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María José Martín-Sempere, Belén Garzón-García and Jesús Rey-Rocha

This paper investigates what motivates scientists to communicate science and technology in a science event involving a direct relationship and interaction with the public. A structured questionnaire survey was administered through face-to-face interviews to 167 research practitioners (researchers, technicians, support staff and fellows) at the Spanish Council for Scientific Research (CSIC) who participated in the Madrid Science Fair in the years 2001 to 2004. The motivations of members in each professional category are discussed. The most important motivations have to do with the desire to increase the public's interest in and enthusiasm for science, the public's scientific culture, and public awareness and appreciation of science and scientists. Senior researchers were also highly motivated by a sense of duty. Personal satisfaction and enjoyment were important motivations for younger scientists. This research will help to understand the mechanisms of scientists' motivation, and thus foster and encourage greater and better participation in events of this kind.

Keywords: public communication of science and technology, role of scientists, motivation, science fairs.

1. Introduction

Bringing science closer to society has been claimed at different times to be one of the responsibilities or "duties" of scientists, particularly of those who receive grants from public funds. Scientists, and in general the whole scientific community, should play an essential role in the process of Public Communication of Science and Technology (PCST) (Bodmer, 1985; Royal Society, 1990; Wolfendale Committee, 1995; Gregory and Miller, 1998; Miller, 2001; Pearson, 2001a; Burns et al., 2003). Scientists themselves also recognize a public duty, but to varying degrees (Gascoigne and Metcalfe, 1997; Pearson et al., 1997; Corrado et al., 2001; Bonfil Oliveira, 2003). In this regard, scientific practice and the profession are evolving in a way that should make scientists respond more positively to the need to improve the general public's access to science and should encourage them to take part in activities to improve the public understanding of science (PUS), and even consider it their duty to do so (Bodmer, 1985; Wolfendale Committee, 1995; Rutherford, 2002; Burns et al., 2003). The understanding of

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science is, among other things, a task of social identification with scientific institutions and their actors, which is dependent upon reciprocal trust (Blanco, 2003) in the line of the so-called "contextual approach" to PUS (regarding the "deficit" and the "contextual" models of PUS, see for instance Gross, 1994; Miller, 2001; Michael, 2002; Burns et al., 2003; Sturgis and Allum, 2004).

Nevertheless, many scientists are still reluctant to become involved in PCST activities.[1] Little evidence exists to explain this reluctance, although this situation is most likely the result of a combination of reasons (Bodmer and Wilkins, 1992; Gascoigne and Metcalfe, 1997; Goodell, 1997; Miller, 1998; Corrado et al., 2001). Communication to the public is generally not seen by scientists as a basic part of their work, and is an activity regarded by scientists as neutral or even counter to their prospects for promotion. Other concerns include negative reaction by colleagues, lack of training in public communication, and the need to adapt their work habits and communication skills to a public about whom they don't know much (Levy-Leblond, 1992; Miller, 1998). These efforts are often not seen by scientists to be legitimized, recognized or rewarded.

Despite the importance of scientists in the chain of knowledge dissemination and science communication, few studies have dealt with the role of scientists in the process of PCST, their patterns of communication with the public, or their motivations for participating in PCST and PUS activities (Corrado et al., 2001). Since the early 1990s, when Bodmer and Wilkins (1992: 9) pointed out how limited existing knowledge was on scientists' attitudes and noted the need to improve our understanding of "how we can best help and encourage more members of the scientific community to become involved," few relevant studies have been undertaken. Among the most enlightening publications are the survey conducted by Market and Opinion Research International (MORI) (Corrado et al., 2001) commissioned and funded by The Wellcome Trust, and articles by Gascoigne and Metcalfe (1997) and by Pearson (Pearson et al., 1997; Pearson, 2001b).

The MORI study (Corrado et al., 2001: 3) interviewed a randomly selected sample of over 1600 scientists working in universities and research institutes in the UK. A notable finding of the study was that most scientists interviewed "feel that scientists themselves should have the main responsibility for communicating the social and ethical implications of scientific research to the nonspecialist public" (the vast majority of them believed it is their duty to do so), although "fewer feel that scientists are the people best equipped to do this."

Gascoigne and Metcalfe (1997) examined the factors that encourage and discourage scientists to communicate their work through the media, surveying a selected sample of Australian scientists. They found that communication through the media was seen as an optional activity for scientists, not a basic part of their work, and that they regarded media activity as neutral or harmful to their promotion prospects.

The issue of motivations that prompt scientists to become involved in communicating their research to the public was addressed to some extent by Pearson et al. (1997: 279) who analyzed the attitudes and opinions of 168 scientists and engineers who took their research work into a shopping mall in Bristol for two days. They found that "most of the scientists took part because they were told by senior colleagues," and, after the event, 94 percent of them "wanted to take part again mainly because they had found the experience enjoyable." Public duty was found to be another important reason for taking part. In a later study Pearson (2001b) surveyed a selected group of 147 "PUS-active" scientists in the UK, and found that they were not motivated primarily by a sense of duty but by their enjoyment of PUS activities and their desire to increase the public's interest in, awareness of and excitement for science together with their understanding of basic science.

From this perspective, it is important to consider the human and social capital that the scientific community represents, not only as the main generator of scientific knowledge, but also as an important actor in the process of its dissemination. The "scientific community" is understood to be the whole population of "science practitioners," that is, people who are directly involved in some aspect of the practice of science (Burns et al., 2003), including not only researchers, but also technical and support personnel, pre- and postdoctoral scholars and contracted personnel. If scientists are to be encouraged to become involved in PCST activities, it is crucial to find out more about their role and how they view communication with the public, on "what inspires them, what encourages and motivates them to be involved, and what benefits they can expect" (Pearson et al., 1997: 280).

The research reported here aimed to investigate what motivates scientists to communicate their work to the general public through hands-on experiments in a PCST event involving a direct relationship and interaction with the public. We surveyed personnel of the Spanish Council for Scientific Research (CSIC) who have actively participated in the Madrid Science Fair in the years 2001 to 2004 to investigate their motivations for becoming involved in this event. Here, we try to answer some relevant questions about what motivates and encourages science practitioners to participate in this kind of science event. To what extent are they motivated by intrinsic or extrinsic factors? To what extent are they motivated by personal or professional factors? Do they feel communication of science to the public to be part of their job, i.e., do they feel motivated by a sense of duty to communicate science? To what extent do they participate as a result of their commitment to PCST and their concern for the public understanding of science and scientific culture? Do motivations differ depending on the individuals' professional category and age?

