in the Eurobarometer. The first decision the analysts have had to make is selecting the appropriate metric level of the items (interval vs. ordinal) and applying corresponding statistical procedures: Pearson product-moment correlation or, alternatively, polychoric correlation. Durant *et al.* have opted for treating the attitudinal items as interval measures, while other researchers have preferred to approach the same data from a stricter perspective, not assuming any property beyond that of an ordinal metric.[62] We cannot deal here with the general question of the consequences of maintaining or loosening up the typologies of measurement scales as a basis for selecting appropriate statistical procedures that were proposed by S. S. Stevens more than half a century ago, a topic of great interest and hot debate.[63] Suffice it to say that one of the main consequences of choosing between the computation of Pearson and polychoric correlations, the possible different magnitude of correlations between items (higher for the polychoric correlations calculated for ordinal variables), is negligible from the perspective of our analysis here and does not modify the pattern of low relationship between items.[64] More precisely, if we compare the matrix of Pearson correlations for the subset of 11 items used by Durant *et al.* for building an attitudinal scale (a matrix that contains the majority of the highest correlation values) with the corresponding matrix of polychoric correlations (see Tables 17 and 18), we find some differences in the expected direction, but their magnitude is small and does not change the weak level of relationship between the items.[65]

In any case, outside of the type and range of measurement, the really decisive factor is the content and quality of the item formulation, because if every one of them measures different issues that do not relate to latent shared dimensions, or if these questions appear cognitively and valuatively remote to the public, the analysis will hardly reveal any strong relation between them.

If the results of the correlation matrix already indicate the very low internal consistency of a scale that is constructed with these items, the data regarding the correlation between an item and the total score of the scale (calculated without the item in question) point in the same direction: it remains below 0.40. This means that what is measured by each item and what is measured by the set of other items has at most a 16% interrelation; put differently, at least

Table 17. Matrix of Pearson product-moment correlations between 11 items[a].

	Life comfort	Resources	Science	Environment	Researchers	Work	Way of life	Future	New technology	Industry	Benefits
Life comfort	1.000										
Resources	0.133	1.000									
Science	−0.064	0.096	1.000								
Environment	−0.093	0.182	0.193	1.000							
Researchers	−0.004	−0.036	0.146	0.062	1.000						
Work	0.243	0.175	−0.003	−0.002	0.000	1.000					
Way of life	−0.053	0.042	0.266	0.132	0.234	0.028	1.000				
Future	0.283	0.172	−0.026	−0.040	−0.031	0.374	−0.016	1.000			
New technology	−0.059	0.190	0.150	0.281	0.046	−0.013	0.111	−0.031	1.000		
Industry	−0.125	0.177	0.166	0.310	0.039	−0.032	0.108	−0.072	0.342	1.000	
Benefits	0.252	0.156	−0.020	−0.016	−0.043	0.221	−0.015	0.288	−0.015	−0.056	1.000

[a] Total effective sample size = 12.705 (listwise deletion).

Table 18. Matrix of polychoric correlations between 11 items[a].

	Life comfort	Resources	Science	Environment	Researchers	Work	Way of life	Future	New technology	Industry	Benefits
Life comfort	1.000										
Resources	0.166	1.000									
Science	−0.062	0.110	1.000								
Environment	−0.124	0.223	0.231	1.000							
Researchers	0.005	−0.050	0.173	0.068	1.000						
Work	0.307	0.197	0.003	−0.014	0.023	1.000					
Way of life	−0.041	0.042	0.307	0.152	0.278	0.047	1.000				
Future	0.356	0.191	−0.025	−0.060	−0.015	0.442	0.008	1.000			
New technology	−0.079	0.221	0.169	0.339	0.048	−0.023	0.117	−0.045	1.000		
Industry	−0.170	0.223	0.196	0.393	0.028	−0.062	0.108	−0.121	0.419	1.000	
Benefits	0.311	0.174	−0.021	−0.034	−0.041	0.272	−0.004	0.348	−0.025	−0.095	1.000

[a] Total effective sample size = 12.705 (listwise deletion).

84% of the interrelation is random. All this suggests that the items mostly have significance on their own, but no strong connection to a latent dimension that all of them share.

Factor analysis of the items

A matrix of weak correlations implies that in a factor analysis of the items, the factors explain only a small percentage of the total variance. The items that make up each factor have little commonality, and one cannot conclude that they represent a solid block with unequivocal meaning. When this happens, the factor analysis only confirms the high level of specificity of each item and its lack of relation with the others. This is indeed what emerges from the various factor analyses that have been carried out for the Eurobarometer data.

Factor analysis of all items

The loadings shown in Table 19 indicate a lack of statistical explanation for the overall meaning of the 23 items. Four factors capture only 37.28% of the total variance, a small percentage for reducing the number of variables and for detecting *structure* in the relationships between variables (especially when one takes into account the high number of components). There are no associations or strong item groups, but rather a random distribution from which individual units rather than subsets stand out; that is, no latent shared dimensions emerge. The "commonality" of the items—that is, the percentage of variance in each item that is "explained" by the set of calculated factors—is also very small. The specificity of each item along with error outweighs the significance that is shared with other items. Many of them do not attain a commonality of 40%, some not even 30%. This situation could be compared to the attempt to put together a jigsaw puzzle from 23 pieces of different size, color, and design that in reality represent specific images of their own. Or, to put it less metaphorically, these low commonalities show emphatically that it is extremely difficult to construct a robust scale from such disparate construction materials.

Factor analysis of 11 items

In the analysis of scientific culture in Europe by Durant *et al.*,[66] a selection of 11 out of 23 items leads to three components that explain 47.31% of total variance (Table 20). Durant *et al.* do not give any reasons for the selection of these 11 and not other items, though possibly it is based on their behavior in the statistical analysis. Excluding 12 items improves the factor analysis by 10 points, which is evidence that, for the purpose of constructing a summated scale, the omitted items generate confusion and noise. Although they might be measuring interesting issues that could be relevant in a different type of analysis, they do not contribute strong dimensions that capture general attitudes toward science and technology. There are higher levels of internal connection between the components of these subsets (even though the commonalities continue to be small, they have increased to above 50% for four items) than when they were combined with the other items. The correlation coefficients do not vary and continue to be small, but this weak relation is now better explained than before. Obviously, a strong random component continues to be present (52.7%). Other factor analyses on various subsets of items revealed a similar absence of strong groupings.

Reliability analysis

The reliability coefficient, Cronbach's Alpha, for the 23-item scale and for the total sample with homogenized data is $\alpha = 0.65$. Neither this coefficient nor those of each of the two

Table 19. Principal components solution for 23 items (varimax rotation).

