Do You Know Your Brain? A Survey on Public Neuroscience Literacy at the Closing of the Decade of the Brain

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What does the public know about the developments offered by brain research? What factors influence public neuroscience literacy? What issues need to be emphasized to the public? To address these questions, a survey was conducted using a questionnaire with 95 assertions, answered by indicating yes, no, or I don't know. The opinions of 35 senior neuroscientists and 2158 members of the public of Rio de Janeiro were heard on issues such as the mind-brain relationship, the senses, learning, and memory. The incidence of "correct" answers among the public improved the most with schooling, followed by reading of popular science magazines and of newspapers. An analysis of the responses to each assertion revealed which themes are well- or poorly known to the public. The results attest for the importance of popular scientific communication and indicate issues on which communication efforts should be concentrated in order to increase public awareness about the brain. NEUROSCIENTIST 8(2):98–110, 2002

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Brain research offers the unique possibility of glimpsing at what the human mind is made of. The last decades of the 20th century were particularly fruitful. To name only a few developments, candidate cellular and molecular mechanisms of learning have been identified; the role of sensory experience in cerebral development has been recognized and its mechanisms are under study; neuronal correlates of perception and attention are being uncovered; emotion has become a bona fide field of study, and its importance in decision making has been demonstrated; endogenous neuromodulators and hormones have been causally implicated in mood disturbances and depression; mechanisms of action of psychotropic and addictive drugs are being identified; the pathologies behind conditions such as Alzheimer's and Parkinson's diseases are better understood, and soon these diseases may even be amenable to a cure (reviewed in Albright and others 2000). But is the public aware of these developments? How much of the knowledge gained about the brain actually reaches the public? Previous surveys on how much science in general the public understands suggest that the answer is "not much" (Durant and others 1989; National Science Board 1981, 1983, 1985, 1988, 1993; Eurobarometer 1993).

An ensemble of activities dedicated to the communication of brain research to the public are currently being implemented in the Museum of Life in Rio de Janeiro. To ensure that these activities meet the needs of the public, it was first necessary to evaluate the state of public neuroscience literacy. What do people really know about the brain? What misconceptions might they have? What are the best- and worst-known themes, that is, where is communication needed the most? What do people believe is the relationship between brain and mind? Finally, what do they think neuroscience has to offer? These were the objects of a survey conducted between June and December of 1999 next to senior neuroscientists of different nationalities and the Museum's target population: the citizens of Rio de Janeiro, Brazil, and students in particular.

Methods

Survey Design

The survey was conducted by means of a four-page questionnaire containing 95 multiple-choice assertions in a pseudo-random order (Table 1). Each assertion was to be responded by selecting either yes, no, or I don't

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know as the answer that most closely reflected one's opinion. Two types of assertions were included in the questionnaire. The majority (n = 83) was designed to measure the level of information of the general public on discoveries of brain research ("objective" assertions). These assertions were elaborated with care not to use specialized vocabulary such as the nouns *neuron*, *cortex*, and *synapse*, that might hinder understanding of the concepts, and were distributed among the following themes: neuroscientific folklore, brain size and intelligence, research techniques, principles of organization and function, learning, memory, senses, movement, emotions, sleeping and dreaming, development, regeneration and compensatory mechanisms, brain metabolism, brain chemistry and homeostasis, pathology, and individuality. The remaining 12 assertions were designed to assess the public's opinions on themes concerning brain-computer similarities, the mind-brain relationship, and the importance of brain research in improving life quality ("subjective" assertions). At the end of the questionnaire, respondents were requested to provide personal information such as age, region of the city inhabited (North, South, West, or Downtown), highest level of education (high school, college, or graduate), newspapers and magazines usually read, and the number of books read per month (0-1, 2, 3, 4, and 5 or more).

Six thousand copies of the questionnaire were distributed to different segments of the population of the city of Rio de Janeiro, Brazil, observing that all four geographic zones of the city would be equally well represented. The survey was directed toward students of private and public schools, which constitute the main target population of the Museum of Life. The questionnaire was distributed by hand or by regular mail to students and teachers of 10 private and 9 public schools that had previously agreed to participate; college students and professors; subscribers to a popular science magazine, *Ciência Hoje*; and professionals of various fields of interest. No questionnaires were distributed to members of the public visiting the museum, as this might bias the sample toward individuals with a stronger interest in science, and therefore better informed about it (Durant and others 1989). As a reference against which to compare the public's responses, 270 regular members of the Society for Neuroscience were consulted via e-mail, with an electronic, English version of the same questionnaire. A total of 2193 filled-in questionnaires were collected, 35 of which were from senior neuroscientists of different nationalities.

Statistical Analysis

To compare the responses of different segments of the population, the public's questionnaires (n = 2158) were classified according to several criteria: respondent's level of education, number of books read per month, field of specialization, reading of newspaper, and reading of popular science magazines.

High school students or other members of the public who indicated high school as their highest level of education were grouped as "high-school" respondents; college students or respondents with a college degree were grouped as "college" respondents; and graduate students and others with graduate-level education were grouped as "graduate" respondents.

Those respondents who indicated spontaneously that they read at least one of the three popular science magazines available in Rio de Janeiro (*Galileu*, *SuperInteressante*, and *Ciência Hoje*) were grouped as "science magazine readers"; all others were grouped as "non-readers". Additionally, all respondents were independently classified according to whether they read newspapers: those who indicated spontaneously that they read at least one of the three major newspapers available in Rio (*Jornal do Brasil*, *O Globo*, and *O Dia*) were grouped as "newspaper readers"; all others were grouped as "newspaper non-readers".

Statistical analysis was performed using the Statview software (SAS, Cary, NC, USA). The methods of analysis were designed with three goals in mind: first, a quantitative comparison of the different segments of the public, to identify those factors that might influence the level of neuroscience literacy of the public; second, the identification of those themes about which the public is well informed, poorly informed, or misinformed; and finally, a comparison of how neuroscientists and the public see the functioning of the brain and its relationship to the human mind.

