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Neurons in sparkling space: scientific objectivity and 'blurry' images in neuroscience

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Abstract

This article employs quantitative and qualitative approaches to examine images of neurobiology published in a science news database, sampled across a two-year interval. Upon comparing the images to article headlines, the author argues that identifiable digital effects — such as blobs of bright colour, sparks of light, superimposed lines — correlate with articles reporting on new observations of neuronal action. A qualitative semiotic analysis of characteristic examples forwards the idea of a "blurry image", denoting how audiences must cognitively blur the line between objectivity and subjectivity, between the "real" and the enhanced performative action evident in digital images tingling with vibrant life. The conclusion suggests that digital image making can increase aesthetic pleasability even as it serves as a partner in the cognitive task and, accordingly, the argumentation of the neuroscientist. Future research can investigate whether or not digital overlays and image features identified as obvious and attractive impact assessments of scientific research or alter evaluations of objectivity.

Keywords Representations of science and technology; Science and technology, art and literature; Visual communication

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Examining the epistemic apparatus around scientific images is now a well-established exercise. Lynch [1985], as one early scholar of the area, argues that visuals take shape from "a larger and more inclusive set of operations involving complex instruments, simple hand tools, manual tasks, specimens and their residues" [p. 38]. Galison [1997] likewise shows that a scientific image does not "speak for itself"; he details the so-called "Golden event, or the single picture of such clarity and distinctness that it commands acceptance", and in so doing, he stresses inter-group negotiation about the creation of images [p. 22]. Mersch [2008] adds the idea of "epistemic parameters" for acceptable images in science, which exist "relative to instruments and experimental arrangements" [p. 193]. Latour [2014] says something similar, arguing that scientific images are dependent upon "a number of transformations along a chain" [p. 3]. Image making in science is so totally engulfed with disciplinary work, Latour tells us, that it reveals what it means to be "scientific" [p. 2–3]. Overall, this kind of work critiques the positivist worldview, exposes sociocultural influences on scientific productions, and seeks to overturn the notion that images can be "certified free of human interference" [Daston and Galison, 1992, p. 81].

One task required to document the epistemic apparatus of scientific images is to identify how exactly they retain an aura of objectivity despite the constant "interference" of humans and nonhumans. One proposal is that scientists discard or overlook any aesthetic pleasurability to give their images the raw, untouched look and feel of objectivity. As Gross and Harman [2013] note, "whether a visual is good, bad, or ugly from a purely artistic perspective is a matter of no particular consequence from a purely scientific perspective" [p. 10]. Indeed, Henri Poincaré [1914/2009] argues that ugly images can appear more convincing when they reflect a "disinterested pursuit of truth" [p. 24]. The observation stands in some tension with a lingering belief among surveyed scientists who say that form and function will naturally lead to visual "simplicity and elegance" in material structures [Agapakis, 2012, para 2]. Indeed, at present, the extent to which beauty and pleasability is shunned as an exercise in upholding scientific objectivity falls into question, especially amid the adoption of digital tools allowing for various means of visual enhancement.

Reviewing the recent overlap between art and science in digitally enhanced images, Yu [2017] suggests that scientists still do seek objectivity, but when scientists "turn to artists for innovative and critical new perspectives, what is artistic and what is scientific have started to blend" [p. 90]. As an example, Yu examines images of the Ebola virus, which beam yellow and blue and look like heavenly meteorites covered in glowing fibers, projecting a "mysterious splendour" [p. 93]. As she notes, these images, and others like them, display what Philipsen and Schmidt Kjærgaard [2018] have called "an ideal of prettiness and clarity in the production of scientific visuals" but without any explicit recognition of their "aesthetic features" [p. xiii]. Presumably, the lack of reference to aesthetics underscores the underlying intention to offer colorful, striking images for public communication while striving to adhere to values of scientific objectivity.