	F.I	F.II	F.III	F.IV	Commonality
"Life comfort"	0.543	−0.126	−0.080	−0.098	32.6%
"Work"	0.594	0.077	−0.107	0.089	37.8%
"Average person"	0.532	0.091	0.026	−0.074	29.7%
"Future"	0.642	0.029	−0.129	−0.003	42.9%
"Government"	0.483	−0.374	0.076	−0.072	38.4%
"Inventions"	0.498	0.193	0.093	0.176	32.5%
"Economy"	0.538	−0.204	0.117	0.069	35.0%
"Illness"	0.525	−0.330	0.157	0.037	41.0%
"Benefits"	0.591	−0.014	−0.002	−0.135	36.8%
"Resources"	0.320	0.550	−0.147	−0.139	44.5%
"Environment"	−0.050	0.565	0.193	−0.059	36.3%
"Daily life"	−0.093	0.443	0.288	0. 119	30.2%
"New technology"	−0.048	0.586	0.087	0.079	36.0%
"Industry"	−0.134	0.640	0.063	0.034	43.3%
"Computers"	−0.089	0.393	0.269	0.152	25.8%
"Science"	0.003	0.289	0.512	−0.007	34.5%
"Researchers"	0.023	−0.028	0.643	0.067	41.9%
"Way of life"	0.047	0.149	0.672	−0.061	48.0%
"Animals"	0.179	0.118	0.149	−0.677	52.6%
"Products"	0.061	0.120	0.155	0.612	41.7%
"Progress"	0.443	0.387	−0.132	−0.207	40.6%
"Jobs"	0.172	0.373	−0.329	−0.123	29.2%
"Lucky number"	0.102	0.368	0.057	0.333	26.0%
Eigenvalue (λ)	3.153	2.643	1.616	1.162	
% Explained variance	13.71%	11.49%	7.03%	5.05%	
% Cum. explained variance	13.71%	25.20%	32.23%	37.28%	

Table 20. Principal components solution for 11 items (varimax rotation).

	F.I	F.II	F.III	Commonality
"Life comfort"	0.628	0.142	0.034	41.6%
"Work"	0.676	−0.018	−0.066	46.2%
"Future"	0.726	0.027	0.010	52.8%
"Benefits"	0.617	−0.014	0.050	38.4%
"Resources"	0.412	−0.522	0.067	44.6%
"Environment"	0.052	0.658	0.148	45.8%
"New technology"	0.040	0.692	0.061	48.4%
"Industry"	0.128	0.714	0.055	53.0%
"Science"	0.020	0.286	0.580	41.8%
"Researchers"	0.023	−0.098	0.709	51.3%
"Way of life"	−0.009	0.103	0.744	56.4%
Eigenvalue (λ)	1.952	1.819	1.433	
% Explained variance	17.75%	16.54%	13.03%	
% Cum. explained variance	17.75%	34.28%	47.31%	

splits reaches the cutoff point at which a summated scale can be considered reliable.[67] That is, none reaches a value of $\alpha = 0.75$. (A value of $\alpha = 0.70$ is considered small by Nunnally and Bernstein, although satisfactory in the early stages of construct validation.[68] Other authors have calculated the range and the median reliability coefficients for a number of attitude scales, which provide a sort of guideline: low 0.47, median 0.79, and high 0.98.[69])

It should be remembered that the formula for calculating the reliability coefficient is

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{1}^{K} S_j^2}{S_{\mathrm{T}}^2}\right)$$

with K the number of items, S_j^2 the variance of each item j, and S_{T}^2 the variance of the total scores attained by subjects on the scale. As it is easy to deduce, the larger the denominator is, the lower is the number to subtract from 1 and, therefore, the higher the reliability. In other words, a high variance in the total scores of subjects (denominator) indicates a great deal of heterogeneity among these subjects, which means that the summated scale has made a significant discrimination among them. None of the data matrices examined earlier—total sample, split A, split B, with original or homogenized scores—reaches an acceptable level of discrimination. The reliability analysis merely confirms what was already detected by means of the principal component analysis: The 23 items do not constitute a measuring tool with internal consistency or an acceptable level of reliability.

When one examines the reliability of the 23-item scale in terms of the variable of the interviewee's "level of scientific knowledge" (a variable that was measured through questions in the Eurobarometer itself), no statistical relation beyond pure coincidence emerges ($r^2 = 0.064$).[70] Figure 1 demonstrates this lack of connection between level of knowledge and reliability by nation because all the nations with the lowest levels of scientific knowledge (Greece, Portugal, Spain, and Ireland), as well as some of those with the highest levels (Belgium, Italy, France, and West Germany), fall in between reliability values of 0.62 and 0.66.

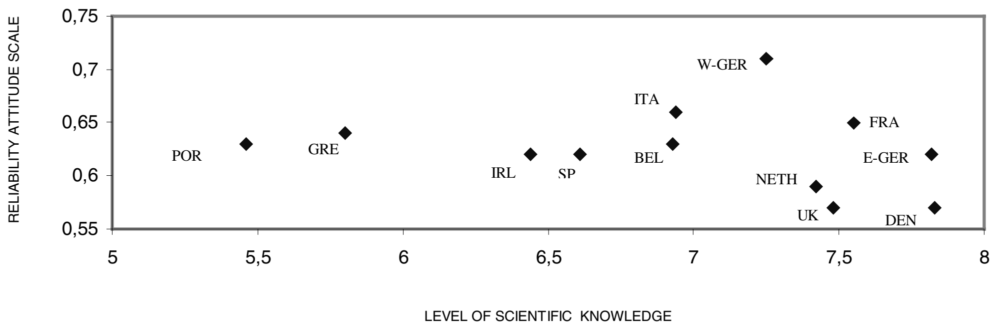

Figure 1. Reliability of the attitude scale (23 items) by scientific knowledge.

When one examines the 11-item subset used by Durant *et al.* to interpret the European public's attitudes toward science and technology, the reliability of this scale is $\alpha = 0.51$, a value that is clearly insufficient for the scale to be considered a consistent construct. The 11 items are "Life comfort," "Resources," "Science," "Environment," "Researchers," "Work," "Way of life," "Future," "New technology," "Industry," and "Benefits."

Reliability calculated by country (Table 21) as well for different types of subjects according to years of education, income, age, and leadership (Table 22) nowhere rises above 0.56 and falls to 0.44 for the group of subjects aged 55 or over.