This study sheds light on the motivations that led practitioners to get involved in the Fair and the mechanisms that underlie these motivations. It is hoped that our findings will help foster these motivations in a way that increases participation in this event by CSIC scientists.

2. The Madrid Science Fair

Among the actions and initiatives aimed at raising the level of public understanding of science, "Science Weeks" and more specifically "Science Fairs," are perhaps the events that foment the closest interaction between scientists and the public. Science fairs in particular bring science to the citizens in an interactive way.

In Spain, the first science fair was held in A Coruña in 1996, and since 2000, annual fairs have been held in seven different locations: A Coruña, the Balearic Islands, Barcelona, Castilla-La Mancha, Madrid, Murcia and Seville. In Madrid, the Science Fair has been an annual four-day-long weekend event since 2000. It is organized by the regional government of the Community of Madrid within the framework of the Scientific Culture and Citizen Participation Program as a local initiative involving some 500 activities based on hands-on experiments and demonstrations. Overall, 200 organizations belonging to different institutional sectors are involved: universities, research centers, museums, educational centers, scientific societies, organizations from the local, regional and national governments, foundations, and private companies related to science. In 2004, 200 researchers and university lecturers participated, together with 200 teachers, 2000 primary and secondary school students and 100 professionals. Visitors numbered some 122,500 (25.2 percent of them children, 35.9 percent young people and 38.9 percent adults) (Comunidad de Madrid, 2004). The Madrid Science Fair makes special efforts to raise the public's interest in science and technology as well as to encourage scientists to be more sensitive to the needs of the public. Participation by CSIC personnel in the Fair tends to be organized on a top-down basis, with researchers invited to participate on the basis of their research areas' relevance to the Fair.

3. Methods

The population we studied consisted of CSIC personnel who actively participated in the Madrid Science Fair in the years 2001 to 2004. The first Fair in 2000 was not included in this analysis because of its experimental nature, and because the researchers' participation consisted mainly of poster presentations. In other words, there was little direct interaction with the public.

We did not include participants from two CSIC centers: the National Museum of Natural Sciences and the Royal Botanical Garden. Both centers, in addition to their research activity, have stable programs in scientific communication and specialized staff members whose institutional participation in the Fair is arranged through a very different process to that of the rest of the CSIC personnel. The present study did not take into account personnel who participated in purely organizational aspects of the Fair such as physical set-up of the stands or transport and installation of equipment.

The population thus consisted of 220 individuals belonging to 21 CSIC research centers and institutes. The CSIC is the largest public research organization in Spain. As a multidisciplinary body, it covers all fields of knowledge from basic research to advanced technological development.[2] All five professional groups of CSIC research practitioners are represented in the population we studied. These groups differ in academic level, professional category and contractual link with the CSIC. Senior researchers (23.6 percent of the population) are permanent staff members of the CSIC with a full-time research position. Technicians and support staff (20.5 percent) also belong to the permanent staff, and their main task is to provide support for the researchers at the center to which they belong. Postdoctoral fellows (8.2 percent) are personnel who hold a Ph.D. degree and work at the CSIC on contract or with a postdoctoral fellowship, and whose tasks are similar to those of senior researchers. Predoctoral fellows (29.1 percent) are personnel whose main duty is to carry out research oriented towards obtaining their doctoral degree. Technicians with a temporary position (18.6 percent) hold an undergraduate or graduate university degree and are temporarily linked to the CSIC through a contract or fellowship to support research. While CSIC personnel constitute a consistent, well-defined population which is representative of the different research practitioners doing full-time scientific research in Spain, nevertheless, this sample must not be considered representative of the whole Spanish scientific community, which includes scientists working in different institutional contexts (university, private companies, etc.).

The study was carried out as a detailed structured questionnaire survey. The questionnaire was administered to most of the participants through face-to-face interviews. One of the many advantages of this method (Lahlou et al., 1992) was that it allowed a complex questionnaire to be developed, a structured procedure for data processing, and control over timing of the fieldwork. Although this is a costly information-gathering procedure, in this case the size of the population, together with its geographical concentration, facilitated the use of this technique.

The structured questionnaire, tested on a selected group of scientists from the population, included questions requiring scaled responses and a number of free response questions. Respondents were offered the chance to express their opinions on any particularly sensitive aspect of the questions posed. Interviews were scheduled to last between 20 and 30 minutes.

Experimental studies have demonstrated that the interpersonal interaction between the interviewee and the interviewer can influence the results, thus different interviewers can obtain different (biased) results (Lahlou et al., 1992; Kvale, 1996). To reduce interviewer bias due to interviewer variance, all interviews were performed by the same two researchers (authors of this paper).

Owing to the small size of the population studied, no sampling strategy was used. A letter was sent to all participants stating the reasons for the survey and the principle of the study. Shortly thereafter, they were contacted by telephone to make an appointment for the interview. A total of 167 individuals were surveyed, accounting for 75.9 percent of all participants in the Fair. The percentage response rates were the following: senior researchers 86.5 percent; technicians and support staff 75.6 percent; predoctoral fellows 77.8 percent; postdoctoral fellows 68.8 percent; and technicians with a temporary position 73.2 percent. The rest of the participants either could not be contacted (51 individuals) for different reasons (retired, moved to another institution, abroad, etc.) or refused to participate (2 individuals).

Information was gathered regarding (among other aspects) the motivations that encouraged research practitioners to take part in the Fair. Items in the survey required participants to respond to the question, "Please indicate to what extent the following motivations influenced your decision to take part in the Fair" on a five-point scale ranging from 1 (not important at all) to 5 (very important). These items reflect "values" or "self-attributed needs," in the sense that they are conscious states that the person recognizes and may describe (i.e., they are openly acknowledged by the actor), as opposed to the "motives" or "implicit needs" which affect behavior without conscious awareness on the actor's part (McClelland et al., 1953, 1989). In this sense, values are better predictors of conscious choices of conduct, such as decisions on how much effort to put into a task, and may predict specific answers concerning a particular situation.