To compare quantitatively the responses of different segments of the public, the following strategy was used. The neuroscientists' responses to the 83 objective assertions were analyzed first. Those that met a criterion of at least 70% accord among neuroscientists were used to elaborate a key against which the public's responses were scored. Of the 83 assertions, 56 met the criterion (see Table 1, assertions in bold). For each questionnaire, the incidence of answers matching that chosen by 70% or more neuroscientists was then calculated as the percentage of correct answers. Since questions left unanswered were very seldom, they were simply considered incorrect; in contrast, those questionnaires with at least one of the four pages left blank were deemed incomplete (n = 105, 79 of which were from the same participating school) and were not considered in this particular analysis. Since the percentage distribution of correct answers was normal (not shown), they were compared among the different segments of the public using a two-tailed t-test.

The public's responses to the individual assertions were next studied. The identification of those themes about which the public is well informed, poorly informed, or misinformed was carried out based on all 2158 questionnaires. Of all 83 objective issues, 3 were left out of this analysis, as there is as yet no consensus in the literature (assertions 21, 47, and 72; see Table 1). According to the distribution of yes, no, and I don't know answers among the public, each assertion could be classified as belonging to one of four categories: mostly correct answers (above 50%), mostly incorrect answers (above 40%), mostly "I don't know" answers (above 40%), and evenly distributed answers. The public was

Table 1. Relation of all 95 assertions in the order they appeared in the questionnaire.

Assertion	Neuroscientists, %		
	Yes	No	D.K.
1. We use our brain 24 hours a day.	97	3	0
2. The bigger the animal, the bigger its brain.	43	57	0
3. The brain is the body organ that consumes the most oxygen.	74	12	14
4. The volume of blood in the brain increases with physical effort.	31	52	17
5. Communication between different parts of the brain happens through electrical impulses and chemical substances.	100	0	0
6. Tobacco's nicotine has a direct effect on the brain.	94	0	6
7. It is with the brain, and not with the heart, that we experience happiness, anger, or fear.	94	0	6
8. Damaged portions of the human brain regenerate and get well again.	9	88	3
9. To learn how to do something, it is necessary to pay attention to it.	63	31	6
10. Memory is stored in the brain much like in a computer, that is, each remembrance goes in a tiny piece of the brain.	6	82	12
11. The human brain stops growing at the end of adolescence.	56	35	9
12. People who lost sight at an early age hear better than people with normal vision.	76	6	18
13. Coma is a deep sleep state.	12	74	14
14. *The mind is a product of the working of the brain.*	91	0	9
15. In the eye, there are cells that identify each color that we see.	34	66	0
16. Dogs have much better audition and olfaction than we do.	94	0	6
17. The electroencephalogram gives a measure of the development of each brain region.	0	97	3
18. Hard thinking about difficult problems leads the brain to fatigue, and we start making mistakes.	29	56	15
19. Each small portion of the brain has a different function.	79	21	0
20. Performance in activities such as playing the piano improves as a direct function of the number of hours spent practicing.	77	17	6
21. The harder the mental calculation, the more brain cells necessary to solve it.	24	26	50
22. Learning is due to modifications in the brain.	97	0	3
23. Babies younger than 6 months can already recognize the mother's native tongue.	68	6	26
24. In the brain, there are cells that recognize specific objects visually: hands, faces, soda cans, dice, toys.	55	33	12
25. Sensation and Perception are two words with the same meaning: our experience of the world.	9	85	6
26. Brain activity can be measured by the incorporation of radioactive molecules administered to the blood.	100	0	0
27. *Knowing our brain we can understand better how our thoughts, our reasoning, and our memories work.*	100	0	0
28. Depression can be caused by the lack of certain chemical substances in the brain.	94	3	3
29. *If it were possible to transplant our brain to another body we would still be ourselves, albeit in a new body.*	51	20	29
30. Brain activity can be studied through the oxygen consumption of specific brain areas.	100	0	0
31. The brain itself is not sensitive to pain; this is why brain surgery can be performed under local anesthesia.	94	0	6
32. In the majority of right-handed people, speech is a specialty of the left brain hemisphere.	94	3	3
33. Memory is stored in a net of many cells scattered throughout the brain.	77	9	14
34. Correcting strabismus has esthetic purposes only, since strabismus does not affect vision.	3	86	11
35. The enhancement of the sense of touch in the blind is due to an increase in the number of receptors in the fingertips, and not to changes in the brain.	3	91	6
36. One's environment can influence hormone production, and in turn, personality.	83	6	11
37. Our brain has maps of the surface of the body and of the visual field.	100	0	0
38. *"State of Mind" is a reflection of the brain state in a given moment.*	77	3	20
39. The electrical activity of the brain of a dreaming person is similar to that of a waking person.	67	33	0

(continued)

