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Brief article

Seeing is believing: The effect of brain images on judgments of scientific reasoning ☆,☆☆

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Abstract

Brain images are believed to have a particularly persuasive influence on the public perception of research on cognition. Three experiments are reported showing that presenting brain images with articles summarizing cognitive neuroscience research resulted in higher ratings of scientific reasoning for arguments made in those articles, as compared to articles accompanied by bar graphs, a topographical map of brain activation, or no image. These data lend support to the notion that part of the fascination, and the credibility, of brain imaging research lies in the persuasive power of the actual brain images themselves. We argue that brain images are influential because they provide a physical basis for abstract cognitive processes, appealing to people's affinity for reductionistic explanations of cognitive phenomena.

Keywords: Scientific communication; fMRI; Brain imaging; Persuasion; Cognitive neuroscience

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1. Introduction

Understanding scientific data is often a complex process for both scientists and the lay public alike. Scientific communication is facilitated by presenting summaries of data, summaries that often take the form of tables, graphs, or images, and convey information about the quality or importance of the scientific data. For example, physical sciences such as chemistry and physics use graphs to represent data far more often than social sciences, such as sociology and economics, which use tables to a greater degree (Smith, Best, Stubbs, Archibald, & Roberson-Nay, 2002). Thus, to the extent that physical sciences are perceived as more credible than social sciences, visual displays are associated with a greater degree of scientific credibility (Smith et al., 2002).

Data from cognitive research is usually summarized using tables and/or graphs, but other methods of presentation are often used. For example, in cognitive neuroscience, brain activity measured using fMRI (functional magnetic resonance imaging) or PET (positron emission tomography) is sometimes presented in tables or graphs, but is often represented using images of the brain with activated areas highlighted in color. These brain images have been portrayed in the media as localizing brain areas associated with a wide range of cognitive, emotional, and spiritual functions, including lying, being in love, and believing in God, among other things (Nicholson, 2006). Furthermore, both scientists and the media have suggested that using brain images to represent brain activity confers a great deal of scientific credibility to studies of cognition, and that these images are one of the primary reasons for public interest in fMRI research (Carey, 2006; Dobbs, 2005; Racine, Bar-Ilan, & Illes, 2005).

The excitement about brain imaging research has not been without controversy. Many scientists, particularly cognitive neuroscientists and ethicists, are concerned about how the data from fMRI studies are being interpreted, particularly by the lay media and the general public, both of whom have shown a tendency to oversimplify and misrepresent conclusions from brain imaging studies. Racine et al. (2005) have argued that popular press coverage of brain imaging research has led to a type of *neuro-realism*, such that the phenomena under study become, "uncritically real, objective or effective in the eyes of the public" (p. 160). Similarly, Dumit (2004) has argued that brain images naturally communicate that different "kinds of people" (e.g., normal or depressed) are represented by different patterns of brain activation, and that these images are intuitively interpreted as being credible representations of cognitive activity. This tendency to interpret brain images as credible may be related to people's natural affinity for reductionistic explanations of cognitive phenomena (cf., Weisberg, Keil, Goodstein, Rawson, & Gray, in press), such that physical representations of cognitive processes, like brain images, are more satisfying, or more credible, than more abstract representations, like tables or bar graphs.

The primary purpose of the present study was to examine whether brain images actually do have a particularly powerful persuasive influence on the perceived credibility of cognitive neuroscience data. In order to achieve this goal, ratings of the quality of articles summarizing cognitive neuroscience data were examined for articles that were accompanied by brain images, and those that were accompanied by other representations of data, or no representation at all.

2. Experiment 1

In the first experiment participants read fictional articles summarizing cognitive neuroscience research, modeled after news service articles, that either included no image, a brain image, or a bar graph depicting the critical results. After reading the article, participants were asked to rate the soundness of the scientific reasoning in the article. This design allowed an examination of whether presenting brain images would lead people to be more persuaded by cognitive neuroscience research, which would be indicated by higher ratings of scientific reasoning when brain images were present, compared to when they were absent, or when a bar graph was presented. Moreover, because bar graphs are a particularly effective way to communicate scientific data (Latour, 1990), and brain imaging data are often presented using bar graphs in research articles, a comparison between the brain image and bar graph conditions allowed a straightforward test of the hypothesis that there is something particularly persuasive about using brain images to convey neuroscientific data, relative to a realistic alternative visual representation of the data.

2.1. Methods

2.1.1. Participants

One-hundred fifty-six Colorado State University undergraduates between the ages of 18 and 25 participated for course credit.