With reliability scores around 0.50 for the total sample as well as for different groups of subjects, and with a maximum correlation between item and total sample score of 0.30

Table 21. Reliability of the 11-item scale, by nation.

	Cronbach's α
West Germany	0.56
Italy	0.51
France	0.51
Spain	0.50
Belgium	0.48
Greece	0.47
Netherlands	0.47
UK	0.46
East Germany	0.45
Portugal	0.45
Ireland	0.44
Denmark	0.43

Table 22. Reliability of the 11-item scale by sociodemographic variables.

	Years of education				Income			
	15 or less	16–19	20 or more	Current student	(−−) lowest	(−)	(+)	(++) highest
Cronbach's α	0.48	0.51	0.50	0.47	0.54	0.51	0.53	0.47
	Age				**Leadership**			
	15–24	25–39	40–54	55 or more	(−−) low	(−)	(+)	(++) high
Cronbach's α	0.51	0.54	0.51	0.44	0.50	0.50	0.52	0.53

(in the case of the item "Resources"), it is clear that these 11 items make up a disconnected and heterogeneous group that captures different and independent issues regarding science and technology.

Interpreting the factors

Each of the three factors identified by Durant *et al.* explains only 17.75%, 16.54%, and 13.03% of the total variance, respectively; their interrelation is zero, since they were extracted as orthogonal to each other (varimax rotation). An alternative oblique rotation was attempted to test the null hypothesis of complete independence between the factors, but we failed to reject it: the correlation between Factor I and Factor II was 0.000, −0.064 between Factor I and Factor III, and 0.153 between Factor II and Factor III. This result corresponds to that of Miller, Pardo, and Niwa, who found virtual independence between the two components ("Promises" and "Reservations") of a factor solution for the same data and virtually the same items.[71] Obviously the loadings of the items with an oblique rotation were virtually identical to the ones obtained for an orthogonal rotation, and so following standard guidelines, varimax rotation was applied (which, from another perspective, has the advantage of replicating Durant's results).[72]

The three factors that were obtained from the analysis of 11 items are labeled "Progress," "Panacea," and "Future shock" in Durant's study. Factor I, "Progress" consists of the items "Life comfort," "Work," "Future," and "Benefits"; factor II, "Panacea" includes the items "Resources," "Environment," "New technology," and "Industry"; factor III, called "Future shock," is made up of the three items "Science," "Way of life," and "Researchers."

The significance of the three factors is easier to understand when one examines the mean value of the items loading on each factor (see Table 23, "1" strongly agree, "5" strongly disagree). The first factor, labeled "Progress" by Durant *et al.*, implies a strong agreement with the belief that science increases standards of living, ensures greater opportunities for future generations, yields more benefits than side effects, and leads to the improvement of work. This factor offers a measurement of the belief in progress that is associated with science and technology; a clear majority of European societies subscribes to this perception.

Table 23. Mean values of the 11 items.

F.I	"Future"	2.31
	"Work"	2.52
	"Life comfort"	2.07
	"Benefits"	2.46
F.II	"Industry"	3.93
	"New technology"	3.56
	"Environment"	3.66
	"Resources"	3.59
F.III	"Way of life"	2.58
	"Researchers"	2.46
	"Science"	2.92

The meaning of the second factor, "Panacea," is less clear, and the interpretation of the four items that constitute it turns out not to be obvious. It is true that two of them point to a sort of "scientism" or belief in a "technological fix" concerning the environment and the role of science in conservation as well as exploitation. Subjects recognize that science can play an important role in environmental conservation; but a majority believe that natural resources are and will remain finite, no matter how much scientific knowledge advances. Conceptually, the two remaining items (which are precisely the ones that obtain the highest loadings in factor analysis) are only weakly linked to the notion of "Panacea." The great majority of the population disagrees with the statement that new technologies do not depend on basic scientific research, as well as with the statement that industry does not depend on science and technology. However, one has to keep in mind the great percentage of "don't know" answers for the first of these two items (17.5% in split A and 20.4% in split B, 18.9% in the total sample), and in any case, the notion of "Panacea" as a latent dimension linking them seems far-fetched.

The third factor, "Future shock," really measures alienation with regard to science and technology, anxiety about the pace of social change associated with science, and the power of researchers, as well as reservations about what is perceived as a greater reliance on science than on religion. Since the original content of the three items expressed reservations about science, a score below 2.5 suggests an important degree of distance or fear of science.[73] The analysis of the mean values indicates that the tensions between science and religion have diminished in the cognitive maps of individuals in advanced societies, but social images of the scientist à la Frankenstein persist, as do perceptions of accelerated changes of lifestyle.[74]

The last two factors, "Panacea" and "Future shock," are transformed into a new metric tool by the authors (one that cannot really be called a "factor") on the basis of three items: two that relate to the factor "Panacea" ("Industry" and "Environment"), and one that relates to "Future shock" ("Way of life"), which together become an index that the authors label "pessimism."[75] Optimistic subjects manifest their consent to the role of science and technology in industrial development and in environmental protection and do not believe that life is changing too rapidly. Pessimists, by contrast, attribute a limited role to science in industrial development, do not believe in science's role in the solution of environmental problems, and perceive the disruptive power of science on traditional ways of life with anxiety.

The interpretations of scientific culture in various European societies that Durant *et al.* present are based on how different countries score on the factor "Progress" and the new index "Pessimism," and relate the scores to the levels of industrialization of these countries. This analytic strategy is suggestive but inelegant, since it does not succeed in clarifying which variables could explain why countries with similar levels of industrialization score differently on the two indicators. The adoption of a conceptual schema inspired by Piaget—assimilation and accommodation to science—is clearly strained. But our main reservation has to do with the obvious weakness of the measurements that serve as the basis for the summated scales.

The construction of three scales on the basis of the factor analysis results and a new index that is based on a selection of items from factors 2 and 3 does not have the required formal properties; in particular, it does not reach an acceptable reliability threshold for the "Future shock" and "Pessimism" scales (Table 24):

Table 24. Reliability (Cronbach's α) of the four scales.

Subscale "Progress"	0.60
Subscale "Panacea"	0.56
Subscale "Future shock"	0.45
Subscale "Pessimism"	0.40

Table 25. Reliabilities of the four subscales, by nation.