Table 1. Continued

Assertion	Neuroscientists, %		
	Yes	No	D.K.
40. All our actions are conscious and decided consciously.	6	94	0
41. To imagine that you are practicing a sport, with no simultaneous actual physical exertion, improves your performance in that sport.	41	26	30
42. Negative emotions such as fear, disgust, and anger are processed in the same brain region.	45	15	40
43. The sensitivity of a body part can change according to its use.	88	3	9
44. Any brain region can perform any function.	0	97	3
45. Locomotion consists of a series of reflexes; this is why we can do other things and walk at the same time.	60	37	3
46. *There is no single "real world"; each of us creates his own real world from the experience of the world.*	54	26	20
47. The diversity of stimuli in the environment stimulates the production of brain cells.	37	52	11
48. In our daily life, it is necessary to coordinate the entire brain, every small region working at the same time.	40	46	14
49. Varied sensory experience is necessary to the normal maturation of the brain functions.	97	0	3
50. Dreaming is important to learning because during this sleep phase we consolidate what we learn.	63	11	26
51. Keeping a phone number in memory until it's dialed, remembering recent events, and recalling distant experiences are different abilities of a single memory system.	17	80	3
52. Dreaming occurs any time during sleep.	9	91	0
53. When we sleep, the brain enters into rest.	6	88	6
54. Emotions disturb reasoning and decision processes; when making tough decisions, better let the emotions cool off.	50	18	32
55. When a brain region is damaged and dies, other parts of the brain can take up its function.	70	24	6
56. Normal embrionary development of the human brain involves birth but also death of brain cells.	97	0	3
57. *The brain works like a computer, that is, with data collection, processing, and exit of decisions.*	47	35	18
58. Each taste, such as chocolate or banana, is identified in the mouth independently of the other senses.	6	86	8
59. An olfactory cell can identify thousands of different odors.	15	70	15
60. All body parts are equally sensitive.	0	100	0
61. Motor coordination works independently of the sense of touch.	15	82	3
62. *If there are means of studying brain activity, the mind can be studied through them.*	57	17	26
63. Personality depends on genetic factors but also on memory, that is, on the capacity of remembering what we've already been through.	80	6	14
64. The brain has areas specialized at certain functions, such as mathematics; the development of these brain areas can be identified through the shape of the skull.	0	97	3
65. *Without a brain, consciousness is not possible.*	83	6	11
66. The bigger the brain, the more intelligent the animal.	6	91	3
67. The passage of time is perceived with the senses.	28	36	36
68. We usually utilize only 10% of our brain.	6	68	26
69. An epileptic crisis results from the temporary silencing of a brain area; this is why epileptics lose consciousness during a crisis.	3	91	6
70. When imagining an object, we use the same brain areas activated when seeing it.	51	40	9
71. Language is inborn; even if raised in solitary, human beings will speak.	11	83	6
72. Being right- or left-handed is a matter of being, respectively, left or right brain hemisphere dominant.	31	52	17
73. Body function regulation through hunger, thirst, and temperature control are functions of a certain brain area.	97	3	0
74. Damaged portions of a newt's brain regenerate and get well again.	37	24	29
75. Learning is due to the addition of new cells to the brain.	3	91	6
76. In the blind, Braille reading activates brain regions left unused by the absence of vision.	70	12	18

(continued)

Table 1. Continued

Assertion	Neuroscientists, % Yes	No	D.K.
77. Drugs such as cocaine are addictive and affect the mind because they alter the chemical balance of the brain.	88	6	6
78. Hormones influence the body's internal state control, but not personality.	12	82	6
79. In the brain, there are cells that identify each color that we see.	56	38	6
80. We are more sensitive in the hands than in the arms because, of the two, the hands possess more receptors.	91	3	6
81. Magnetic resonance imaging unveils the anatomy of the brain, but not its working.	29	60	11
82. Mental effort raises oxygen consumption by the brain.	91	0	9
83. *One day it will be possible to use a machine to read other people's thoughts.*	14	46	40
84. The bigger the animal, the more intelligent it is.	0	100	0
85. Mental effort raises blood volume in the brain.	57	32	11
86. Brain activity is completely dependent on the external environment: when the senses are not stimulated, we don't see, hear, or feel anything.	6	88	6
87. All mammals are capable of dreaming.	43	8	49
88. Sections of the spinal cord can already be repaired.	20	63	17
89. Diseases such as Parkinson's or Alzheimer's are due to cell death in some brain areas.	91	3	6
90. Madness and dementia result from brain disturbances.	91	0	9
91. Cognitive abilities such as intelligence are hereditary and not modifiable with the environment or life experience.	3	94	3
92. *With more knowledge about our brain, we can improve our quality of life.*	83	0	17
93. Learning occurs through the modification of the brain's nervous connections.	100	0	0
94. *Intuition is a "special sense" that cannot be explained by the brain.*	3	60	37
95. *The mind is the result of the action of the spirit, or of the soul, on the brain.*	3	62	35

Assertions were not numbered in the printed version of the questionnaire but are numbered here to ease presentation. The 12 "subjective" assertions are shown in italics; the remaining are the 83 "objective" assertions, and of these, the 56 assertions that at least 70% of neuroscientists agreed upon an answer are indicated in bold. The columns on the right indicate the percentage of neuroscientists who responded yes, no, or I don't know (d.k.) to each assertion.

considered to be well informed about those issues falling into the first category, misinformed about those falling into the second category, and poorly informed about those issues falling into the latter two categories.

Finally, to determine whether reading science magazines or newspapers affects public literacy homogeneously or differently depending on the issue, a contingency analysis was made for the distribution of yes, no, and I don't know answers to each assertion. Contingencies were considered significant for *P*-values smaller than 0.05.

Results

Respondents

The 2158 questionnaires answered by the general public were classified into several categories based on the personal information provided. The large majority of respondents (86.6%) belonged to the high school group (Fig. 1*A*) and were less than 20 years of age (77.9%; Fig. 1*B*). A minority of the population surveyed (6%) spontaneously indicated reading popular science magazines (Fig. 1*C*), whereas a much larger proportion (50%) indicated reading newspapers (Fig. 1*D*).

The respondents were equally distributed among the three major residential areas of the city; only a minority inhabited the downtown business area (Fig. 1*E*). As to the volume of reading, the majority of respondents (63.8%) declared reading only 0 or 1 book per month (Fig. 1*F*).

Quantitative Analysis

The public scored an average of 48.4% ± 13.9% correct answers, against an average score of 87.1% ± 6.7% obtained by neuroscientists (Fig. 2*A*). The average correct score varied markedly with the level of education, increasing from only 46.3% ± 12.9% among high school respondents to 64.4% ± 13.4% among graduate respondents (Fig. 2*B*). Among high school respondents, there was a small gradual increase in the incidence of correct answers from one grade to the next (not shown). College students majoring in psychology were put in a separate group for comparison, because contrary to other majors, these students receive formal college instruction in neuroscience. As could be expected, psychology students achieved a significantly higher score than other college respondents (68.5% ± 11.4% against 58.3% ± 11.4%), and their score was comparable to that of graduate respondents. All groups obtained significantly lower

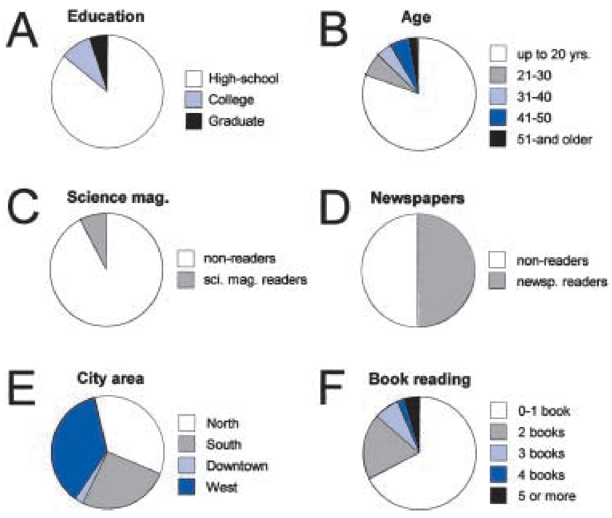

Fig. 1. Distribution of nonneuroscientist respondents (n = 2158) according to level of instruction (*A*; n = 2050), age group (*B*; n = 1962), reading of popular science magazines (n = 1598), reading of newspapers (*D*; n = 1597), geographic zone inhabited (*E*; n = 2053), and number of books read per month (*F*; n = 1926). Missing data correspond to information not provided by the respondents.