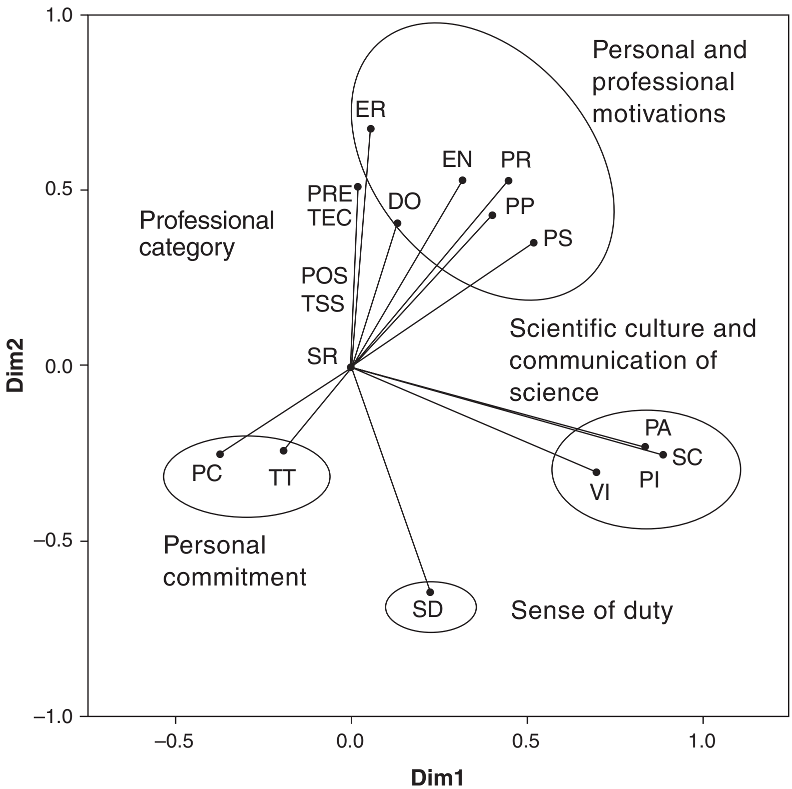
Statistical analysis was performed with the SPSS (v. 12.0) for Windows. Categorical principal components analysis (CATPCA) was used to investigate the relationships between the variables. This analysis uses optimal scaling to generalize the principal components analysis procedure so that it can accommodate variables of mixed measurement levels (scale, ordinal and nominal). This makes it possible to find and summarize the relationships between variables (relationships that cannot be extracted directly from data tables), reducing the original set of variables to a smaller set of noncorrelated components that represent most of the information found in the original variables.

The outcome of CATPCA is interpreted by reading a plot in which component loadings are shown as the orientation of lines along the principal axes. The relationships between ordinal variables represented by their correlations with the principal components are displayed as vectors pointing towards the category with the highest score. The length of a vector reflects the importance of the variable: the longer the vector, the more variance is accounted for. The angle between two vectors reflects the correlations between the variables they represent: the more orthogonal the vector, the less correlated the variables are.

Two levels of CATPCA were used. First, the relationships between the values assigned to the different motivations were analyzed, as well as their correlations with professional category. Once the relationship between variables (motivations) was determined, a second analysis was performed using an index created from the original variables. A model was obtained to reduce the information to a smaller number of variables and to account for the largest possible percentage of the variance. This index was calculated by adding the values given to variables that were related, and dividing this sum by the number of variables, according to the formula:

$$I = \frac{\sum_{l=1}^{n} YiPi}{n}$$

where Y_i is the value given to each variable (from 1 to 5), P_i the weight assigned to the variable (in this case all were equally weighted, hence $P = 1$), and n the number of variables used to calculate the index.



Professional categories: SR: senior researchers; TSS: technicians and support staff; POS: post-doctoral fellows: PRE: predoctoral fellows; TEC: technicians with a temporary position.
Motivations: PI: arousing or increasing the public's interest in and enthusiasm for science; SC: increasing the public's scientific culture; PA: increasing the public's appreciation of the scientist's work; VI: make my center better known or more visible; SD: sense of duty; TT: told to by somebody else; PC: Personal commitment; PS: personal satisfaction; EN: enjoyment; PR: professional relationships; PP: professional promotion; ER: economic reward; DO: days off reward.
Appendix 1 shows the CATPCA model summary, the variance accounted for by each variable, and correlations among variables.

Figure 1. Relationships between "motivations" and "professional category."

4. Results

Figure 1 shows the component loadings plot obtained with CATPCA to summarize the relationships between the different motivations, as well as the relationships between motivations and professional category.

The first dimension of the CATPCA plot separates a first group of closely correlated motivations that formed a bundle with negative component loadings in this dimension. This group, called "personal commitment," comprises the motivations "personal commitment" and "told to by someone else." The remaining motivations formed three bundles that were separated mainly in the second dimension. The first bundle, called "personal and professional motivations," comprised motivations with a personal or personal–professional aspect ("enjoyment," "professional relationships," "professional promotion" and "personal satisfaction"), together with two motivations related to short-term personal rewards ("economic reward" and "days off reward"). The second bundle, called "scientific culture and communication of science," represents researchers' commitment to the communication of science and their concern for the public's scientific culture. This bundle comprised the motivations "desire to increase the public's scientific culture," "arouse or increase the public's interest in and enthusiasm for science," "increasing the public's appreciation of the scientist's work," and "make their center better known or more visible." The third bundle comprises only the "sense of duty" motivation and stands alone in the Figure.

All motivations within the same bundle are highly (positively) correlated. In other words, the higher the value given to one motivation, the higher the value likely to be given to the rest of the motivations within the same bundle.