2.1.2. Materials and procedure

Participants read three brief articles, each summarizing the results of fictitious brain imaging studies. The articles made claims that were not necessitated by the data (e.g., *reverse inference* errors; Poldrack, 2006), giving participants some basis for skepticism in their ratings. For example, in the article entitled, 'Watching TV is Related to Math Ability', it was concluded that because watching television and completing arithmetic problems both led to activation in the temporal lobe, watching television improved math skills. This similarity in activation was depicted in a bar graph or brain image (shown in Fig. 1a), or was only explained in the text (the control condition). The other articles, entitled, 'Meditation Enhances Creative Thought', and, 'Playing Video Games Benefits Attention', also included errors in scientific reasoning, and preceded the 'Watching TV' article (in that order). Each article was approximately 300 words long presented on a single page, with the rating questions below the article on the bottom of the page, and the image embedded in the text. Whether the article included a brain image, a bar graph, or only text was manipulated within-subjects, and the order of these conditions was counterbalanced. After reading each article, participants were asked to rate their agreement with three statements: (1) *The article was well written*, (2) *The title was a good description of the results*, and (3) *The scientific reasoning in the article made sense*. Responses were made on a four-point Likert scale, with response options including ''strongly disagree'', ''disagree'', ''agree'', and ''strongly agree'' (coded 1, 2, 3, or 4, respectively, for purposes of data analysis).

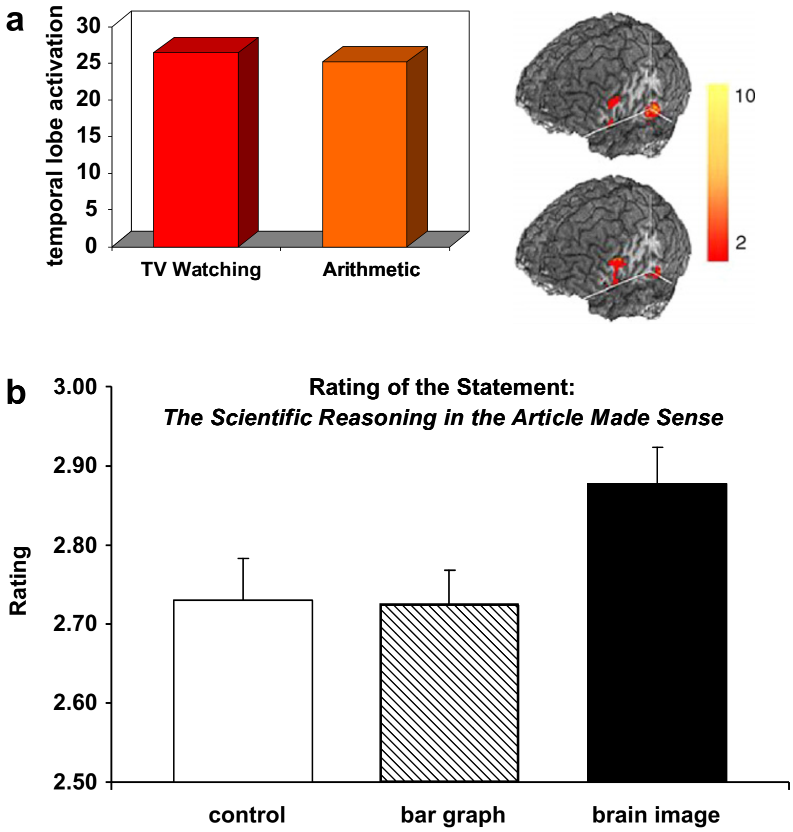

Fig. 1. (a) Examples of the bar graph and brain image used for the article entitled, 'Watching TV is Related to Math Ability', in which watching television and completing arithmetic problems led to similar levels of temporal lobe activation. (b) Mean ratings of scientific reasoning for the articles as a function of experimental condition (control, bar graph, and brain image). Error bars represent standard errors of the mean.

2.2. Results and discussion

Results of statistical tests were significant at $p < .05$. A one-way within-subjects ANOVA was conducted separately for each question, with image type (control (no image), bar graph, brain image) as the independent variable. There was no significant effect of image type on the title question (M range = 2.55–2.60; all F's < 1), but there were significant effects for both the writing, $F(1,155) = 3.68$, $MSE = 1.06$, and reasoning questions, $F(1,155) = 4.09$, $MSE = 1.18$. Planned comparisons revealed that both the brain image ($M = 2.92$, $SEM = .04$) and bar graph ($M = 2.90$, $SEM = .04$) conditions were rated as better written than the control condition ($M = 2.77$, $SEM = .05$), $F(1,155) = 5.82$, $MSE = 1.82$; $F(1,155) = 3.92$, $MSE = 1.28$, respectively. Critically, as shown in Fig. 1b, texts accompanied by a brain image were given the highest ratings of scientific reasoning, differing reliably from both the control, $F(1,155) = 5.87$, $MSE = 1.70$, and bar graph conditions, $F(1,155) = 8.38$, $MSE = 1.85$.