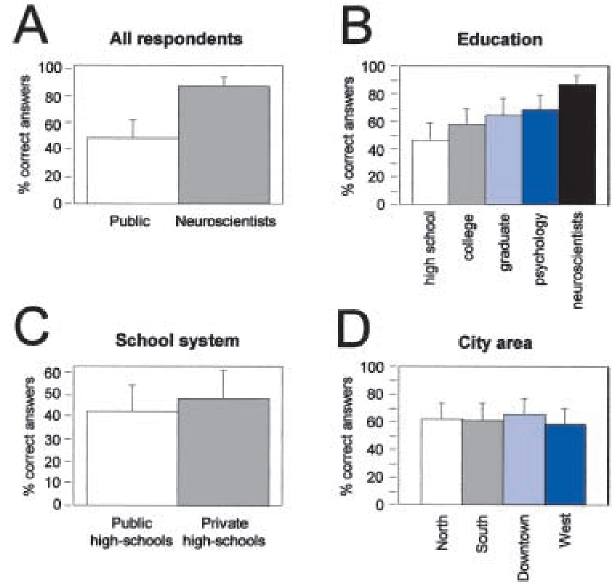

Fig. 2. Average percentage incidence of correct answers (abscissa) among each group of respondents. Bars indicate standard deviation (SD). *A*, Correct answers for the public (n = 2053) and neuroscientists (n = 35; $P < 0.0001$). *B*, Correct answers obtained by high school (n = 1770), college (n = 162), graduate respondents (n = 97), psychology majors (n = 21), and neuroscientists (n = 35). All differences are significant ($P < 0.01$), except for that between psychology students' and graduate respondents' scores (P = 0.1980). *C*, Correct answers among high school students of private (n = 931 respondents) and public schools (n = 816 respondents; $P < 0.0001$). *D*, Correct answers among college and graduate respondents inhabiting West (n = 56), Downtown (n = 18), North (n = 85), and South Rio (n = 106). West scores are significantly lower than Downtown and North ($P < 0.05$), but not South Rio (P = 0.1468), which interestingly is the richest zone of the city.

scores than the participating neuroscientists. Not surprisingly given the current poor state of public high school education in Brazil, students of private schools obtained a significantly higher average score than did public school students (49.2% ± 13.1% against 43.1% ± 11.9%; Fig. 2*C*).

The influence of geographic zone inhabited on the public's score was calculated only for college and graduate respondents, as an analysis of high school scores in each geographical area was not granted by the small number of schools surveyed in each area. Respondents inhabiting West Rio, a developing area, were the only group whose correct score was significantly different from the other groups' (Fig. 2*D*).

Age seemed to have a small but significant correlation with respondents' score, according to a Spearman rank analysis (rho = 0.235; $P < 0.0001$). This correlation might, however, be due to the fact that low-scoring high school respondents were also the youngest in the population surveyed (mean age, 16.8 ± 4.4 years; college, 39.7 ± 12.6; graduate, 41.6 ± 11.9). Analysis within high school, college, and graduate respondent groups in separate revealed that age was not significantly correlated with the respondents' score within any of the three groups ($P > 0.05$).

Effect of Reading Books, Science Magazines, and Newspapers

Respondents who declared reading no books or only one per month obtained a significantly lower average score than two-book and three-book readers. Reading more than three books a month, however, did not increase further the respondents' scores (Fig. 3*A*).

The average score also varied with reading of popular science magazines. Because many readers were high-scoring graduate respondents, the effect of reading science magazines was analyzed separately for the different education groups. Among high school respondents, science magazine reading was associated with a 16% increase in the incidence of correct answers (Fig. 3*B*). A significant, although smaller, increase was also observed on the score of graduate respondents. In contrast, reading popular science magazines did not appear to affect the average score of college respondents.

Newspaper reading was associated with a 9% increase in the average score of high school respondents (Fig. 3*C*). The effect on the score of other groups was not assessed, as fewer than 25 respondents declared not to read newspapers.

The average score increased gradually from high school readers of neither newspapers nor popular science magazines to readers of either to readers of both as shown in Figure 3*D*. Science magazine readers who also read newspapers did not have significantly higher scores than readers of science magazines but not newspapers.

Taken together, the quantitative analysis of the average scores obtained by each subgroup of the population

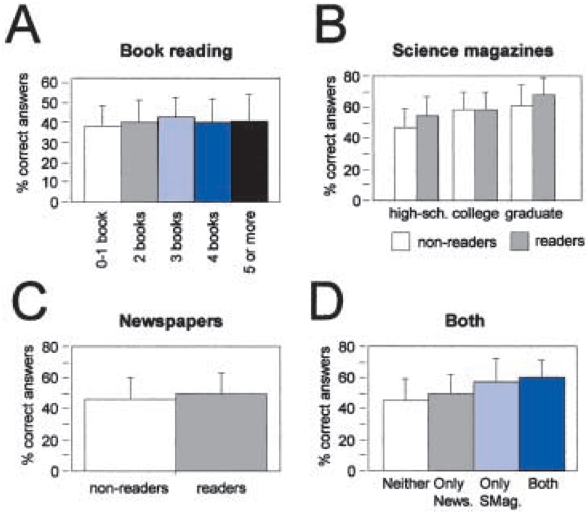

Fig. 3. Average percentage incidence of correct answers (abscissa) according to reading. *A*, Correct answers among readers of zero or one book per month up to five or more. Zero-or-one book readers obtained significantly lower scores that two- and three-book readers ($P < 0.0001$), but not than the other groups ($P > 0.05$). *B*, Correct answers among readers and nonreaders of popular science magazines for each group. High school respondents, $P < 0.0001$; college, $P = 0.8552$; graduate respondents, $P = 0.0335$. *C*, Correct answers among high school readers and nonreaders of newspapers ($P < 0.0001$). *D*, Average percentage incidence of correct answers among high school readers and nonreaders of newspapers and/or popular science magazines. All pairwise comparisons yield *P*-values smaller than 0.0001, except for "only science magazines" against "both" ($P = 0.2709$). Bars indicate standard deviation. SMag = popular scientific magazines.