	"Progress"	"Panacea"	"Future shock"	"Pessimism"
West Germany	0.64	0.62	0.51	0.40
Italy	0.59	0.52	0.39	0.42
France	0.58	0.59	0.48	0.48
Spain	0.64	0.54	0.42	0.27
Belgium	0.57	0.61	0.48	0.41
Greece	0.66	0.49	0.35	0.06
Netherlands	0.51	0.57	0.43	0.42
UK	0.58	0.55	0.50	0.42
East Germany	0.62	0.55	0.29	0.42
Portugal	0.58	0.56	0.54	0.12
Ireland	0.62	0.45	0.51	0.42
Denmark	0.52	0.53	0.54	0.37

When these reliability scores are calculated by nation (Table 25) or by different sociodemographic variables (Table 26), the inconsistency of the four subscales becomes even more obvious. Their reliability does not reach statistically acceptable values for any group of subjects, and in many cases it decreases, sometimes very significantly. On the indicator "Pessimism," Greece scores 0.06, Portugal 0.12, Spain 0.27; Ireland scores 0.45 on "Panacea," East Germany 0.29, and Italy 0.39; on "Progress," the Netherlands attain a reliability score of 0.51 and Denmark 0.52.

The total scores of various types of European subjects that were calculated by means of the four subscales "Progress," "Panacea," "Future shock," and "Pessimism" cannot be considered sufficiently reliable; their use as an empirical basis for corroborating theories about scientific culture in late-modern societies is inadequate. The formulation of hypotheses that can be

Table 26. Reliability (Cronbach's α) of the four subscales, by sociodemographic variables.

	Years of education				Income			
Subscales	15 or less	16–19	20 or more	Current student	(−−) lowest	(−)	(+)	(++) highest
"Progress"	0.61	0.59	0.63	0.57	0.61	0.59	0.64	0.59
"Panacea"	0.49	0.56	0.50	0.54	0.55	0.56	0.53	0.50
"Future shock"	0.43	0.42	0.46	0.43	0.50	0.42	0.45	0.44
"Pessimism"	0.33	0.38	0.37	0.38	0.44	0.39	0.35	0.34
	Age				**Leadership**			
Subscales	15–24	25–39	40–54	55 or more	(−−) low	(−)	(+)	(++) high
"Progress"	0.58	0.62	0.61	0.60	0.60	0.59	0.61	0.60
"Panacea"	0.58	0.59	0.57	0.49	0.52	0.54	0.57	0.52
"Future shock"	0.41	0.49	0.44	0.38	0.43	0.44	0.46	0.46
"Pessimism"	0.42	0.42	0.38	0.34	0.38	0.35	0.41	0.42

rigorously tested (even to be disproved), as Durant and colleagues have done, is certainly a most welcome step for the development of an exciting research area with important policy implications. These researchers deserve credit for their contribution to opening up new paths for the study of scientific culture. But it is precisely the many advances in the field of public understanding of science and its current state that allow and, in our opinion, require the launching of a new research program for the development of questionnaires and other observational instruments that are better supported theoretically, more finely grained, and better aligned with the rich literature on the conceptualization and measurement of attitudes and values.

7. Conclusion

The methodological and statistical analysis of the Eurobarometer items and the scales measuring attitudes toward science leads to the conclusion that they are formally and conceptually weak instruments, far removed from the standards of other areas of social-scientific research. The most empirically oriented literature in the field of public understanding of science has in the last few years proposed some suggestive hypotheses and conceptual schemas for central issues, such as the relationship between knowledge and attitudes and the transformations of scientific culture associated with the transition from industrial to postindustrial societies (degree of interest, specialization of knowledge and interests, public perception of promises and dangers of science in the more advanced societies). This literature, making a virtue out of necessity, has had to rely on the only instruments and data currently available for comparative analysis. But it is clear that the scales that have been used are seriously flawed and threaten the stability and truthfulness of at least some of the obtained results. Some important assumptions underlying the scale-building process need to be made explicit and subjected to formal scrutiny, and their compatibility with the findings of the existing literature on the conceptualization and measurement of attitudes needs to be assessed. The alignment of theory, methodology, and statistical analysis should be a major goal for making progress in the field, and more stringent protocols for communicating the findings and problems encountered in the interpretation of the evidence need to be put in place to facilitate the replication of results by independent researchers.

To construct robust explanatory models of the structure and dynamic of scientific culture in late modernity, questionnaires are necessary that are able to capture the different facets of attitudes toward science and technology, that are sensitive to the degree of salience each facet has for the population under study, and that are based on a metric that can accommodate greater variability.[76] Only in this way will it be possible to create scales with the reliability and validity required to support theories and interpretations. There are items we have inherited from an earlier period that can perhaps be integrated without any problem into the new questionnaires, which would enable useful measurements for the analysis of stability and change in perceptions of science over the last 50 years. But the focus of the next generation of research projects must be the introduction of new facets of science that more closely match late-modern developments in science and technology (some of the most recent Eurobarometers, such as 52.1 on Modern Biotechnology [1999], have already initiated this process). Obviously, what is needed is not only greater attention to methodological factors but, in parallel, theoretical work that is more sophisticated and better connected to other areas of the social sciences.

Issues that need to be resolved are the possible fragmentation of attitudes into distinct clusters; the existence or absence of general attitudes toward science in different types of subjects and, if they do exist, their ability to predict more specific attitudes; the different levels of salience that various aspects of contemporary science and technology have, and particularly, the role that other "families" of attitudes and values play in the valuation of science (such as perceptions of the natural environment, perceptions of risk, globalization, complexity, and "worldviews" at the beginning of the twenty-first century). The appropriate metric to apply in questionnaires (starting with the number of response options), and a more thorough analysis of the profile(s) of "nonopinion" and "no opinion" individuals regarding science, should be subject to experimentation and analysis, respectively.

Science and technology are present in so many different forms today that we will inevitably find varying assessments as we move across different areas. This variation will require the construction of a greater repertoire of scales to reflect different dimensions of science. Many areas of science will be assessed favorably or will provoke no strong valuation, while others will quite possibly be viewed critically or cautiously. The overlap between science and social institutions has expanded in so many different directions that it may well turn out to be very difficult to find general, clearly structured attitudes in the great majority of the population who do not deal with science and technology professionally; instead, there may be attitudes toward subsets of science (an important question that has been raised by Daamen, Van der Lans and Midden).[77] What is indeed plausible is that there are different facets in the perceptions and valuations of science, and part of the work program must be to identify these facets, their level of salience for different populations, and the types of connections that exist between them.