Table 1. Distribution of responses (expressed as percentage of respondents) to the question "Please indicate to what extent the following motivations influenced your decision to take part in the Fair"

	Motivations												
	PI	SC	PA	VI	SD	TT	PC	PS	EN	PR	PP	ER	DO
Senior researchers (*n* = 45)													
1+2	4.4	6.7	8.9	17.7	4.4	60.0	55.5	28.9	60.0	66.7	88.9	100	100
4+5	88.9	82.2	77.8	68.9	82.2	28.9	26.6	48.9	20.0	11.1	4.4	0.0	0.0
Average	*4.4*	*4.3*	*4.0*	*3.8*	*4.2*	*2.3*	*2.3*	*3.2*	*2.2*	*2.0*	*1.4*	*1.0*	*1.0*
Technicians and support staff (*n* = 34)													
1+2	8.8	11.7	5.8	17.6	32.3	52.9	73.5	20.6	55.9	47.1	88.3	82.4	88.3
4+5	70.6	73.5	76.4	70.6	55.9	29.4	20.6	58.8	32.3	29.4	2.9	11.8	8.8
Average	*3.8*	*3.9*	*4.1*	*3.8*	*3.3*	*2.4*	*1.9*	*3.6*	*2.4*	*2.7*	*1.4*	*1.6*	*1.5*
Postdoctoral fellows (*n* = 14)													
1+2	7.1	7.1	14.2	21.4	14.2	42.9	85.7	21.4	71.4	57.2	85.7	78.6	100
4+5	92.8	92.9	78.6	57.1	64.3	21.4	7.1	42.8	21.4	14.2	7.1	14.2	0.0
Average	*4.5*	*4.3*	*4.0*	*3.5*	*3.7*	*2.4*	*1.6*	*3.3*	*2.2*	*2.5*	*1.7*	*1.8*	*1.1*
Predoctoral fellows (*n* = 44)													
1+2	6.8	6.8	9.0	20.4	36.4	38.6	70.5	11.3	31.9	31.8	70.5	56.9	97.7
4+5	84.1	75.0	70.5	54.5	36.4	25.0	15.9	63.6	40.9	29.6	15.9	18.2	0.0
Average	*4.2*	*4.0*	*3.9*	*3.5*	*2.9*	*2.7*	*1.9*	*3.7*	*3.0*	*2.9*	*2.0*	*2.2*	*1.1*
Technicians with a temporary position (*n* = 30)													
1+2	10.0	10.0	13.4	26.7	30.0	36.7	60.0	13.4	20.0	36.7	83.3	63.3	96.7
4+5	73.3	73.3	56.7	50.0	36.7	40.0	23.3	73.3	43.3	23.4	10.0	13.3	0.0
Average	*4.0*	*4.0*	*3.7*	*3.4*	*3.0*	*3.1*	*2.2*	*3.9*	*3.2*	*2.7*	*1.8*	*2.1*	*1.1*

Scale: 1 = not important at all; 2 = slightly important; 3 = moderately important *(not shown)*; 4 = fairly important; 5 = very important.

Motivations: PI: arousing or increasing the public's interest in and enthusiasm for science; SC: increasing the public's scientific culture; PA: increasing the public's appreciation for the scientist's work; VI: make my center better known or more visible; SD: sense of duty; TT: told to by somebody else; PC: personal commitment; PS: personal satisfaction; EN: enjoyment; PR: professional relationships; PP: professional promotion; ER: economic reward; DO: days off reward.

Below, we analyze these motivations in some detail, beginning with those scored highest by the surveyees. The response distribution to the questions asked in the survey is summarized in Table 1.

The responses reveal a high level of concern and commitment by CSIC personnel concerning Communication of Science, Public Understanding of Science, and the Public's Scientific Culture. The motivations that received the highest scores from the surveyees are directly linked to these aspects. Most surveyees stated that they were fairly or highly motivated by the desire to "arouse or increase the public's interest in and enthusiasm for science," and to "increase the public's scientific culture." This characteristic is common to all groups; however, it was scored highest by senior researchers, predoctoral fellows and postdoctoral fellows.

Two other important motivations related to the two leading motivations noted above were identified, both of which involved a personal aspect. First, the motivation for "increasing the public's appreciation of the scientist's work" was scored highly by all groups. This motivation reflects scientists' desire for their work to be not only well known, but also socially recognized. Second, participants expressed a strong desire to "make their center better known or more visible." This reflects their motivation to make science known to the public, not only through the dissemination of scientific knowledge, but also by introducing scientists and research centers to the public. Although it also received high scores, this motivation was less important than the ones noted above, and was associated fundamentally with permanent staff (senior researchers, and technicians and support staff), who seem to be more committed to gaining visibility for their centers.

"Sense of duty," in terms of considering scientific popularization and communication of science as part of a scientist's job or a duty, is a motivation that is closely related to awareness of the need to communicate science, as well as to the set of values represented by motivations in the "scientific culture and communication of science" group.

Senior researchers appeared to be highly motivated by a "sense of duty." This was also an important motivation for postdoctoral fellows and technicians and support staff, whereas the youngest individuals in the sample (predoctoral fellows and technicians with a temporary position) were not primarily motivated by a sense of duty.
Most of the senior researchers surveyed were concerned with the importance of communicating science to the public as an activity that should be considered a scientist's duty. Some of them offered specific explanations:

> Communicating science to the public is a duty [of scientists], but should be recognized by the institution [the CSIC].
>
> We must show solidarity with society, since after all we work with public funds.
>
> We should present our work to society, so that society demands greater support for science.
>
> I think that popularization of science is more important than any research we set out to do. And communicating to the public well is more difficult than writing a scientific article.

Although other researchers participated in the Fair, they were of the opinion that PCST need not be one of the activities or tasks of the scientists, but that it should be left in the hands of other professionals: "There should be an intermediate echelon between the scientist and the public; a professional in science communication to the public."

On the other hand, some scientists expressed doubts regarding the use of science fairs and similar activities to bring science closer to the public:

> I believe that caution is needed in handling the image of the CSIC. A balance needs to be found between combining activities for children with other activities that highlight the high scientific and technological level of the CSIC.

Some participants expressed clear reluctance, believing that these activities might "trivialize" science to some degree. Different opinions were offered by CSIC staff who participated in the Fair regarding the extent to which science should be displayed in an event involving a certain element of entertainment. Among these reluctant scientists, one surveyee noted with regard to the potential entertainment value of science:

> Science should not have to be displayed at leisure events. Places exist for science dissemination, such as museums, technical fairs, etc. Museums, science documentaries, and especially teachers play important roles in bringing science closer to children.