indicates that schooling is the factor that improves neuroscientific culture the most (30% increase from high school to graduate respondents), followed by reading of science magazines (16.3% increase) and of newspapers (8.9% increase). Formal neuroscientific instruction increases the score of college respondents by 17.5%, although an equally high score can also be achieved through nonneuroscientific, graduate education.

What the Public Knows, Does Not Know, and Believes It Knows about the Brain

Although the scores obtained by the public were low, analysis of the responses to individual objective assertions indicated that not all themes are equally unknown to the public; in fact, some had a very high incidence of correct answers. Because schooling had the strongest influence on public neuroscience literacy, the identification of concepts that are known or unknown to the public and their possible misconceptions about the brain was carried out separately for each group. Although for many assertions there were indeed large differences in the incidence of correct answers among the groups, overall each issue tended to consistently classify as either well known, poorly known, or misknown to high school, college, and graduate respondents alike, or at least to two of these groups. Only three issues were classified differently among high school and graduate respondents.

Among what the public seems to know about the brain, or correctly accepts, appear several pieces of "brain trivia" such as the superiority of canine hearing and olfaction compared to ours, but also important notions such as the nonstop working of the brain, the functional specialization of different brain areas, and the fact that addictive drugs act on the brain. Table 2 shows the 44 issues receiving more than 50% correct answers from high school and/or college and/or graduate respondents. A positive effect of schooling on the incidence of correct answers is readily observed for several assertions.

Among the issues the public is uninformed about were three of four assertions on techniques to study brain function (assertions 26, 30, and 17). Most important, the public seems not to be aware that learning corresponds to modifications in the brain, more specifically in the nervous connections (assertions 22 and 93). A total of 18 issues were classified as poorly known among the public, as shown in Table 3.

The public seems to have several important misconceptions about the brain, as suggested by the 21 issues that received mostly incorrect answers from the public, listed in Table 4. Some notions regard brain trivia such as the misconceptions that brain size does not increase with animal size (it does) and that the volume of blood in the brain increases with mental or physical exertion, when it is remarkably constant in healthy individuals (Kety and Schmidt 1948). Other misconceptions concern notions that have important consequences for everyday life: for example, the public seems to believe that emotions as a rule are disruptive, when it is already known that they are in fact essential for wise decision-making (Damasio 1994). Memory is another example: the public seems to mistakingly believe that there is a single memory system in the brain, whereas in truth there are several (for very short-, short-, and long-term memory; for things that can be expressed in words; and for procedures that cannot; reviewed in Squire 1982), and to suppose that each individual memory is stored in a piece of the brain, much like in a computer, whereas the elements that compose each memory are believed to be scattered throughout the brain (Fuster 1997). Finally, the myth that we use only 10% of our brain seems to be remarkably widespread among the public, particularly among college respondents.

Does Reading of Science Magazines Work for All Themes?

The analysis of the incidence of correct answers for each assertion among readers and nonreaders of popular science magazines revealed that rather than improving knowledge homogeneously on all themes, only a few themes were significantly affected.

Among graduate respondents, readers of popular science magazines chose the correct answer significantly more often than nonreaders in only four instances (average increase, 66.9% ± 57.3%), and in no case less often. Reading had a remarkable positive effect on their answers to assertion 26, "Brain activity can be measured by the incorporation of radioactive molecules adminis-

Table 2. Concepts and related assertions meeting with at least 50% correct answers from the public, listed by incidence among high school respondents.

Correct Concept and Related Assertion	% Correct Answers hs	col	gr
Learning requires attention (A9)	91	82	73
Addictive drugs alter the chemical balance of the brain and affect the mind (A77)	89	94	86
We use our brain 24 hours a day (A1)	88	88	92
Dogs have better audition and olfaction than humans (A16)	86	97	97
Each brain region has a different function (A19)	83	83	85
The larger brain of bigger animals does not make them more intelligent (A84)	82	93	98
Emotions are experienced with the brain, not with the heart (A7)	79	94	97
Madness and dementia result from brain disturbances (A90)	79	61	53
Performance improves with practice (A20)	76	83	82
Brain size does not correlate with intelligence (A66)	74	75	74
Damaged portions of the human brain do not regenerate (A8)	70	73	70
There are cells in the brain that recognize objects visually (A24)	70	53	(39)
The brain does not stop during sleep (A53)	66	76	80
Early loss of sight can be compensated with improved hearing (A12)	65	76	65
All body parts are not equally sensitive (A60)	65	76	85
Body sensitivity can change according to use (A43)	64	75	72
Tobacco's nicotine acts directly on the brain (A6)	64	80	80
All brain regions must work coordinately (A48)	62	54	54
The environment influences hormone production and, in turn, personality (A36)	62	62	64
Young babies can already recognize their mother's native tongue (A23)	62	70	61
Personality depends both on genetics and memory (A63)	61	66	75
Any brain region does not perform any function (A44)	60	76	79
Hunger, thirst, and body temperature are controlled by the same brain area (A73)	60	68	71
Memory is scattered throughout the brain (A33)	60	56	65
Parkinson's and Alzheimer's disease are due to cell death in the brain (A89)	59	63	61
Mental effort leads to brain fatigue (A18)	59	56	(38)
Signal transmission in the brain is chemical and electrical in nature (A5)	57	84	96
There are cells in the brain that identify each color that we see (A79)	57	54	(44)
Body sensitivity depends on receptor density in the skin (A80)	56	73	80
All actions are not conscious (A40)	56	83	94
Mental effort raises oxygen consumption in the brain (A82)	53	74	68
Cognitive abilities are hereditary but also modifiable with experience (A91)	50	76	91
Language is not inborn; raised in solitary, humans do not speak (A71)	(42)	76	75
Increased activity of certain brain areas does not modify the shape of the brain (A64)	(41)	66	65
Sensation and perception are two different processes (A25)	(40)	60	68
Learning is not due to the addition of new cells to the brain (A75)	(39)	65	82
Normal maturation of brain function requires varied sensory experience (A49)	(38)	70	83
Depression can be caused by the lack of certain substances in the brain (A28)	(37)	75	96
Flavor identification requires the combination of taste and olfaction (A58)	(34)	58	62
Strabismus must be corrected early in life, otherwise vision is compromised (A34)	(32)	56	52
Enhanced tactile sensitivity in the blind is due to changes in the brain (A35)	(32)	52	59
Hormones influence both body state and personality (A78)	(26)	(42)	58
Dreaming occurs mostly during a certain sleep period (REM sleep) (A52)	(25)	50	64