The assessment of attitudes toward science may have to move beyond labels such as "positive," "negative," or "ambivalent" to make room for research on more complex, qualitative, and non-linear sets of relationships that may exist between different facets. Such an analysis would have to take into account the evaluation criteria that the population uses to assess science: among others, questions of economic usefulness, moral considerations, issues concerning the perception of nature and the natural, perceptions of risk and technological stigma, concerns about the complexity of contemporary life, about health benefits for humans, or about impacts on the social stratification of specific countries and between different types of countries. Weighing items equally that in fact represent criteria of quite dissimilar relevance for the population at the turn of the century, and assuming as a matter of course that those who do not form part of the professional scientific community have one single conception of science, are assumptions without empirical support. There are theoretical indications and some empirical evidence to suggest that what prevails is rather an abundance of microperspectives or fragmented valuations, some at odds with each other, others coexisting without significant interaction. This appears to be true of the general culture as well as of the cognitive and evaluative maps of individuals, and has been described with a different vocabulary in some of the literature on postmodernity.[78] Possibly, most people in the second half of the twentieth century have had to learn how to organize and give meaning to their lives without an all-encompassing, harmonious image of reality and its most representative objects and constructions—such as science. Science itself has contributed to this change by eroding and delegitimizing *Weltanschauungen* of romantic origin.

To make progress in the analysis of whether we are indeed in the midst of such changes of sensibility or perception, it is desirable and necessary to complement work that aims at the construction of scales and the detection of structure with an examination of the qualitative perceptions people have of various facets of science. Despite their limitations, the available data do enable steps to be taken toward the dual objective of creating a preliminary chart of some facets of attitudes to science and technology, a map to be used as a heuristic aid in the design of new observational instruments, and of characterizing some vectors of the scientific culture at the turn of the century. Parsimonious analysis of the Eurobarometer data by means of multivariate statistical techniques of an exploratory nature (such as correspondence analysis, classification and regression trees), which do not impose as much structure and restrictions on data as techniques aimed at the testing of hypotheses, should, in our view, be the first method of choice. In the realization of this research program, historiographical perspectives and qualitative methodologies will also be necessary.

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2 Institute for Social Research at the University of Michigan, *The Public Impact of Science in the Mass Media* (Michigan: Institute for Social Research, 1958).

3 It is true, however, that the analysis of resistance to science was by no means confined to science literacy, but also investigated other variables, such as religious values, "orientations to the world in general," and the high salience of some negative "by-products [of science] in the minds of the public" in those years, particularly atomic weapons and the prospect of annihilation.

4 National Science Board, *Science Indicators 1980* (Washington, D.C.: U.S. Government Printing Office, 1981), 157–179.

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6 Geoffrey Evans and John Durant, "Understanding of science in Britain and the USA," in *British Social Attitudes: Special International Report: The 6th Report*, eds. Roger Jowell, Sharon Witherspoon, and Lindsay Brook (Hants: Gower-SCPR, 1989).

7 Philip E. Converse, "The nature of belief systems in mass publics," in *Ideology and Discontent*, ed. David E. Apter (London: Free Press of Glencoe, 1964), 206–261; "Comment: The status of nonattitudes," *The American Political Science Review* 68 (1974): 650–660.

8 The notion of "attentiveness" was an extension of Gabriel Almond's notion of the "attentive public" for foreign policies matters (cf. Gabriel Almond, *The American People and Foreign Policy* [New York: Harcourt, Brace and Company, 1950]) and elaborated by Miller and collaborators in Jon D. Miller, Robert W. Suchner, and Alan M.

Voelker, *Citizenship in an Age of Science: Changing Attitudes among Young Adults* (New York: Pergamon Press, 1980).

9 Dancker D. L. Daamen, Ivo A. Van der Lans, and Cees J. H. Midden, "Cognitive structures in the perception of modern technologies," *Science, Technology, & Human Values* 15, no. 2 (Spring 1990): 202–225.

10 One of these new developments (which we will not elaborate here) has been the application of Cognitive Science notions to the measurement and understanding of attitudes toward science, substituting the theoretical concept of "schemas" regarding *promises* and *reservations* about science for the more conventional perspective of a unique or unidimenional continuum (from negative to positive) of the attitudinal domain. This approach makes more complex and robust the indexes of benefits and risks of science introduced in earlier work by Miller *et al.* (1980). Other novelties include the use of advanced multivariate statistical techniques, such as confirmatory factor analysis and structural equation modeling in the analysis of the data (cf. Jon D. Miller, Rafael Pardo, and Fujio Niwa, *Public Perceptions of Science and Technology: A Comparative Study of the European Union, the United States, Japan, and Canada* [Madrid–Chicago: Fundación BBV–Chicago Academy of Sciences, 1997]).

11 John Durant and collaborators are the main internal critics of assumptions underlying the scientific literacy paradigm, regarding both the literacy concept and the association between literacy and attitudes toward science (cf. Geoffrey Evans and John Durant, "The relationship between knowledge and attitudes in the public understanding of science in Britain," *Public Understanding of Science* 4 [1995]: 57–74; Martin Bauer, John Durant, and Geoffrey Evans, "European public perceptions of science," *International Journal of Public Opinion Research* 6, no. 2 [1994]: 163–186.)

12 Evans and Durant, "The relationship between knowledge and attitudes in the public understanding of science in Britain."

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14 John Durant *et al.*, "Two cultures of public understanding of science and technology in Europe," in *Between Understanding and Trust: The Public, Science and Technology,* eds. Meinolf Dierkes and Claudia von Grote (Amsterdam: Harwood Academic Publishers, 2000), 131–156.

15 Georges Gaskell *et al.*, "Europe ambivalent on biotechnology," *Nature* 387 (26 June 1997): 845–847.

16 Georges Gaskell, Martin Bauer, John Durant, and Nicholas C. Allum, "Worlds apart? The reception of genetically modified foods in Europe and the U.S.," *Science* 285 (16 July 1999): 384–387.