The social sciences scholarship seems to take scientists at their word. That is, although many scientists uphold that their images are made for investigation purposes and not geared to be pleasing, per se, particularly attractive digital images released by scientists are still not typically understood as having an epistemological function. The images are more often said to be the result of market forces in the media [Nelkin, 1995; Wassman, 2015; Hornmoen, 2010], of the communicative needs for "selling science" [Veldhus, 2018, p. 79], of the acclaim for mesmerizing images in new contests held by scientific institutions [Madhusoodanan, 2016], or they are born of a need to boil down complexity for an untrained eye [Rafner and Schmidt Kjærgaard, 2018]. The enhanced digital scientific image with strong contrasts and bright colors is situated as an audience-specific product to catch attention, not as an integral part of an argument serving to instantiate a new scientific perspective.

Yet, scholars in Science Communication and Science and Technology Studies should note the possibility, first, that some epistemic functions may lead to or encourage aesthetic pleasability and, second, that some scientists do shift evaluations of appropriate visual parameters when making certain kinds of images with digital tools, whether those images end up circulating in the media or not. How a visually stunning digital image functions in relation to the scientific argument in a particular context has been largely set aside, I am suggesting, amid a scholarly preference to relegate beautiful creations to Capitalist needs or pop-sci impulses. Yet, digital editing enables scientists to enhance particular features or to foreground any number of parameters with software programs, making more apparent their own observations, visualizing strategic image aspects, as they wish. If desired, scientists can choose flashy, brilliant, and beautiful images over ugly, dull, or visually complex ones, and scientists may well find alternative modes and functions for alluring images.

Of course, choosing noticeably vivid or stylistic images pushes up against a long history of scientific professionalization where epistemic relevance was assured by a lack of ornamentation [see: Poincaré, 1914/2009]. Daston and Galison [2007] argue that scientific images need to be produced according to a rigorous criterion and follow a "mechanical record" in order to align with the values of objectivity informing the sciences [p. 31]. Mersch [2008] likewise argues that the image "is meant to record and repeat the real as authentically as possible" [p. 183]. Yet, the adoption of digital capabilities and perhaps a growing preference for alluring images [Weingart and Huppauf, 2012, p. 21] lends a new precariousness to scientific objectivity for images, traditionally conceived as deastheticized. Clear lines of separation between a "dispositif" of measurement and creative imagination are increasingly difficult to locate. As Mersch notes, "we are dealing with a fundamental inability to differentiate between denotation and construction" [p. 194]. For Mersch, this "inability" is a serious epistemic problem for scientists trying to uphold objectivity while playing around with bright, colorful digital enhancement that might undercut the idea of the givenness of "Nature". However, as I show through a broad sample of brain images and then a close reading of two cases, an unvarnished or rote presentation of "Nature" is not always fitting to the available (digital) means of making an argument.

Looking across 32 brain images produced by neuroscience laboratories and appearing in a broader sample of 108 popular neuroscience news articles having various kinds of images, I suggest that neuroscientists sometimes strategically blur lines between "denotation and construction" [Mersch, 2008, p. 194] for epistemic purposes, namely, to build arguments where colleagues need to see something new in the image. Brain images containing obvious digital overlays and creative enhancements litter the data set, suggesting that the epistemic status of images may be less about what is raw and "right there" and more about seeing the image the way the scientist sees it. In the images sampled, the enhancement often foregrounds the dance of the biological structure, its movement or activity; the *implied action* in the image serves the epistemic function. I argue that digital manipulation highlights, often in bright sparks and colors, what the neuroscientist wants to show about what brain structures can seemingly *do*.

In the era of digital manipulation and an ever-growing mistrust of media institutions [see: Silverman and Singer-Vine, 2016; Allcott and Gentzkow, 2017], a specific kind of communicative function for neuroscientific images may be arising amid some disregard for the deaestheticized image that retains the distanced, mechanical aura of scientific objectivity. Suggesting that perhaps the cultural landscape influences neuroscientists' orientation to images is merely sociological conjecture at this point; nevertheless, building an image that can illuminate an interpretation of brain functionality likely would not in any way harm a neuroscientist seeking to engage a skeptical public through the media. But more to the point: digitally enhanced images of brains from this sample, I argue, support interpretations of neuronal action that may otherwise not be self-evident in an image of the biological structure or not easy to see or understand *as movement*. To this end, I examine only lab-created images, excluding all images not credited to the lab itself, underscoring the idea that aesthetics holds an important place amid representations of neuronal functionality. This insight leads to the conclusion that digitality offers the opportunity for a slight shift in what scientific objectivity can mean today, at least in contexts where beautiful images might aid and not oppose epistemic functions.