The "personal commitment" group of motivations represents the extent to which individuals feel motivated or committed to attend the Fair because of their professional relationship or sense of commitment to another person. This person might be their supervisor, a colleague, one of the coordinators of institutional participation by the CSIC in the Fair, or even a representative of the regional government of Madrid, the organizer of the event. Both variables in this bundle ("told to by somebody else" and "personal commitment") showed a weak, inverse correlation with professional category (–0.02 and –0.04, respectively).

The youngest members of the population (predoctoral fellows and technicians with a temporary position) are those for whom being told to participate by somebody else had the highest motivational value. For these individuals, participation in the Fair depended in most cases on the decision of their supervisor, i.e., the senior scientist and leader of the research team. In contrast, personal commitment seemed to affect the decision to participate mainly among senior researchers, on the one hand, and technicians with a temporary position on the other. For senior researchers, participation in the Fair was sometimes induced by a personal rather than professional commitment to the director of their research center or to the organizers of the event. In the same vein, some technicians with a temporary position felt a personal commitment to comply with their supervisor's instructions.

Finally, within the "personal and professional motivations" bundle are purely extrinsic motivations such as "economic reward" and compensation in the form of "days off" and "professional promotion," in addition to other fundamentally intrinsic motivations such as "personal satisfaction," "professional relationships" and "enjoyment."

This bundle includes two motivations of medium-scale importance in terms of how the surveyees scored them: "personal satisfaction" and "enjoyment." These motivations, which can be considered strictly personal in nature, were relatively important for the youngest members of the population (predoctoral fellows and technicians with a temporary position), and slightly less important for technicians and support staff, in comparison to the groups of senior researchers and postdoctoral fellows.

Personal motivations wane in importance when they overlap the professional sphere ("professional relationships" and "professional promotion"), and factors such as "economic reward" or rewards in the form of "days off" were considered motivations of little importance by most of the people we surveyed. In this regard, senior researchers indicated that they were not motivated to any degree by either reward. "Economic reward," the variable that showed the highest correlation (0.46) with professional category (i.e., the one that best discriminated among categories) was judged fairly or very important by a small percentage of technical and support staff, postdoctoral and predoctoral fellows and technicians with a temporary position, whereas "days off" was a motivation only for technical and support staff. However, the limited motivational capacity of these two rewards may be conditioned to a large degree by previous knowledge of institutional regulations with regard to days off, as well as the modest amounts involved in economic rewards.

In addition to the motivations included in the questionnaire, other motivations were indicated by some of the surveyees. Some individuals specifically mentioned the satisfaction of working with children and watching them enjoy science. A closely related factor was motivation by the opportunity to reach out to a young public—the pipeline of future scientists—and to stimulate interest in science as a vocation among young persons. Other aspects that were mentioned were helping to communicate the participation of women in science, getting away from the research routine, a change of scene and chance to meet other colleagues in another environment, and the decision to participate in place of other colleagues who showed no interest in taking part in the Fair, to ensure that a particular research center was represented at the event.

According to comments offered by the participants during the interview, two aspects of their own or their colleague's motivation for participating in the Fair stood out: "professional promotion" and "lack of turnover."

First, "professional promotion" was not a factor in general, and indeed, in many cases participation in events of this nature was considered to have negative repercussions on the participant's career. According to some respondents, certain colleagues consider that those who participated in this type of PCST event "have nothing better to do" or "aren't good enough for more important activities." This is an opinion that extends to any activity other than carrying out funded research and the subsequent publication of results in prestigious international journals. Some of the senior researchers surveyed made specific mention of this perception:

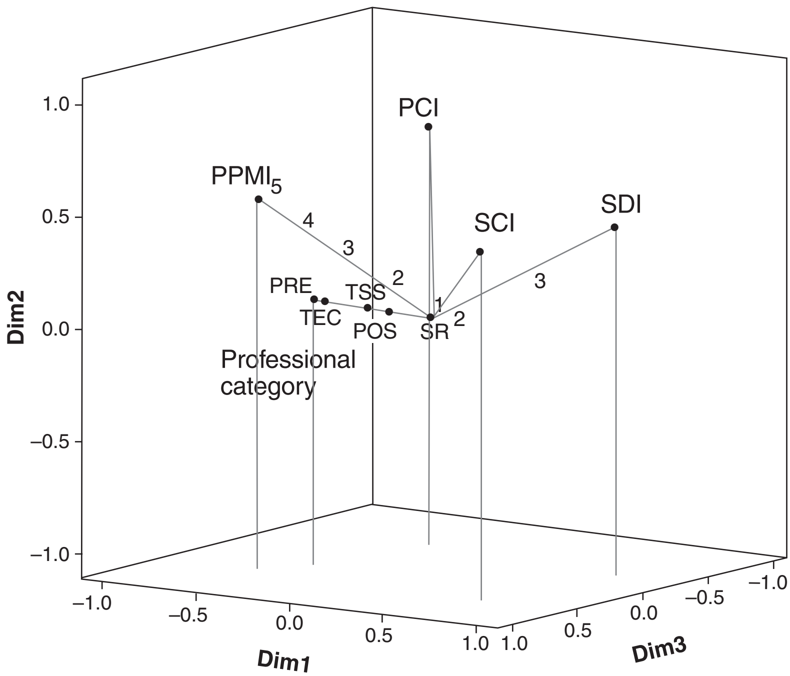
> Participation in the Fair is unfavorable because there is an assumption that those colleagues who do take part have nothing better to do.
>
> Scientists are conscious of the value of popularization of science, but they would rather let others do it, that is, others who they assume are less skilled [in scientific research] or "less clever" because they themselves have more important things to do. Nevertheless, it is true that prominent scientists are involved in popularizing science, because for them it is "the cherry on top" of their career.

Second, "lack of turnover" often acts as a negative motivator since some of the participants are unenthusiastic due to the lack of interest and collaboration from their colleagues. This means it is "always the same people" who participate.