17 James Burke, *Connections* (Boston: Little, Brown and Company, 1978).

18 In this paper, we repeatedly refer to the concept of "modernity," with and without qualifiers ("late modernity," "postmodernity"). Like many other terms that are designed to capture both core dimensions of society and a more or less clearly bound time period, "modernity" and "postmodernity" can be fuzzy labels with varied and imprecise meanings. A speculative and anachronistic style of theorizing in some areas of the social sciences generates a continuous flow of such notions, which are often superseded by other labels only a few years later (a list of more than 75 societal transformations identified and labeled between 1950–1985 can be found in James R. Beniger, *The Control Revolution* [Cambridge, MA: Harvard University Press, 1986], 4–5.) But modernity, despite its varied meanings and uses, is a concept of central importance to the work of many social scientists and historians, from Max Weber to Ronald Inglehart and Anthony Giddens. "Modernization" or, to use an expression less loaded with undesirable connotations today, the "*formation of modernity*" refers to the interaction of several large-scale changes, including the emergence of the modern state, the constitution of a market economy, the industrial revolution, processes of urbanization, the development of modern science, and the rationalization of a growing number of public and private spheres. Modernity refers to that cluster of institutions or, in Giddens's words, "modes of social life or organization that emerged in Europe from about the seventeenth century onwards and which subsequently became more or less worldwide influence" (Anthony Giddens, *The Consequences of Modernity* [Stanford, CA: Stanford University Press, 1990]). Most authors include the Enlightenment as a central cultural force in the historical emergence of modernity; this term admittedly suffers from the same indeterminacy as "modernity," but its meaning encompasses "a cluster of ideas and attitudes," "a way of thinking set in place in Western culture [. . .] the free play of critical and constructive reason, employing available knowledge in the humanistic search for a better society, better behaviour, greater happiness on earth" (cf. John W. Yolton, ed., *The Blackwell Companion to the Enlightenment* [Oxford: Blackwell Publishers, 1995]). Some of the main ideas and beliefs of modernity about rationality, knowledge, and control of the natural world and about the progress of society have their roots in the so-called "Enlightenment Project." Despite the difficulties in defining the precise meaning of notions such as "Enlightenment" and "modernity," their use is important in our context because some of the most interesting critiques, analyses, and debates about changes in the perception of science and technology and in values have been framed in terms of these concepts (cf. Gerald Holton, "What place for science in our culture at the 'end of the modern era'?," in *Einstein, History, and Other Passions* [Woodbury, NY: American Institute of Physics Press, 1995], 91–125; for additional discussions of modernity, cf. Ronald Inglehart, *Modernization and Postmodernization: Cultural, Economic, and Political Change in 43 Societies* [Princeton, NJ: Princeton

University Press, 1997], particularly Chapter 1 on the meanings of "modernity" and "postmodernity"; see also Stuart Hall et al., eds., *Modernity: An Introduction to Modern Societies* [Oxford: Blackwell Publishers, 1996]). The literature on "postmodernity" to which we refer in this paper revolves around the thesis of a substitution, in the last decades of the twentieth century, of fragmented and heterogeneous perspectives, on an (allegedly) equal epistemic footing, for the so-called "grand narrative" (Lyotard) or overarching modern story line giving meaning to the past and the future; this grand narrative is closely associated with science, rational control, and progress. It is not necessary to make any commitment to the assumptions and style of theorizing of the postmodern perspective to see the heuristic value of this thesis regarding the multiplication of different visions claiming equal rights to knowledge. Finally, we use the expression "late modernity" to indicate that the observed transformations in the last part of the twentieth century (globalization, knowledge economies, changes in values), constitute important novelties to be analyzed, but we do not think that there is enough evidence to support the thesis that central modern institutions and culture (specifically the belief in science and progress) have been superseded by a new set of principles and modes of social organization. Like Giddens, we believe that "rather than entering a period of post-modernity, we are moving into one in which the consequences of modernity are becoming more radicalised and universalised than before" (cf. Anthony Giddens, *The Consequences of Modernity*).

19 Geoffrey Thomas and John Durant, "Why should we promote the public understanding of science?" in *Scientific Literacy Papers*, ed. M. Shortland (Oxford: Department of External Studies, 1987), 1–14.

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23 Steven Shapin, "Science and the public," in *Companion to the History of Modern Science*, eds. R. C. Olby *et al.* (London: Routledge, 1990), 990–1007; J. B. Morrell, "Professionalization," ibid., 980–989; Joseph Ben-David, *The Scientist's Role in Society: A Comparative Study* (Chicago: University of Chicago Press, 1984), 108ff.

24 Cf. David C. Mowery and Nathan Rosenberg, *Technology and the Pursuit of Economic Growth* (Cambridge: Cambridge University Press, 1989).

25 John Ziman, *Prometheus Bound: Science in a Dynamic Steady State* (Cambridge: Cambridge University Press, 1994); Claude E. Barfield, ed., *Science for the 21st Century: The Bush Report Revisited* (Washington, D.C.: AEI Press, 1997).

26 David H. Guston and Kenneth Keniston, "Introduction: the social contract for science," in *The Fragile Contract: University Science and the Federal Government,* eds. David H. Guston and Kenneth Keniston (Cambridge, MA: MIT Press, 1994).

27 Norman Levitt, *Prometheus Bedeviled: Science and the Contradictions of Contemporary Culture* (New Brunswick, NJ: Rutgers University Press, 1999).

28 Morris H. Shamos, *The Myth of Scientific Literacy* (New Brunswick, NJ: Rutgers University Press, 1995).

29 Brian Wynne, "Misunderstood misunderstandings: social identities and public uptake of science," *Public Understanding of Science* 1 (1992): 281–304.

30 Albert O. Hirschman, *Exit, Voice, and Loyalty* (Cambridge, MA: Harvard University Press, 1970).

31 Cf. Simon Joss and John Durant, eds., *Public Participation in Science: The Role of Consensus Conferences in Europe* (London: The Science Museum, 1995); E. F. Einsiedel, E. Jelsøe, and T. Breck, "Publics at the technology table: the Consensus Conference in Denmark, Canada, and Australia," *Public Understanding of Science* 10 (2001): 83–98.

32 Godin and Gingras' recent proposal of a multidimensional model of scientific and technological culture represents a valuable approach for introducing more clarity and complexity into the study of scientific culture, even though it remains largely disconnected from the empirically oriented literature of the PUOS field (cf. Benoit Godin and Yves Gingras, "What is scientific and technological culture and how is it measured? A multidimensional model," *Public Understanding of Science* 9 [2000]: 43–58).

33 Cf. the methodological conclusions in Durant *et al.*, "Two cultures."

34 Jum C. Nunnally and Ira H. Bernstein, *Psychometric Theory*, 3rd ed.. (New York: McGraw-Hill, 1994); John P. Robinson, Phillip R. Shaver, and Lawrence S. Wrightsman, "Scale selection and evaluation," in *Measures of Political Attitudes*, eds. John P. Robinson *et al.* (San Diego: Academic Press, 1999); Duane F. Alwin, Michael Braun, Janet Harkness, and Jacqueline Scott, "Measurement in multi-national surveys," in *Trends and Perspectives in Empirical Social Research*, eds. Ingwer Borg and Peter Ph. Mohler (Berlin: Walter de Gruyter, 1994), 26–39.