Accumulation of digital effects in some scientific contexts blurs old notions of traditional objectivity tied to deaestheticization. Signaling this insight, I offer the term "blurry images", which denotes how audiences must cognitively blur the line between objectivity and subjectivity, between the "real" and the imagined or theatrical action, in some digitally enhanced brain images. As will be evident in the characteristic examples, images acquire what social semioticians would describe as attractions or aesthetic qualities, including color wheel compliments, balanced lines, and indicative framing, all of which are used to display neuronal life. Of course, this study does not seek to resolve the intention of the scientist but, rather, to focus on the ways that neurobiological images light up the page and ask how this then bears on notions of objectivity in scientific images.

In what follows, I first review the literature on functions of scientific images and neuroscience images in particular. I then detail the methodology for the selection of images and report the results. I argue that so-called "blurry images" are identifiable and are being produced primarily within laboratories, as they have certain topical positionings in common — almost all in the sample are featured below headlines about newly discovered forms of neural activity. This leads to the qualitative analysis of two characteristic examples where I show that coloring, overlays, and contrasts come together to display neural action in support of the scientist's evidential requirements. I conclude that digital tools have released neuroscientists from the strict confines of mechanical deaetheticization, at least in cases where the image requires sharpening or staging to better illuminate motion. Ultimately, I suggest that digital image making has become a partner in both the cognitive task and communicative enterprise of the neuroscientist. Accordingly, it is no longer sufficient to claim that pretty images are only for the public; standards of objectivity shift with technologies, disciplinary regimes, and epistemic requirements.

Review of functions for scientific images

Examination of the "mechanical objectivity" of scientific images [Daston and Galison, 1992, p. 82] has spurred increasingly nuanced investigations of image functions. Despite little suggestion that beautiful images made by scientists intend to function evidentially, scholars now agree that there is not a singular representational function for all scientific images. Downes [2012], for instance, argues that "scientific images function in a number of ways, doing different kinds of epistemic work and, sometimes, none at all" [p. 117]. The function or role of a scientific image may align with their contexts of use [p. 117]. Data displays such as graphs might prove evidential to a conclusion [Perini, 2005]; other images can show the object of analysis [Biagioli, 2006]; others serve to present an especially controversial depiction of scientific objects for political reasons [Sommer, 2006]; some might serve educational functions or be incorporated into broader process descriptions [Alcíbar, 2017; Van Eijck and Roth, 2008]; or, a scientific image, such as a macro-depiction of migration routes, might serve as a tool of enculturation in educational settings [Van Dijck, 2006].

Mößner [2018] argues that the particular function likely relates to the "modes and aims of communication on the content transmitted" and that scientists "attempt to adapt the idea to an assumed level of the audience's background knowledge" and situated context, revealing which aspects scientists and image designers think essential or relevant [p. 326–327]. Mößner's conclusions resonate with the ideas forwarded in this article. However, what stands out when looking at the enclosed sample of laboratory produced images from neuroscience news is the way that the aesthetic choices are wielded specifically to overturn old perspectives on neuronal action. That is, Mößner's findings are useful and appropriate for stressing situated context, but patterns of adapting images are likely to proceed from background knowledge of the field's general stance on the topic and the evidential needs for new arguments to go forward in those communities. Consequently, reviewing sets of images made inside of neuroscience laboratories in relation to the popular article topics and the type of publication begins to chart such patterns, showing how scientists — or cognitive neuroscientists in this case — use digital enhancement in their own knowledge domains of argumentation.