3. Experiment 2

Experiment 1 established that including brain images, a seemingly direct physical representation of brain activity, with summaries of fictional cognitive neuroscience data, increased ratings of scientific reasoning for those summaries. The control condition including a bar graph representing the data had no influence relative to a control condition with no visual depiction of the data. A possible alternative explanation for the effect of brain images on judgments of scientific reasoning was that they were more visually complex than bar graphs, and that the complexity of the images influenced judgments of scientific reasoning. To address this, in Experiment 2 participants were presented with articles that were accompanied by brain images, and others that were accompanied by topographical maps of brain activation (see Fig. 2; panel a). The topographical map was visually similar to the brain image in terms of represented brain activation in a complex color visual image, but these maps are not typically used in the popular press, and presumably are not as easily identified as representing a brain. Thus, if the effect of brain images in Experiment 1 was due to visual complexity, there should be no difference between the brain image and the topographical map conditions in Experiment 2.

3.1. Methods

3.1.1. Participants

One-hundred twenty-eight Colorado State University undergraduates participated for course credit.

3.1.2. Materials and procedure

The articles entitled, 'Watching TV is Related to Math Ability', and, 'Playing Video Games Benefits Attention', from Experiment 1, were used in Experiment 2. The brain image and topographical map conditions were within-subject variables, and the order of these conditions was counterbalanced across participants. In Experiment 2, only the statement, *The scientific reasoning in the article made sense*, was rated following each article.

3.2. Results and discussion

As shown in Fig. 2b, texts accompanied by a brain image were given higher ratings of scientific reasoning than those accompanied by a topographical map, $t(127) = 1.85$. These data suggest that it was not simply the visual complexity of the brain images that influenced ratings of scientific reasoning, because both the brain image and topographical map were visually complex.

4. Experiment 3

Experiments 1 and 2 established an effect of the presence of brain images on judgments of the soundness of the scientific reasoning, and suggested that this effect was

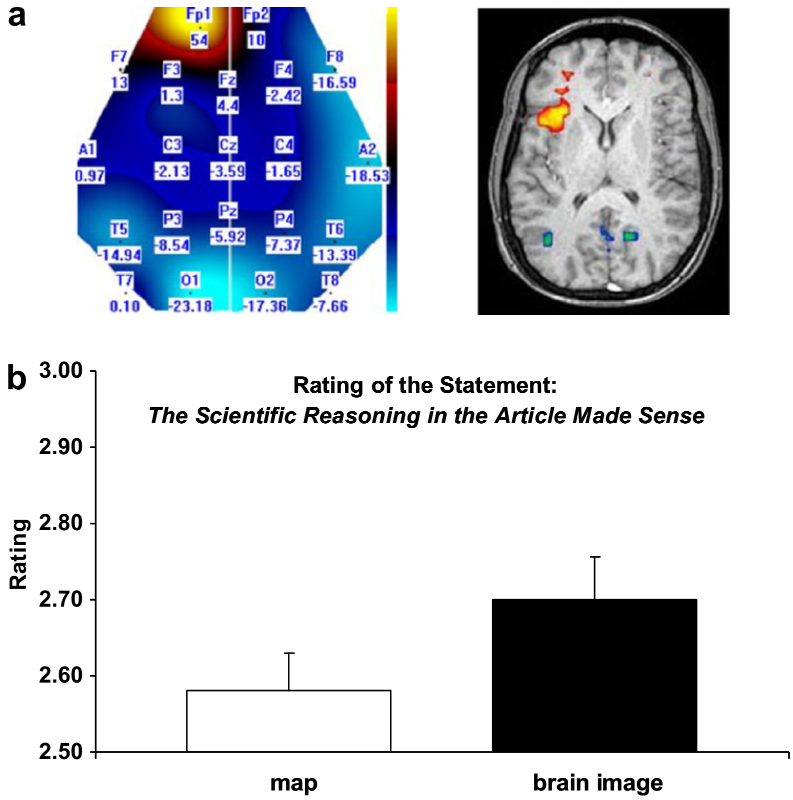

Fig. 2. (a) Examples of the topographical map and brain image used for the article entitled, 'Watching TV is Related to Math Ability', in which watching television and completing arithmetic problems led to similar levels of frontal lobe activation. (b) Mean ratings of scientific reasoning for the articles as a function of experimental condition (control, bar graph, and brain image). Error bars represent standard errors of the mean.