Assertion numbers refer to Table 1. hs = high school; col = college; gr = graduate respondents. Scores below 50% are indicated in parentheses.

tered to the blood" (159.0% increase) and increased by about 30% the incidence of correct answers to two assertions related to learning (Table 5).

Among high school respondents, readers obtained significantly higher scores than nonreaders for 13 of 80 assertions (Table 6). Remarkable positive effects of reading of science magazines on the incidence of correct responses among high school respondents were observed for assertion 52, "Dreaming occurs at any time during sleep" (150% increase), and for assertion 55, "When a brain region is damaged and dies, other parts of the brain can take up its function" (114% increase).

Table 3. Concepts and related assertions meeting with at least 40% "I don't know" answers from the public or even response distribution, listed by incidence among high school respondents.

	% "I Don't Know"		
Correct Concept and Related Assertion	**hs**	**col**	**gr**
Brain activity can be measured by the incorporation of radioactive molecules (A26)	68	65	44
Speech is a specialization of the left cerebral hemisphere (A32)	58	49	48
Brain activity can be studied through the oxygen consumption of brain areas (A30)	54	45	(26)
Spinal cord sections can already be repaired to some extent (A88)	52	62	44
During normal development, there is both birth and death of brain cells (A56)	51	44	(31)
The human brain stops growing in size at the end of adolescence (A11)	50	43	44
Learning occurs through the modification of nervous connections in the brain (A93)	50	40	(30)
Contrary to the human brain, the newt brain can regenerate when damaged (A74)	49	61	58
All mammals are capable of dreaming (A87)	48	60	68
The brain itself is not sensitive to pain (A31)	43	42	46
The electroencephalogram measures brain activity, not development (A17)	43	(32)	(25)
Epilepsy results not from electrical silence in the brain but runaway activity (A69)	42	47	49
The brain has maps of the body and visual field (A37)	42	44	(33)
All negative emotions are not processed in the same brain region (A42)	40	65	72
Mental imagery uses the same circuits as actual vision (A70)	(37)	40	40
Learning corresponds to modifications in the brain (A22)	(36)	(30)	(24)
In the blind, Braille reading activates brain regions unused by vision (A76)	(32)	(36)	41
Memory consolidation occurs during dreaming (A50)	(28)	42	42

Assertion numbers refer to Table 1. hs = high school; col = college; gr = graduate respondents. Scores below 40% are indicated in parentheses.

Table 4. Misconceptions, correct concepts, and related assertions meeting with at least 40% incorrect answers from the public, listed by incidence among high school respondents.

	% Wrong Answers		
Misconception, Correct Concept, and Related Assertion	**hs**	**col**	**gr**
Emotions always disturb reasoning (they are often necessary) (A54)	81	83	70
Coma is similar to deep sleep (it is not) (A13)	79	55	41
Bigger animals do not have bigger brains (they do) (A2)	77	86	79
Locomotion is a chain of reflexes (it is not) (A45)	74	71	70
Dreaming occurs anytime during sleep (dreaming occurs mainly during REM sleep) (A52)	67	(35)	(26)
Olfactory receptors identify thousands of different stimuli (they do not) (A59)	66	57	57
There is a single memory system in the brain (there are several different systems) (A51)	65	49	49
Functional reorganization in the damaged brain does not occur (it does) (A55)	59	43	(28)
Memory is stored in the brain like in a computer (no, it is distributed in the brain) (A10)	58	54	41
Mental practice does not improve performance (it does) (A41)	58	60	53
Flavor identification does not require the combination of taste and olfaction (it does) (A58)	55	(34)	(32)
Eye cells identify each color that we see (they do not) (A15)	54	40	(39)
Epilepsy results from electrical silence in the brain (it results from runaway activity) (A69)	51	42	(24)
The volume of blood in the brain increases with physical exertion (it does not) (A4)	51	57	49
Hormones do not influence personality (they do) (A78)	51	(36)	(24)
Brain activity depends entirely on the external environment (it does not) (A86)	50	48	(33)
The passage of time is perceived with the senses (no, time is not a stimulus to the senses) (A67)	46	54	44
Motor coordination does not depend on the sense of touch (it does) (A61)	43	47	41
The electrical activity of the dreaming brain does not resemble that of waking (it does) (A39)	41	55	56
The volume of blood in the brain increases with mental effort (it does not) (A85)	40	62	54
Magnetic resonance imaging cannot unveil brain functioning (it can) (A81)	(32)	43	58
We use only 10% of the brain (we use the entire brain) (A68)	(32)	59	48

Assertion numbers refer to Table 1. hs = high school; col = college; gr = graduate respondents. Scores below 40% are indicated in parentheses.

Table 5. Effect of reading of popular science magazines on the incidence of "correct" answers to objective assertions among graduate respondents.