35 John W. Tukey, *Exploratory Data Analysis* (Reading, MA: Addison-Wesley, 1977); J. P. Benzécri, *Correspondence Analysis Handbook* (New York: Marcel Dekker, 1992); L. Breiman, J. H. Friedman, R. A. Olshen, and C. J. Stone, *Classification and Regression Trees* (Monterey, CA: Wadsworth & Brooks, 1984).

36 The main report was published under the title *The Public Impact of Science in the Mass Media* (cf. note 2); some

of its most salient results are also presented in Stephen B. Withey, "Public opinion about science and scientists," *Public Opinion Quarterly* 23, no. 3 (Fall 1959): 382–388.

37 National Science Board, *Science Indicators: 1972* (Washington, D.C.: U.S. Government Printing Office, 1973); National Science Board, *Science Indicators: 1974* (Washington, D.C.: U.S. Government Printing Office, 1975); National Science Board, *Science Indicators: 1976* (Washington, D.C.: U.S. Government Printing Office, 1977.) Each report referred mainly to surveys conducted a year earlier and also to a number of available secondary sources (such as the General Social Survey.)

38 National Science Board, *Science Indicators: 1978* (Washington, D.C.: U.S. Government Printing Office, 1979), viii.

39 Cf. Miller, Suchner, and Voelker, *Citizenship in an Age of Science*.

40 The main indexes introduced were the ones on risks and benefits, developed by Miller, Suchner, and Voelker in their 1980 book, *Citizenship in an Age of Science*.

41 The different number of response options for attitudinal questions in the European Union and the U.S. (five vs. four) did not prevent a comparison of agreement levels in the *Science & Engineering Indicators* of 1991 and 1993. These comparisons, however, have to be taken with a certain amount of caution. Cf. *Science & Engineering Indicators: 1991* (Washington, D.C.: U.S. Government Printing Office, 1991); *Science & Engineering Indicators: 1993* (Washington, D.C.: U.S. Government Printing Office, 1993).

42 Commission of the European Communities, *The European Public's Attitudes to Scientific and Technical Developments* (Brussels: mimeo, 1979).

43 Even the Science & Engineering Report of 1998, which introduced several conceptual and methodological novelties (mainly the notion of promises and reservations schemas), did not make use of the scientific literacy index (labeled in that report "Index of Scientific Construct Understanding") in the analysis of attitudes toward science, but used science education and the already familiar variable of attentiveness instead. Cf. *Science & Engineering Indicators: 1998* (Arlington, VA: National Science Foundation, 1998.)

44 Cf. Evans and Durant, "The relationship between knowledge and attitudes in the public understanding of science in Britain," p. 60. Evans and Durant mention that some of the nine questions used to measure general attitudes toward science in the 1988 British survey "were taken from previous studies [Withey, Miller], and others were devised following pilot studies of discussion groups of between ten and twelve people."

45 Miller, Suchner, and Voelker, *Citizenship in an Age of Science*.

46 The ATOSS scale was introduced in the *Science & Engineering Indicators: 1993*. (Washington, D.C.: U.S. Government Printing Office, 1993).

47 For details regarding the construction and transformation of the "promises" and "reservations" schemas, see Miller, Pardo, and Niwa, *Public Perceptions of Science and Technology*.

48 Cf. John Ziman, "Public understanding of science," *Science, Technology, & Human Values* 16, no.1 (1991): 99–105; Jean-Marc Lévy-Leblond, "About misunderstandings about misunderstandings," *Public Understanding of Science* 1 (1992): 17–22; Bruce V. Lewenstein, "Science and the media," in *Handbook of Science and Technology Studies*, eds. Sheila Jasanoff *et al.* (Thousand Oaks, CA: Sage, 1995), 343–360; Brian Wynne, "Public understanding of science," ibid. 361–388; Brian Wynne, "Misunderstood misunderstandings: social identities and public uptake of science," in *Misunderstood Science? The Public Reconstruction of Science and Technology*, eds. Alan Irwin and Brian Wynne (Cambridge: Cambridge University Press, 1996), 19–46.

49 General information about the history, characteristics, and role of the Eurobarometer can be found in Karlheinz Reif and Ronald Inglehart, eds., *Eurobarometer: The Dynamics of European Public Opinion. Essays in Honour of Jacques-René Rabier* (New York: St. Martin's Press, 1991).

50 INRA (Europe) and Report International, *Europeans, Science and Technology: Public Understanding and Attitudes* (Brussels: European Commission/Directorate General XII, 1993.) The fieldwork of the Eurobarometer 38.1 was carried out by INRA (Europe) between November 3 and November 29 on behalf of the European Commission, with a sample of 13,000 European citizens, representative of the total population of the member states aged 15 years and over. The sample design that was applied to all member states is multi-stage and random: "In each EU country, a number of sampling points was drawn with probability proportional to population size (for a total coverage of the country) and to population density. [...] The points were drawn systematically from all "administrative regional units," after stratification by individual unit and type of area. [...] In each of the selected sampling points, a starting address was drawn at random. Further addresses were selected as every Nth address by standard random route procedures, from the initial address. In each household, the respondent was drawn at random. All interviews were face-to-face in people's homes and in the appropriate national language" (INRA [Europe] and Report International, *Europeans, Science and Technology*, 117.) The confidence limits for samples of 1,000 interviews are $\pm 1.9\%$ for observed percentages of 10% or 90%, $\pm 2.5\%$ for observed percentages of 20% or 80%, $\pm 2.7\%$ for observed percentages of 30% or 70%, $\pm 3.0\%$ for observed percentages of 40% or 60%, and $\pm 3.1\%$ for observed percentages of 50%. As far as we know, no response rate has been reported for this survey.

51 As of this writing, a preliminary report for the 2001 Eurobarometer 55.2 has been released that can be accessed at http://europa.eu.int/comm/research/press/2001/pr0612en-report.pdf.

52 The main novelty in terms of content compared to the 89 Eurobarometer was the introduction of a large number of questions about the natural environment that addressed not only attitudes, but also awareness and knowledge.

53 Icek Ajzen and Dagmar Krebs, "Attitude theory and measurement: implications for survey research," in *Trends and Perspectives in Empirical Social Research*, eds. Ingwer Borg and Peter Ph. Mohler (Berlin: Walter de Gruyter, 1994), 250–265. On the crucial notion of "salience of beliefs," Fishbein and Ajzen have written that "although a person may hold a large number of beliefs about any given object, it appears that only a relatively small number of beliefs serve as determinants of his attitude at any given moment. [. . .] under most circumstances, a small number of beliefs serve as the determinants of a person's attitude. Clearly, salient beliefs are also subject to change; they may be strengthened or replaced by new beliefs." Despite the methodological problems of capturing all the salient beliefs of a person, these authors recommend as a "rule of thumb" the identification of the first five to nine beliefs "as the basic determinants of attitude" and "to ascertain the modal salient beliefs within a given population" through the use of a representative sample (cf. Martin Fishbein and Icek Ajzen, *Belief, Attitude, Intention and Behavior* [Reading, MA: Addison-Wesley Publishing Company, 1975], 218–219).