not simply due to visual complexity. The third experiment was conducted in order to generalize the findings beyond the conditions used in the first two experiments. Experiment 3 used a real news service article taken from the BBC website, entitled, *Brain Scans Can Detect Criminals*, that summarized cognitive neuroscience data from a study published in the journal *Nature*. This article was used to extend the previous findings to material that would actually be encountered in the real world. Moreover, there were no errors in scientific reasoning in the article, allowing an examination of whether the effect would generalize beyond conditions in which there were these sorts of errors. Additionally, the critical statement regarding the credibility of the findings was changed to: *Do you agree or disagree with the conclusion that brain imaging can be used as a lie detector?*.

4.1. Methods

4.1.1. Participants

One-hundred eight undergraduates from Colorado State University and University of California, Los Angeles participated for course credit.

4.1.2. Materials and procedure

The materials and procedures were the same as in the first experiment except where noted. The article used was from the BBC website, and was followed by two statements that participants rated: (1) *Do you agree or disagree that the title,* Brain Scans Can Detect Criminals*, is a good summary of the results*? and (2) *Do you agree or disagree with the conclusion that brain imaging can be used as a lie detector*? For half the participants the last paragraph of the article included text of a researcher criticizing the conclusion that brain imaging could be used as a lie detector to detect criminal activity in the real world, but for the other half this text was omitted (this variable was crossed with whether there was a brain image accompanying the article of not).

4.2. Results and discussion

A 2 (brain image: present, absent) × 2 (criticism: present, absent) between-subjects ANOVA for the question regarding whether subjects agreed with the conclusion reached in the article revealed a main effect of brain image, such that the ratings of agreement were higher when the brain image was present, as compared to when it was absent, $F(1, 104) = 4.60$, $MSE = 1.90$ (see Fig. 3). However, the effect of criticism was not significant, $F(1, 104) = 1.63$, $MSE = 0.67$, and there was no interaction ($F < 1$). Repeating the ANOVA for the rating of the question regarding the appropriateness of the title revealed no effect of the brain image ($F < 1$; see Fig. 3), a main effect of criticism, $F(1, 104) = 7.21$, $MSE = 3.05$, and no interaction ($F < 1$). Thus, subjects' rated the title, *Brain Scans Can Detect Criminals*, as more appropriate when the article was not criticized ($M = 2.41$, $SEM = .10$) compared to when it was criticized ($M = 2.07$, $SEM = .08$), but the presence or absence of a brain image had no effect. The effect of criticism on the title question was not surprising because the text criticizing the research involved experts arguing that the results of the study could not be generalized beyond the lab to situations involving real criminal activity, a criticism directly refuting the claim made in the title of the article.

5. General discussion

The use of brain images to represent the level of brain activity associated with cognitive processes influenced ratings of the scientific merit of the reported research, compared to identical articles including no image, a bar graph, or a topographical map. This effect occurred for fictional articles that included errors in the scientific reasoning in the articles, and in a real article in which there were no such errors. The present results lend support to the oft mentioned notion that there is something particularly persuasive about brain images with respect to conferring credibility to cognitive neuroscience data.

Brain images may be more persuasive than other representations of brain activity because they provide a tangible physical explanation for cognitive processes that is easily interpreted as such. This physical evidence may appeal to people's intuitive

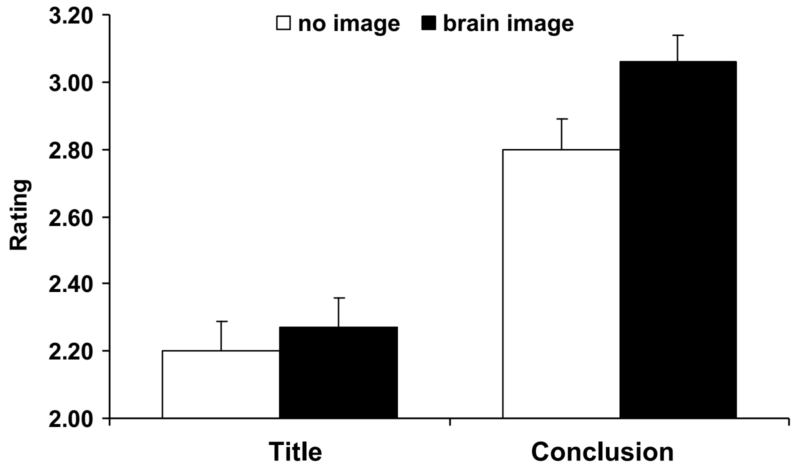

Fig. 3. Mean ratings regarding the appropriateness of the title, and whether participants agreed with the conclusions reached in the article, when it was accompanied by a brain image and when it was not. Error bars represent standard errors of the mean.