It is important to note that neuroscience images, in particular, often receive scrutiny for their seductive capacities. Much research from Science and Technology Studies, Rhetoric, and Sociology has been geared toward understanding how and to what extent brain scan images do have "seductive power" [Weisberg, Keil et al., 2007], if at all. McCabe and Castel [2008] argue that popular news articles with images of functional magnetic resonance (fMRI) brain scans prove highly persuasive even when placed over top of illogical interjections of neuroscience information [p. 343]. Rhodes, Rodriguez and Shah [2014] similarly suggest that neuroscience information "may provide an illusion of explanatory depth" [p. 1432]. The finding is reconfirmed by Weisberg, Taylor and Hopkins [2015]. However, other studies argue that brain images show little or no special persuasive influence when compared to other images used over the same neuroscience articles [Gruber and Dickerson, 2012] or that any "seductive allure" of brain scan images has little basis in data from audience responses [Farah and Hook, 2013]. There is, then, a divergence in the social science literature between the effect of neuroscience images and exposure to written information about neuroscience. That noted, Im, Varma and Varma [2017] stress the persuasive capacity of combinations. They argue that brain scan images once set over top of texts situated as educational do have a measurable effect on participants' ratings of a text's credibility [p. 518–520]. Neuroscience images, in brief, may not, in and of themselves, be necessarily "seductive" or wholly evidential, but when combined with other framings, they might then be understood as evidential, influential, and/or explanatory. Such research is important because it exposes how brain images, once thought to be automatically alluring independent of any context, were also being simultaneously considered in the social sciences as mostly there to enhance the popular profile of neuroscience. That is, if brain images were automatically alluring, then they were not seen as offering real or genuine evidence to interested and critical audiences but just aesthetic seductions for deficit model audiences [see: Veldhus, 2018].

Yet Gibbons [2007] notes that brain images “are salient points of reference regarding popular understandings of scientific arguments” even if they “are translated minimally, if at all” by media writers [p. 176]. Here, Gibbons suggests that the same brain scan image can appear in a scientific journal article and be discussed as one piece of evidence contributing to a broader theory while re-appearing in a popular media article without much direct discussion, despite being situated as totally sufficient to explain the phenomena [p. 176–178]. Considering the other research [Rhodes, Rodriguez and Shah, 2014; Gruber and Dickerson, 2012; Farah and Hook, 2013], it may well be the case that audiences implicitly connect neuroscience images to multiple points of information, tending toward conclusions through a complex arithmetic of textual content, publication type, and the quality and content of the images.

If Gruber and Dickerson [2012] are correct in showing that many kinds of images, including wild science fiction images, can shift ratings of scientific reasoning and credibility at roughly the same rates as fMRI images, then probably what needs further investigation is not the exact persuasive capacity for the different types of images in the media; what needs investigation is how an image performs a function in a context. This article initiates that line of inquiry, setting out to articulate how the aesthetics of brain images might be shaped at the intersection of content-argument-audience and, in some cases, push toward new conceptions of scientific objectivity. Indeed, neuroscientists may need to step beyond the photographic demeaner. Put another way, when Roskies [2007] argues that neuroscience imagery “diverges from photography” in its process even though audiences still tend to view brain images within the photographic analogy [p. 860–861], she does not consider how the glimmering aesthetic allure of brain images might seriously complicate the impulse to see them as rote photographs. Crucially, images with digital flourishes and pleasabilities — essentially performative images — act on us and can change the way we see the brain.

Methods

Data collection

This study is based upon a Science Daily database search. The site was chosen specifically because of its popularity as a science news aggregate site. As a top site for scientific news from around the world,[1] the “Search Archives” tool proves a valuable place to collect neuroscientific image data. Likewise, as an aggregate site, it offers an analysis of “slightly edited press releases”, i.e. popular news delivered mostly from the scientists’ own perspectives [ScienceDaily, n.d.]. Looking across these texts, then, offers an analysis of images approved by scientists and often made in-house in the scientist’s labs, as documented. As a result, choosing ScienceDaily gives a clear picture of how scientists — as opposed to news editors — make known their referents and compose an argument from an image.[2]

[1]Science Daily advertises this designation and often appears as the first or second result for science news when using Google from North America. See: https://www.sciencedaily.com/about.htm.