Once we had identified the motivations characteristic of each professional category and the relationships between these motivations, an index was created to represent each group of motivations obtained with CATPCA. The four resulting indexes were called "personal commitment," "personal and professional motivations," "scientific culture and communication of science," and "sense of duty." This last index consisted solely of the variable of the same name.

A second CATPCA was then carried out to determine motivational behaviors of the sample according to individuals' professional status. The results of this analysis were consistent with the previous one, although the second CATPCA explained a significantly higher percentage of variance (89.6 percent). The model is summarized in the three-dimensional graph (Figure 2) that displays the relationships between the indexes and the different professional categories.

All indexes accounted for a similar amount of variance (eigenvalues ranging from 0.85 to 0.92). "Personal and professional motivations" together with "sense of duty" were the indexes that showed the highest correlations with professional category. The



Professional categories: SR: senior researchers; TSS: technicians and support staff; POS: post-doctoral fellows: PRE: predoctoral fellows; TEC: technicians with a temporary position.
Indexes: PCI: personal commitment index; SDI: sense of duty index; SCI: scientific culture and communication of science index; PPMI: personal and professional motivation index.
Appendix 2 shows the CATPCA model summary, the variance accounted for by each variable, and correlations among variables.

Figure 2. Relationships between motivation indexes and professional category.

"personal and professional motivations" index, which included motivations with a highly personal or individual component, correlated well with professional category (0.46). These motivations were considered least important by senior researchers and most important to the technicians with a temporary position. The opposite was found for the "sense of duty" index (correlation –0.39), which was the most important motivation mainly for senior researchers whereas technicians with a temporary position and predoctoral fellows seemed to be less motivated by this factor. The vectors of the "personal commitment" and "scientific culture and communication of science" indexes were orthogonal to the professional category vector, reflecting a low correlation (0.1 and –0.15, respectively) and thus a limited ability to discriminate between professional categories.

As noted above, "sense of duty" showed a high correlation with professional category. Closely related to the individuals' sense of duty was the manner in which they got involved in the Fair, which also varied significantly depending on professional category. The greater degree of professional autonomy of senior researchers was reflected in the high percentage of individuals (more than 50 percent) who participated in the Fair of their own initiative, regardless of whether they considered participating in the Fair as a duty.

In all professional categories, most individuals took part in the Fair because they were told to by somebody else. The differences here were substantial not only quantitatively but also qualitatively. Among senior researchers, 60 percent of whom stated that they participated because they were told to, the initiative normally came from administrators or managers responsible for coordinating CSIC participation either personally or through the director of the center to which the researcher belonged. In the remaining categories, particularly in non-permanent personnel (where the percentage of individuals who participated because they were told to was notably high), the initiative or request usually came from the research team leader. Several individuals noted that although they took part initially at the behest of somebody else, they ultimately considered that they participated on their own initiative, accepting in some cases that the task was part of their job. Senior researchers, who gave the highest scores to "sense of duty" as a motivation for participating in the Fair, were the only group in which a number of individuals (11 percent) for whom communication of science to the public is not among their "official" duties nonetheless claimed to consider this part of their job.

The "sense of duty" correlated highly with the "scientific culture and communication of science" index (0.38), and particularly with the variable "make my center better known or more visible" (Figure 1). This latter is the motivation that showed the highest direct correlation (0.3) with sense of duty, indicating that individuals' sense of duty was largely associated with their commitment to making their research units or centers more visible.

The motivations within the "scientific culture and communication of science" index reveal a high level of concern and commitment on the part of CSIC personnel to the communication of science, the public understanding of science, and the public's scientific culture. This concern and commitment are also reflected by the number of individuals who participated repeatedly in two or more annual fairs. Among permanent staff members (whose participation in successive annual fairs can be traced), the percentage of individuals who participated in more than one annual fair was noticeably higher among senior researchers (51.2 percent) than among technicians and support staff (41.2 percent). These figures do not include persons who participated for the first time in the 2004 Fair. The decreases in the percentages of postdoctoral fellows (35.7 percent) and especially predoctoral fellows and technicians with a temporary position (13.6 percent and 13.3 percent, respectively) were most likely due to the temporary nature of their positions at the CSIC.

Nevertheless, repeated participation in PCST activities does not always depend solely upon one's own motivation, but may also depend upon external factors such as the willingness of one's superiors to authorize such activities. Thus, the interest in PCST and particularly the communication of science to the young public is also reflected by individuals' willingness to take part in outreach programs aimed at schoolchildren. Participants were asked specifically about their willingness to make school presentations of the same or a similar activity as at the Fair. The percentage of individuals willing to make school presentations ranged from 76.5 percent of technicians and support staff to 93.2 percent of predoctoral fellows.

5. Discussion and conclusions

The results presented here reveal how the engagement of CSIC research practitioners in the Madrid Science Fair is influenced, to different extents, by an ensemble of extrinsic and intrinsic motivations which involve aspects related to personal or professional benefit along with other, more altruistic considerations. The latter center on the desire to communicate science to the public and increase scientific culture, either by transmitting scientific knowledge, or by providing a better knowledge of research centers and the work carried out by scientists.

The motivations of the participants seem to reflect something more than the simple desire to communicate scientific knowledge. Their motives go beyond public communication of science and technology, which implies a one-way, top-down communication flow from scientists to the general public, where the public is often seen as a passive and sometimes poorly qualified receiver, in accordance with the so-called "deficit model" of public understanding of science. The researchers we surveyed seemed to be concerned with "scientific culture," in line with the "contextual approach" or "contextual model" of public understanding of science which depicts communication as a two-way interaction and dialogue between science and its public. Thus, the most important motivations were related to the desire to stimulate the public's interest in and enthusiasm for science, to increase the public's scientific culture, and to enhance public awareness and appreciation of science and scientists. Our results are consistent with those of Pearson (2001b), who surveyed a selected group of 147 "PUS-active" scientists in the UK. These scientists were found to be motivated mainly by the desire to stimulate the public's interest in, awareness of and excitement for science, together with their understanding of basic science.

In this regard, the vision of science communication held by CSIC research practitioners seems to be in line with the "vowel analogy" proposed by Burns et al. (2003: 190), according to which science communication aims to produce one or more of the following personal responses to science: "Awareness of science; Enjoyment or other affective responses to science; Interest in science; the forming, reforming or confirming of science-related Opinions (or attitudes); and Understanding of science."