Assertion and % Correct Answers among Neuroscientists	% Correct Answers Nonreaders	Readers	Improvement
Brain activity can be measured by the incorporation of radioactive molecules administered to the blood (A26) (100% yes)	22	57	159
The electroencephalogram gives a measure of the development of each brain region (A17) (97% no)	49	73	49
Learning is due to modifications in the brain (A22) (97% yes)	42	57	36
Learning is due to the addition of new cells to the brain (A75) (91% no)	73	97	33

Shown are only those cases where reading had a significant effect ($P < 0.05$, contingency analysis). Assertion numbers refer to Table 1. "Improvement" indicates percentage change in incidence of "correct" responses among "read" group relative to "don't read" group.

Table 6. Effect of reading of popular science magazines on the incidence of "correct" answers to objective assertions among high school respondents.

Assertion and % Correct Answers among Neuroscientists	% Correct Answers Readers	Nonreaders	Improvement
Dreaming occurs any time during sleep (A52) (91% no)	60	24	150
When a brain region is damaged and dies, other parts of the brain can take up its function (A55) (70% yes)	30	14	114
Brain activity is completely dependent on the external environment: when the senses are not stimulated, we don't see, hear, or feel anything (A86) (88% no)	38	20	90
Each taste, such as chocolate or banana, is identified in the mouth independently of the other senses (A58) (86% no)	58	34	70
Communication between different parts of the brain happens through electrical impulses and chemical substances (A5) (100% yes)	87	57	53
Cognitive abilities such as intelligence are hereditary and not modifiable with the environment or life experience (A91) (94% no)	71	50	42
Sensation and perception are two words with the same meaning: our experience of the world (A25) (85% no)	55	40	38
Language is inborn; even if raised in solitary, human beings will speak (A71) (83% no)	58	43	35
All our actions are conscious and decided consciously (A40) 94% no)	75	57	32
All body parts are equally sensitive (A60) (100% no)	81	66	23
Any brain region can perform any function (A44) (97% no)	75	62	21
Memory is stored in a net of many cells scattered throughout the brain (A33) (77% yes)	69	59	17
Dogs have much better audition and olfaction than we do (A16) (94% yes)	100	88	14

Shown are only those cases where reading had a significant effect ($P < 0.05$, contingency analysis). Assertion numbers refer to Table 1. "Improvement" indicates percentage change in incidence of "correct" responses among "read" group relative to "don't read" group.

As could be expected from the overall scores, reading of popular science magazines in no instance was associated with increased incidence of correct responses among college respondents but was associated with fewer correct responses to three assertions. For assertion 37, "Our brain has maps of the surface of the body and of the visual field," the incidence of correct answers was 40% lower among readers than nonreaders. For assertion 3," The brain is the body organ that consumes the most oxygen," correct affirmative answers were 13% less frequent among readers than nonreaders. For assertion 68, "We usually utilize only 10% of our brain," the difference was much more remarkable: incorrect acceptance rose by 99%, from 34% among nonreaders to 67% among readers.

Table 7. Responses to subjective assertions on matters of opinion.

Assertion	Answer	% hs	% col	% gr
Knowing our brain, we can understand how our thoughts, our reasoning, and our memories work (A27)	yes	86	89	82
With more knowledge about our brain, we can improve our quality of life (A92)	yes	70	89	82
One day it will be possible to use a machine to read other people's thoughts (A83)	no	40	36	34
	d.k.	41	55	61
If it were possible to transplant our brain to another body, we would still be ourselves, albeit in a new body (A29)	yes	43	43	42
	no	34	26	30
There is no single "real world"; each of us creates his own real world from the experience of the world (A46)	yes	57	74	72
The brain works like a computer, that is, with data collection, processing, and exit of decisions (A57)	yes	84	83	80

Assertion numbers refer to Table 1. hs = high school; col = college; gr = graduate respondents.

Does Newspaper Reading Make a Difference?

Despite an increase of almost 10% in the overall incidence of correct responses among high school readers of newspapers relative to nonreaders, the analysis of the responses to each individual assertion showed that newspaper reading is associated with discreet, and often negative, effects on the level of information of the public. Although newspaper reading affected the incidence of correct answers to 18 objective assertions, this effect was, however, in no case larger than 30%, and could be either positive (mean increase, 14.8% ± 7.0%, $n = 13$) or negative (mean decrease, 16.1% ± 4.9%, $n = 5$), depending on the assertion. Interestingly, although science magazine reading doubled the proportion of high school respondents who agreed that "We use only 10% of our brain," newspaper reading among this group had no effect on their opinion on this issue.

Matters of Opinion

The majority of the public agreed that information about how the brain works can foster improvements in life quality and a better understanding of our thought processes (Table 7). Among the opinions of the public on issues such as the existence of a "real world" and whether intuition can be considered a "special sense," the view that the brain can be likened to a computer stands out, with more than 80% agreement among all groups.

The Mind-Brain Relationship

Elucidating the mind-brain relationship can be considered to be neuroscience's ultimate goal. As shown in Table 8, the great majority of the public, regardless of level of instruction, agrees that the conscious mind is a product of the brain. Interestingly, a large fraction of the public accepts that the brain produces the mind under the command of the soul, or of an immaterial spirit. In contrast to the opinions on the mind-brain-consciousness relationship, which did not differ with respondents' education, belief in the ruling of an immaterial soul on the brain seems to be less common among more educated respondents.

The Brain According to Public and Scientists

Taking into consideration the public's best- and worst-known objective assertions and their responses to the subjective assertions, it is possible to outline how the public sees the functioning of the brain, its relationship to the human mind, and how its view differs from the neuroscientists'. As detailed in Table 9, the major differences relate to learning, memory, the brain-computer analogy, and the possible role of an immaterial soul or spirit in producing the mind. More specifically, although the public accepts that the mind is a product of the brain, many respondents, particularly of the high school and college groups, also accept the intervention of an immaterial soul. This indicates that whereas neuroscientists accept a materialistic view of the mind, more than a third of the public embraces the dualistic notion that the brain merely provides an interface between mind and matter, or between the mind and the soul.

Discussion

How much science does the public understand? "Not much," according to surveys carried out in Europe and the United States (Durant and others 1989). But change the question to how much the public knows about the brain in particular, and the present study offers a different answer: "it depends."

Several factors might account for the difference. The first factor is the aim of the studies: whereas the major concern of previous surveys was assessing "how much science" the public understands, this survey aimed at identifying what the public knows and does not know about the brain.