[2]Note: whether a news editor chose only one image from among many given by a science laboratory cannot be known; what is known is that the images in this study were credited to the laboratory being discussed in the published news article.

Text selection followed a criterion-based sampling method [Merriam, 1998] adhering to three criteria: 1) results must be recent — post January, 2015 — in order to locate current brain images, 2) results must have derived from a science news publisher such as a mass media outlet or university science news publisher, and 3) results must include an image at the top of the page or one embedded above the first paragraph of the news article.[3] This final criterion allows for better comparisons, since one article having an image ten paragraphs down the page might not be fairly compared to another one with an image framing the text at the top, with respect to rhetorical function.

The search proceeded in two stages. The first stage relied upon the search term "neuroscience" and was organized by relevance. The second was similarly organized by relevance and used the search term "brain". To keep the study focused and manageable, the researcher applied a date range (January 2015–December 2017), only collecting articles in that range from the first five pages, equating to an initial 148 articles per 200 in the search.[4] Reviewing those, the first search term yielded 44 articles with images at the top, and the second search yielded 64, a total of 108 meeting the criteria. Articles without images or without images at the top of the archived article were thrown out.[5]

Coding procedure

In turning to an inductive coding method employed by Geisler [2003] as well as Smagorinski [2008], the researcher sought to identify thematic overlap "from commonalities in what emerges from the data rather than a priori categories" [Smagorinski, 2008, p. 400]. This approach informed four separate coding passes with the researcher iteratively moving back and forth between data and coding categories. In the process, an exclusive coding method was developed wherein the image could only receive one code per pass. In the first pass, all images were coded for elements of content, i.e. what they depicted in the foreground of the image. Second, all brain images were coded for attribution, i.e. tag-lines below the images noting their makers, copyrights, or where they originated. Third, all images of neurobiology, excluding artistic sketches, were coded as having digital enhancement or not in a first effort to identify a "seamless" or "rote" image of the body from one with what could be considered visually layered with digital enhancement, at least in a naive way. The final pass coded all headlines associated with all news articles, categorizing the communicative acts; that is, the researcher noted what the headline text aimed *to achieve* in terms of proposing new practices, new theories, or new therapies, etc.

For the first coding pass, six codes were developed, according to the iterative method [Geisler, 2003; Smagorinski, 2008]. The codes delineated image content as follows:

1. images showing scientist/s or researchers;

[3] ScienceDaily is an aggregator; it archives articles through a "materials" link on the same page where it displays the text. If ScienceDaily is not featuring the article at that moment, then the link is needed to see the original article with images.

[4] Search conducted in April, 2018.

[5] Note that the archives can be browsed by date using the following Google search entry: "site:Sciencedaily.com 'keyword here' before:YYYY-MM-DD after:YYYY-MM-DD".

2. images showing the brain or neurobiological tissue;
3. images showing artistic or stylistic drawings of heads or brains (as opposed to images from scans);
4. images showing instruments used in the laboratory, such as brain scanners;
5. images showing everyday people doing activities in everyday non-scientific life settings, such as walking in a park or reading a book; and
6. images showing animals exclusively, usually a laboratory test animal.[6]

The second coding pass looked exclusively at the images of brains. Accordingly, this coding pass noted the credit-line attributions and was applied only to those images falling under code 2 and 3 from the first pass, i.e. only to neurobiological images and to the drawings of the brain or head, a total of 48. Here, four sub-codes were developed. The first identified the images stemming from the specific lab being discussed in the news article or from the scientist featured in the article. The second code identified images coming from stock image websites, such as Adobe or Fotolia. The third code noted the images having no identifiable attribution. The final code indicated attributions to other outside sources, such as other media sites.

A third coding pass sought to identify whether images having code 2 (neurobiological) from the first coding pass were published with or without digital enhancement. This is not to suggest that the images produced by fMRI machines or other technological devices do not emerge absent digital manipulation. As is well documented, fMRI machines, as one example, necessarily involve digital media and produce images through software programs that translate the movement of oxygenated blood through the brain (BOLD) into colorful pictures [see: Stokes, 2015]. Thus, this code rather asked the coder whether or not the image showed features that were *immediately identifiable to them* as digital overlays or artistic flourishes. The code definition was further defined during the process of second coder reliability, as discussed in the next section below.