In addition, senior researchers were highly motivated by a sense of duty, and noted the scientist's commitment to communicate science to the public. The extent to which scientists should consider it their duty to communicate with the public has been a central point in recent discussions of the role of the scientific community in the cause of greater public understanding and awareness of science (Bodmer, 1985; Royal Society, 1990; Wolfendale Committee, 1995; Pearson et al., 1997; Gregory and Miller, 1998; Miller, 2001; Pearson, 2001a; Burns et al., 2003). The few published studies that have investigated this issue reported different results. On the one hand, the vast majority of staff research scientists interviewed by MORI (Corrado et al., 2001) believed it was their duty to communicate their research and its social and ethical implications to policy makers (91 percent agreed) and to the nonspecialist public (84 percent agreed). Different results were found by Pearson et al. (1997), who reported a low percentage (15 percent) of scientists participating in the UK's 1995 National Week of Science, Engineering and Technology as a result of their sense of public duty to communicate science, and 28 percent of them citing public duty as the reason they would take part again. On the other hand, they found that the only significant difference between participants was that "staff had the highest sense of public duty to communicate science" (Pearson et al., 1997: 282). Similarly, in the survey of "PUS-active" UK scientists conducted by Pearson (2001b), only 10 percent of surveyees got involved in PUS activities because of a sense of duty, and only 5 percent considered these activities as part of their job. There are interesting parallels between these results and the CSIC sample with respect to both the sense of duty reported by staff research scientists and the different perceptions of this duty between staff and nonstaff individuals.

In any case, participation rarely results solely from personal initiative, which once again reflects the reduced awareness of the importance of this activity. Our results are again consistent with the findings of Pearson et al. (1997: 282), who reported that most of the scientists who took part in the UK's 1995 National Week of Science, Engineering and Technology did so because "they were told to: the edict had come from on high."

Therefore, the motivations of the group we analyzed involve both a cultural and an aesthetic dimension. In the former, science popularization is seen as an activity important not only to society, but also to the scientist him or herself, as one of the activities that should distinguish an "integral scientist." This conception of PCST considers such activities in their social, informative, educational and useful aspects not only for the public, but also for science and scientists (e.g., PCST as a call that awakens a new vocation, as a booster of public interest in scientific topics, and as a factor that might increase the public's demand for science programs from politicians). The aesthetic dimension involves the notion that science communication to the public may not be seen by the scientist as something "compulsory, necessary or even useful," but simply as something "interesting, beautiful and enriching" (Bonfil Oliveira, 2003: 5). This notion of science communication to the public can open doors and, given the right circumstances, favor the intrinsic motivations of scientists.

Although it is true that this type of intrinsic motivation was strongly held among all the professional groups we studied, the importance of extrinsic motivations cannot be neglected. Unfortunately, the effect of these rewards on the willingness of CSIC personnel to take part in the Fair cannot be inferred from the results of our study, as personnel made the decision to participate even though they knew that the recognition or external rewards that would accrue from their work at the Fair would be limited, and consequently these extrinsic motivations were given low scores by respondents. Further research to elucidate their likely influence should take into account that an appropriate balance between extrinsic and intrinsic motivations can acquire considerable importance for managers. It is not so much the strength of extrinsic motivations but rather their influence over intrinsic motivations which may actually determine how important the former are. It should be mentioned here that, as reported in numerous experiments (Kruglanski et al., 1971; Deci, 1972; Ross, 1975), the intrinsic motivation to perform a task purely for personal satisfaction can decrease under certain circumstances when external rewards are offered. This raises the issue of whether, and to what extent, internal causality (intrinsically motivated conduct aimed at PCST-related activities) is modified towards some degree of external causality.

The collective of young scientists, particularly predoctoral fellows working toward their doctoral degree (tomorrow's scientists), is of particular importance (see for instance Pearson, 2001a). The extent to which this collective is motivated to undertake PUS activities may be the result of the socialization process to which they are subjected during work on their advanced degrees. In contrast to staff researchers, they seemed to be more motivated by enjoyment and personal satisfaction than by a sense of duty. Their motivations seemed to lie in both the cultural and aesthetic dimensions of PCST. It seems that these young scientists are a new generation who do not view popularization as a tedious activity one engages in only out of a sense of duty, or in exchange for recognition or money. Positive experiences in PUS for researchers in the early stages of their scientific training "may encourage them to do more as they continue their scientific career" (Pearson, 2001a: 129).

Our results and the conclusions we have drawn concern the particular sample we studied, and should not be considered to be predictive. It is thus important to avoid drawing inferences that might not hold if applied to other researchers and other research and development frameworks.

The present study has tried to identify the motivations that led this sample of research practitioners to participate in a science fair, a type of PCST event characterized by its particular dynamics and structure, and—more importantly—by the close, direct relationship it obliges scientists to engage in with a public consisting to a large degree of young people. However, identifying the motivations is only the first step toward understanding why scientists whose main task is to carry out research are willing to take part in PCST activities. An additional series of factors that could influence this decision are fundamental to our understanding of the motivational process, and await analysis. Some of these factors are the possible problems and limitations scientists face in participating in PCST activities; their perception of how interested the public is in their participation, and its usefulness; and the benefits to be obtained from participation. In addition, we set out to determine the possible motives that underlie some scientists' negative reactions to participating in this type of PCST event, and to discover the conditions that determine their nonparticipation.

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Table A1. Model summary

		Variance accounted for	
Dimension	Cronbach's alpha	Total (eigenvalue)	% of variance
1	.79	3.65	28.11
2	.61	2.30	17.72
Total	.90[a]	5.96	45.83

[a] Total Cronbach's alpha is based on the total eigenvalue.

Table A2. Variance accounted for

	Total (vector coordinates)		
	Dimension		
Variables	1	2	Total
PI	0.78	0.07	0.85
SC	0.71	0.06	0.77
PA	0.71	0.06	0.77
VI	0.48	0.09	0.57
SD	0.05	0.42	0.47
PS	0.27	0.12	0.39
EN	0.10	0.28	0.38
TT	0.04	0.06	0.10
PC	0.14	0.07	0.20
PR	0.20	0.28	0.47
PP	0.16	0.19	0.35
ER	0.00	0.45	0.46
DO	0.02	0.17	0.18
PCAT[a]	0.00	0.26	0.26
Active total	3.65	2.30	5.96
% of variance	28.11	17.72	45.83

[a] Supplementary variable.