54 Other analysts of the Eurobarometer have opted for the use of only the half (of 6,000 cases) with four options, i.e., for the use of exactly the same metric in the U.S. and in Europe (cf. Miller, Pardo, and Niwa, *Public Perceptions of Science and Technology*).

55 The countries included were Belgium, Denmark, France, Germany, Greece, the Netherlands, Portugal, Ireland, Italy, Spain, and the United Kingdom. Luxembourg was excluded from the analysis because of its small number of cases.

56 Cf. INRA (Europe) and Report International, *Europeans, Science and Technology*, 113–114.

57 Howard Schuman and Stanley Presser, *Questions and Answers in Attitude Surveys* (Thousand Oaks, CA: Sage, 1996).

58 Durant *et al.*, "Two Cultures"; Bauer, Durant, and Evans, "European public perceptions."

59 Jean M. Converse, "Predicting no opinion in the polls," *The Public Opinion Quarterly* 40, no. 4 (Winter 1976-1977): 515–530.

60 G. David Faulkenberry and Robert Mason, "Characteristics of nonopinion and no opinion response groups," *The Public Opinion Quarterly* 42 (1978): 533–543.

61 Durant *et al.*, "Two cultures."

62 Cf. Miller, Pardo, and Niwa, *Public Perceptions of Science and Technology*.

63 For an illuminating critique of Stevens's typology, see Paul Velleman and Leland Wilkinson, "Nominal, ordinal, interval, and ratio typologies are misleading," in *Trends and Perspectives in Empirical Social Research*, eds. Ingwer Borg and Peter Ph. Mohler, 161–177.

64 Karl G. Jöreskog has for many years been one of the most eminent advocates for the use of polychoric correlations with ordinal variables, and their computation is routinely carried out with PRELIS as a preparation for structural equation modeling under LISREL. Cf. *SPSS LISREL 7 and PRELIS: User's Guide and Reference* (Chicago: SPSS Inc., 1990), B4-B9. See also Jöreskog's recent contribution "Analysis of ordinal variables 1: preliminary analysis [revised October 18, 2001]," which can be found (with three other contributions) at http://www.ssicentral.com/lisrel/ord1.pdf.

65 The most relevant characteristics of the two matrices can be summarized as follows: (1) in the matrix of polychoric correlations 31 (out of 55) have values < 0.15 (vs. 35 in the Pearson correlation matrix), 40 < 0.20 (vs. 44 in the Pearson matrix), and 44 < 0.25 (vs. 47 in the Product-Moment correlation matrix); (2) in the polychoric matrix, there are only six correlations with a r^2 higher than 10%, and two in the Pearson correlation matrix. In sum, the magnitude and structure of the differences between the two matrices do not modify the judgment about the weak level of relationship between the attitudinal items.

66 Durant *et al.*, "Two cultures."

67 The reliability coefficient of the 23-item scale with homogenized data in split A is $\alpha = 0.66$. In split B, it is $\alpha = 0.64$. The reliability coefficient for the original data in split A is $\alpha = 0.69$, in split B $\alpha = 0.68$.

68 Nunnally and Bernstein, *Psychometric Theory*.

69 See, G. C. Helmstadter, *Principles of Psychological Measurement* (Englewood Cliffs, NJ: Prentice Hall, 1964).

70 Level of scientific knowledge was measured with a 12-item scale that is useful for an exploratory analysis, even though it is not exempt from conceptual and metrical problems; the items were constructed on the basis of questions Q55 and A56 of the Eurobarometer questionnaire, each with three response options: 1 = True, 2 = False, 3 = Don't know. The summated scale consists of the following 12 items: 1. The center of the earth is very hot; 2. The oxygen we breathe comes from plants; 3. Radioactive milk can be made safe by boiling it; 4. Electrons are smaller than atoms; 5. The continents on which we live have been moving their location for millions of years and will continue to move in the future; 6. It is the father's gene which decides whether the baby is a boy or a girl; 7. The

earliest humans lived at the same time as the dinosaurs; 8. Antibiotics kill viruses as well as bacteria; 9. Lasers work by focusing sound waves; 10. All radioactivity is man-made; 11. Human beings, as we know them today, developed from earlier species of animals; 12. Does the earth go around the sun or does the sun go around the earth?. Cronbach's Alpha reliability is 0.71 for the total sample, ranging from 0.47 for those with 20 or more years of education to 0.77 for the group with 15 or fewer years of education.

71 Cf. Miller, Pardo, and Niwa, *Public Perceptions of Science and Technology*, 88–89.

72 Gorsuch recommends that "if the correlations among the oblique factors are negligible, then the varimax solution should be accepted as a reasonable solution"; cf. Richard L. Gorsuch, *Factor Analysis*, 2nd ed. (Hillsdale, NJ: Lawrence Erlbaum Associates, 1983), 205.

73 The wording of the three items is: "We depend too much on science and not enough on faith," "Because of their knowledge, scientific researchers have a power that makes them dangerous," and "Science makes our way of life change too fast."

74 Jon Turney, *Frankenstein's Footsteps: Science, Genetics and Popular Culture* (New Haven, CT: Yale University Press, 1998).

75 Durant *et al.*, "Two cultures."

76 The two response possibilities that were offered, five categories in split A and four in split B, have proven to be too limited and statistically not very efficient. Regardless of the validity of the construction of the 23 items, the results would certainly have been more nuanced if the response categories had been expanded to seven or even more. The main reason for expanding the spectrum of responses is statistically well known: correlation coefficients tend to increase when the measurement is richer and more diverse, and tend to decrease when the measurement is more reduced and focused. With a broader range, the differentiation of subjects increases, factor analyses are able to identify clearer groups among the variables, subject clusters, or typologies are more easily detectable, and all the statistical results and coefficients definitely acquire greater intelligibility and thereby facilitate interpretation. The amount of differentiation in the responses that can be applied without producing serious side effects is a question open to experimentation, and needs to be explored in relation to attitudes toward science.

77 Daamen, Van der Lans, and Midden, "Cognitive structures."

78 Cf. Jean-François Lyotard, *The Postmodern Condition: A Report on Knowledge* (Minneapolis: University of Minnesota Press, 1984).

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