The fourth coding pass examined the headlines and lead-lines of the articles identified in the third pass. Looking first at the twenty-seven articles published with neurobiological images and also coded as "digitally enhanced", a vast variety of seemingly random neuroscience topics were noted. Consequently, instead of coding the exact topic per se, such as "Alzheimer's" or "addiction", coding for the communicative act proved more useful. To this end, four codes were developed in a non-exclusive coding scheme. The first was object-oriented, marking whether an article discussed a new brain network, system, or object. The second code noted when an article outlined a new method or technique for researchers. The third code indicated whether the article foregrounded new functionality or newly observed processes happening in the brain. The fourth code noted when an article highlighted a new therapy useful to everyday practitioners. The final code accounted for "other", namely two remaining articles, one offering a meta-level discussion and the other a historical revelation. As discussed below, all articles in the sample were eventually coded with these same codes; the goal in applying these codes comprehensively was to understand if, and to what extent,

[6]In cases where elements overlapped (for example: a scientist standing in a lab with a scanner in the background), the element in focus and in the foreground was prioritized and coded.

neurobiological images from neuroscience laboratories differed at all from other images in the sample with respect to what their corresponding news headlines and lead-lines were communicating.

Second coder reliability

Although most of the codes were reasonably straightforward, the possibility for ambiguity remained in the third coding pass in particular. Detecting whether an image contained "obvious digital enhancement" or not could be influenced by pre-existing knowledge of neuroscience methods, of fMRI machines, and of the kinds of images and software programs used in neuroscience laboratories. Likewise, it might also be difficult to tell whether an inherently digital image had any so-called "digital enhancement". Indeed, even professional editors can have a tough time distinguishing between digital photographs and photo-realistic images generated by computers [Lehmuskallio, Häkkinen and Seppänen, 2019]. Thus, asking a coder to differentiate heightened digitality from "plain" brain images is likely to prove difficult given a vast intermeshing of digital visual highlights, compressions, and over-laid elements. As Ahmed, Ahmed and Arshad [2011] note, neuroscientists and radiographers commonly use "image enhancement techniques" such as removing noise, applying filters, and sharpening images in an effort to create better, more defined results [p. 38–41]. Consequently, the code category was refined, and a second coder with no knowledge of fMRI machines or neuroscience was chosen for this role. Second coder reliability was then calculated.

The digital enhancement code was ultimately defined as follows: "Code an image if it contains color, shape, or light not 'natural' to the human body and/or intending to highlight some specific feature using a digital overlay or color or shape apparent or laid over top of the image from your point of view. Do not add a code if the image appears to you to be merely a straightforward scan or picture of the body without any clear and obvious digital addition". In line with Geisler's [2003] recommendations, a second coder reviewed an image sample [p. 70–71]; in this case, the second coder reviewed all of the neurobiological images, i.e. all images holding the second code from the first coding pass. Agreement across 32 total images was 90% ($N = 29/32$) and considered reasonably beyond chance.

Second coder reliability was also conducted on all 27 article headlines associated with the digitally enhanced brain images, which composes 25% of the total data set. The second coder employed the five code categories detailed in the fourth coding pass. Calculated using Cohen's Kappa, no level of agreement for an individual code category fell below .82. As a result, the study moved forward.

Results

In the first coding pass, images featuring neurobiology, not including drawings of brains, proved most frequent, outnumbering all other kinds of images. See Table 1 below.

The second coding pass reviewed brain images and brain/head drawings, as both depict bodily materiality. These images are overwhelmingly attributed to neuroscience laboratories, meaning that they, presumably, were circulated to the

Table 1. First coding pass results — image content codes.

Neurobiological images	*Everyday people / everyday situations*	*Drawings of brains*	*Experimental objects / technical apparatus*	*Researcher / scientist*	*Animals*	*Other symbolic image*
32	19	16	14	13	8	6

Table 2. Credit-line attributions of neurobiological images + brain drawings.