Table A3. Transformed variable correlations

	PI	SC	PA	VI	SD	PS	EN	TT	PC	PR	PP	ER	DO	PCAT
PI	1.00	0.88	0.80	0.59	0.26	0.32	0.11	–0.07	–0.22	0.22	0.20	–0.05	0.01	–0.08
SC	0.88	1.00	0.70	0.53	0.25	0.28	0.11	–0.15	–0.22	0.17	0.15	–0.04	0.02	–0.02
PA	0.80	0.70	1.00	0.62	0.22	0.25	0.15	–0.06	–0.25	0.21	0.20	–0.09	0.04	–0.13
VI	0.59	0.53	0.62	1.00	0.30	0.15	–0.06	–0.02	–0.09	0.23	0.19	–0.07	0.07	–0.15
SD	0.26	0.25	0.22	0.30	1.00	0.03	–0.14	0.11	0.13	–0.16	–0.04	–0.40	–0.20	–0.37
PS	0.32	0.28	0.25	0.15	0.03	1.00	0.55	–0.12	–0.21	0.30	0.28	0.07	0.07	0.17
EN	0.11	0.11	0.15	–0.06	–0.14	0.55	1.00	–0.11	–0.15	0.23	0.24	0.20	0.13	0.27
TT	–0.07	–0.15	–0.06	–0.02	0.11	–0.12	–0.11	1.00	0.36	–0.11	–0.05	–0.08	–0.01	–0.02
PC	–0.22	–0.22	–0.25	–0.09	0.13	–0.21	–0.15	0.36	1.00	–0.22	–0.05	–0.05	–0.08	–0.04
PR	0.22	0.17	0.21	0.23	–0.16	0.30	0.23	–0.11	–0.22	1.00	0.42	0.32	0.24	0.30
PP	0.20	0.15	0.20	0.19	–0.04	0.28	0.24	–0.05	–0.05	0.42	1.00	0.32	0.12	0.23
ER	–0.05	–0.04	–0.09	–0.07	–0.40	0.07	0.20	–0.08	–0.05	0.32	0.32	1.00	0.22	0.46
DO	0.01	0.02	0.04	0.07	–0.20	0.07	0.13	–0.01	–0.08	0.24	0.12	0.22	1.00	0.11
PCAT[a]	–0.08	–0.02	–0.13	–0.15	–0.37	0.17	0.27	–0.02	–0.04	0.30	0.23	0.46	0.11	1.00
Eigenvalue[b]	0.45	0.50	0.42	0.24	0.54	2.30	3.65	0.09	0.68	1.18	1.29	0.90	0.77	

[a] Supplementary variable.
[b] Eigenvalues of correlation matrix excluding supplementary variable.

Table A4. Chi-squared values

Motivation × PCAT	χ^2	*p* value exact (Monte Carlo)[a]
PI × PCAT	16.88	0.394
SC × PCAT	18.50	0.295
PA × PCAT	11.18	0.812
VI × PCAT	14.49	0.575
SD × PCAT	35.58	0.002
PS × PCAT	11.93	0.762
EN × PCAT	31.22	0.012
TT × PCAT	29.15	0.020
PC × PCAT	15.12	0.515
PR × PCAT	29.17	0.019
PP × PCAT	17.85	0.330
ER × PCAT	45.55	0.000
DO × PCAT	19.93	0.196

[a] Significant differences when p value < 0.05.

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Table A5. Model summary

		Variance accounted for	
Dimension	Cronbach's alpha	Total (eigenvalue)	% of variance
1	0.44	1.50	37.39
2	0.26	1.25	31.15
3	–0.25	0.84	21.09
Total	.96[a]	3.58	89.63

[a] Total Cronbach's alpha is based on the total eigenvalue.

Table A6. Variance accounted for

	Total (vector coordinates)			
	Dimension			
	1	2	3	Total
PPMI	0.40	0.29	0.21	0.89
SCI	0.41	0.20	0.31	0.92
SDI	0.56	0.19	0.10	0.85
PCI	0.13	0.57	0.22	0.92
PCAT[a]	0.23	0.00	0.06	0.30
Active total	1.50	1.25	.84	3.58
% of variance	37.39	31.15	21.09	89.63

[a] Supplementary variable.

Table A7. Transformed variable correlations

	PPMI	SCI	SDI	PCI	PCAT
PPMI	1.00	–0.00	–0.26	0.33	0.46
SCI	–0.00	1.00	0.38	–0.08	–0.15
SDI	–0.26	0.38	1.00	0.10	–0.39
PCI	0.33	–0.08	0.10	1.00	0.10
PCAT[a]	0.46	–0.15	–0.39	0.10	1.00
Eigenvalue[b]	1.50	1.25	0.84	0.41	

[a] Supplementary variable.
[b] Eigenvalues of correlation matrix excluding supplementary variable.

Appendix 1

CATPCA showing relationships between "motivations" and "professional category" (PCAT).

Appendix 2

CATPCA showing relationships between groups of motivations and professional category (PCAT).

Notes

1 In Spain the participation of scientists in PCST activities is scarce and limited to certain forums and media. This situation was summarized in the text of the *Spanish National Plan for Scientific Research, Technological Development and Innovation* (CICYT, 2000): "In Spain, researchers and the research centers themselves have little interest in informing society of the results of research activities and in demonstrating their importance, thus raising the level of scientific and technological culture."

2 The CSIC has 125 research centers and institutes throughout Spain, and almost half of them are located in Madrid, where the national headquarters are also situated. More than 12,000 people work at the CSIC, including tenured scientists, technicians, administrative staff and research fellows. About 2000 doctoral students are currently carrying out research for their theses at CSIC institutes. CSIC researchers are responsible for 20% of the scientific output of Spain, and for 0.55% of the world's scientific publications. CSIC is also the leading applicant from Spain to the Patent Cooperation Treaty.

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