reductionist approach to understanding the mind as an extension of the brain (Weisberg et al., in press). This sort of visual evidence of physical systems at work, which is typical of "harder" sciences like physics and chemistry, is not typically apparent in studies of cognition, where the evidence for cognitive processes is indirect, by nature. Indeed, it is important to note that while brain images give the appearance of direct measurement of the physical substrate of cognitive processes, techniques like fMRI measure changes in relative oxygenation of blood in regions of the brain, which is also indirect. Of course, it is unlikely that this subtlety is appreciated by lay readers.

The present data provide support for the notion that there is, indeed, something special about the brain images with respect to influencing judgments of scientific credibility. Indeed, the data conveyed by the brain images in the current study were superfluous, providing information that was redundant with the text. In this respect the present data are unlike previous reports showing that more ostensibly relevant factors, such as the institutional affiliation of the scientists, can influence judgments of scientific credibility (Peters, & Ceci, 1982). Moreover, the information depicted in the brain image, the topographical map, and/or the bar graphs, were "informationally equivalent", such that the same information could be inferred from all sources of information (Simon, 1978). Thus, the present results lend support to the notion that part of the scientific credibility of brain imaging as a research technique lies in the images themselves.

The experiments we report here bear some resemblance to recent research showing that simply mentioning cognitive neuroscience data has an influence on peoples' judgments of the quality of scientific reasoning (Weisberg et al., in press). However, Weisberg et al. found that including cognitive neuroscience data with explanations of cognitive phenomena had a more specific effect, by causing introductory psychology students to increase their ratings of satisfaction for poor scientific explanations, but not good ones. Although we cannot directly compare the present data to the Weisberg et al. findings, the effect of brain images in the current study appears to be a general one, whereby readers infer more scientific value for articles including brain images than those that do not, regardless of whether the article included reasoning errors or not. Although speculative, this difference between our results and those of Weisberg et al. may be the result of different mechanisms being affected in the two studies. The simple addition of cognitive neuroscience explanations may affect people's conscious deliberation about the quality of scientific explanations, whereas the brain images may influence a less consciously controlled aspect of ratings in the current experiments.

The recent finding that simply mentioning cognitive neuroscience data influences judgments of scientific reasoning (Weisberg et al., in press) may partly explain why the effect of brain images in the current study was not large. The effect sizes in Experiments 1, 2, and 3 were .26, .20, and .40, respectively (these effects are in the small-medium range based on Cohen's (1988) criteria). As suggested by Weisberg et al., pre-experimental exposure to brain images in the popular press, which provides a physical explanation for cognitive phenomena, likely influences the allure of cognitive neuroscience data. This pre-exposure to brain images in the real world likely had an effect on ratings in the both the baseline and experimental conditions of the present experiments, and may therefore have precluded the possibility of finding larger effects of brain images in our experiments.

The finding that brain images influenced the perceived credibility of cognitive neuroscience research also has ethical implications. Some have argued that cognitive neuroscientists should become more involved in the dissemination of their data, in an effort to enhance the understanding of techniques such as fMRI (Beaulieu, 2002; Illes, DeVries, Cho, & Schraedley-Desmond, 2006). Indeed, many cognitive neuroscientists have expressed frustration at what they see as the oversimplification of their data, and have suggested that efforts be made to influence media coverage of brain imaging research to include discussion of the limitations of fMRI, in order to reduce the misrepresentation of these data.

Although there may potentially be some negative consequences of brain images in terms of artificially inflating the credibility of cognitive neuroscience research, there are also benefits to the persuasive power of brain images. In particular, including brain images with data is likely to have the effect of lending greater credibility to, and accessibility of, cognitive neuroscience research, and likely, for cognitive research more generally. Since public perception of science can play an important role in funding decisions and the direction of scientific discovery, the public's fascination with brain imaging may have a positive impact on public perception of research on cognition.

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