Other factors are survey method and interpretation. Previous studies on public general scientific understanding addressed some 20 to 30 items about what were considered to be "elementary scientific facts" such as "The

Table 8. Responses to subjective assertions on the mind-brain relationship.

Assertion	Answer	% hs	% col	% gr
Without a brain, consciousness is not possible (A65)	yes	78	85	82
	no	14	7	10
The mind is a product of the working of the brain (A14)	yes	77	74	72
	no	5	10	6
"State of mind" is a reflection of the brain state in a given moment (A38)	yes	58	59	48
	d.k.	28	21	27
If there are means of studying brain activity, the mind can be studied through them (A62)	yes	53	47	50
	d.k.	31	35	34
Intuition is a "special sense" that cannot be explained by the brain (A94)	yes	45	35	25
	d.k.	22	40	39
The mind is the result of the action of the spirit, or of the soul, on the brain (A95)	yes	41	33	18
	no	37	32	31
	d.k.	22	35	51

Assertion numbers refer to Table 1. hs = high school; col = college; gr = graduate respondents.

Table 9. How neuroscientists and the public view the brain, inferred from the majority of responses to the questionnaire.

Neuroscientists Consider That	Whereas the Public . . .
the brain works 24 hours a day	agrees
bigger brains do not make for more intelligent animals	agrees
the brain is organized in functionally different areas	agrees
brain areas communicate using chemical and electrical signals	agrees
drugs act on the mind by interfering with the brain	agrees
learning corresponds to modifications in the brain, more specifically of neuronal connections	does not equate learning with modifications in the brain, nor of neuronal connections in particular
the brain cannot be compared to a computer	accepts the analogy
memory is stored in distributed networks, and not in brain chunks equivalent to computer chips	accepts the notion that memory is stored as in computers, with one piece for each memory
there are different memory systems in the brain	does not acknowledge that there are different memory systems
the brain is required for consciousness	agrees
mental diseases result from cerebral disturbances	agrees
the mind results from the working of the brain, with no intervening immaterial soul or spirit	agrees that the mind is a product of the brain, but also accepts the intervention of an immaterial soul

center of the Earth is very hot," "It is the father's gene which decides whether the baby is a boy or a girl," and "Does the Earth go round the Sun or the Sun go round the Earth?" (Durant and others 1989; National Science Board 1981, 1983, 1985, 1988, 1993; Eurobarometer 1993), then used the answers to create a scale, the Oxford Scientific Knowledge Scale (Durant and others 1989). It is according to this scale that public scientific understanding was considered to be low. In contrast, the present survey was intended to identify major strengths and deficiencies of the public exclusively in neuroscience through an extensive list of issues related to that one theme, and it generated a scale, the incidence of correct answers, with the sole intention of identifying factors that contribute to neuroscience literacy. In fact, both the present survey and previous studies find that the level of public understanding depends very much on the question addressed.

A major drawback of the method chosen by these surveys is that rather than hearing what individual respondents "think" about each issue, only their acceptance, rejection, or acknowledgment of lack of information about each statement is available for analysis. On the one hand, rejection of incorrect assertions suggests that the respondent is informed enough to make the call; on the other hand, agreeing with correct assertions does not imply possessing that bit of knowledge, but only accepting it.

Still, using care and parsimony, important conclusions can be inferred from the public's responses in the present survey. The public recognizes that brain research offers knowledge on human nature that can be explored to improve life quality; considers the mind to be a product of the brain; seems to be aware of several basic facts about the brain; fails to associate learning to modifications in the brain, more specifically in its connections; fails to acknowledge the existence of different types of memory; accepts the comparison of the brain to a computer; and accepts, mistakingly, the notion that we use only 10% of our brain.

This survey also achieved the goal of identifying factors that contribute to the improvement of the lay public's neuroscience literacy, pointing to schooling, reading of popular science magazines, and reading of newspapers as main contributors. Previous studies have also found that educational level was the strongest factor associated with better public "scientific understanding" (Durant and others 1989). That reading of popular science magazines also contributes to scientific literacy is expected from the very content of these publications, and from the observation that 55% of people surveyed in another study claim to obtain information about science mainly from the media, and not in school (Observatório das Ciências e das Tecnologias 1996/97). On the other hand, it could be argued that it is not reading that increases neuroscience literacy, but rather that those who already have an interest in science, and therefore already are more informed (Durant and others 1989), would seek to read these materials. However, if this were the case, there should have been differences between the responses of college-level readers and nonreaders, who incidentally are the major target of these magazines, whereas this was true for only three assertions. Moreover, differences associated with science magazine reading were not universal but restricted to only a few themes. Although the possibility cannot be discarded at this point, it seems unlikely that it would explain all the effects observed here.

Incidentally, improvements associated with science magazine reading were significant but mostly small compared to what one might have expected, because this literature provides a means of obtaining specific information that is most probably not covered in school or university programs. Curiously, some of the themes the public seems worst informed about are constantly on the spot in the media nowadays, such as learning and memory and modern imaging methods. Popular science magazines, therefore, are a potentially effective medium that is apparently not as well explored as it could be, and must be lacking—in what? Appropriate language? Content? Another survey is under way to determine how the different themes covered here have been dealt with by popular science magazines and newspapers, and how this coverage relates to the degree of information of the public.

Although the present survey tried to be as extensive as possible, within reasonable limits, important issues were touched only lightly upon, such as brain anatomy and molecular neurobiology. These and other issues will have to be addressed by future surveys. Additionally, a series of interviews are under way to investigate more carefully the opinions of the public on some of the issues addressed here. It would also be important to apply the same questionnaire in other countries, to determine how the present findings among the public of Rio de Janeiro relate to the state of neuroscience literacy in countries where research in neuroscience is more or less expressive, funded, and covered in the media.

Knowing what the public knows is one of the means to improve communication between neuroscientists and the public. By pointing out the major misconceptions about the brain and those themes about which the public is most in need of accurate information, this survey represents a first step in this direction. If efforts can be mobilized from science educators, science writers, and neuroscientists themselves, the guidelines offered by this survey should help bring benefits to the public in the near future. But not only to the public; neuroscientists themselves can only benefit from knowing how their work is appreciated by the public who funds it.

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