Image credited to laboratory or scientist discussed in article	*Image credited to stock image website*	*No credit line attribution*	*Image credited to other publication*
36	9	2	1

Table 3. Fourth coding pass results — communicative acts of article texts.

New network / brain object seen	*New neuroscience method / new technique developed*	*New brain processes or new functionality seen*	*New therapy recommended*	*Other / random*
3	5	16	1	2

news outlet by the scientist/s involved. Table 2 provides an overview of the four codes applied across 48 images of brains.

Looking exclusively at the 32 neurobiological images, 28 (87.5%) were attributed to neuroscience laboratories or to the neuroscientists being discussed in the article. Of the 16 total drawings of brains or heads, eight (50%) were similarly attributed to laboratories. Most of the remaining drawings derived from stock images websites ($N = 6/37\%$).

The 32 neurobiological images were again analyzed in the third coding pass. In total, 27 (84%) were coded as having perceived digital enhancement. Of those, all were attributed to neuroscience laboratories. Those 27 images remain the primary focus of this article, which seeks to understand what function or strategic role neurobiological images with noticeable visual digital effects — *and ones specifically attributed to neuroscience laboratories* — might serve in neuroscience news contexts.

Five subsequent codes for news headlines and lead-lines associated with the aforementioned 27 (supposed) digitally enhanced images were then developed. Each code at this stage aimed to represent a precise communicative act, i.e. what those articles argued for or promoted. Results for the 27 laboratory-produced neurobiological images are available here in Table 3.

The relatively high number of articles coded as foregrounding newly discovered brain functionality ($N = 16/59\%$) spurred further investigation. In fact, looking across the 16 articles, a focus on action is often evident. Examples are available in Table 4 where action words have been italicized for emphasis.

Table 4. Example headlines with process code (italics in not original).

Characteristic examples of 'Science Daily' headlines with process code
1. Pregnancy *leads to changes* in the mother's brain ScienceDaily, December 19, 2016
2. Brain is ten times *more active* than previously measured ScienceDaily, March 9, 2017
3. This is your brain on God: spiritual experiences *activate* brain reward circuits ScienceDaily, November 11, 2016
4. Menopause *triggers* metabolic *changes* in brain that may promote Alzheimer's ScienceDaily, October 10, 2017
5. HIIT *releases* endorphins in the brain ScienceDaily, August 17, 2017

As the discussion of characteristic examples in the following section explores, these headlines correlate with neurobiological images whose aesthetic features indicate obvious layers of digital enhancement, i.e. the brain images presumably show action, movement, or process. Although different kinds of images — such as images of scientists or animals — may also contain some action-oriented headlines, the data does not support the idea that they necessarily do so in the same frequency compared to digitally enhanced brain scan images.

Returning to the data to code all of the article headlines allowed for a broader sense of what kinds of images actually appear within different headline types. Comparing image types — i.e. what they depict — to news headlines, neurobiological images are by far most frequently occurring when the headlines foreground neurological actions/processes.

As is evident in Figure 1, some process-oriented headlines are used next to images featuring the technical apparatus ($N = 6/14$, 42.8%) but not in the same frequency as neurobiological images ($N = 23/32$, 71.8%). Likewise, other types of images, such as those showing lab animals, are unlikely to be accompanied by headlines about new brain functions or processes ($N = 2/8$, 25%). This data does not mean that these articles do not at points discuss neural functionality in the text itself but rather that their headlines and lead-lines do not foreground this aspect or highlight brain activity. In brief, neurobiological images, by comparison, accompany in high relative percentages news headlines about brain actions or functions.

Qualitative analysis of characteristic examples

A qualitative analysis aids in understanding how the images and texts collected in this study relate. In fact, explaining why neurobiological images made by laboratories appear more often when an article introduces a new discovery about neural action might seem immediately uncomplicated, at first glance — a simple issue of matching the functional imagery possible through an fMRI scan to the journalist's narrative in the headline about new discoveries of brain function. However, the diversity of styles in the data set and the range of possible neurobiological imagery now available to neuroscientists and to news outlets makes this very simple one-to-one interpretation (matching an fMRI to a headline

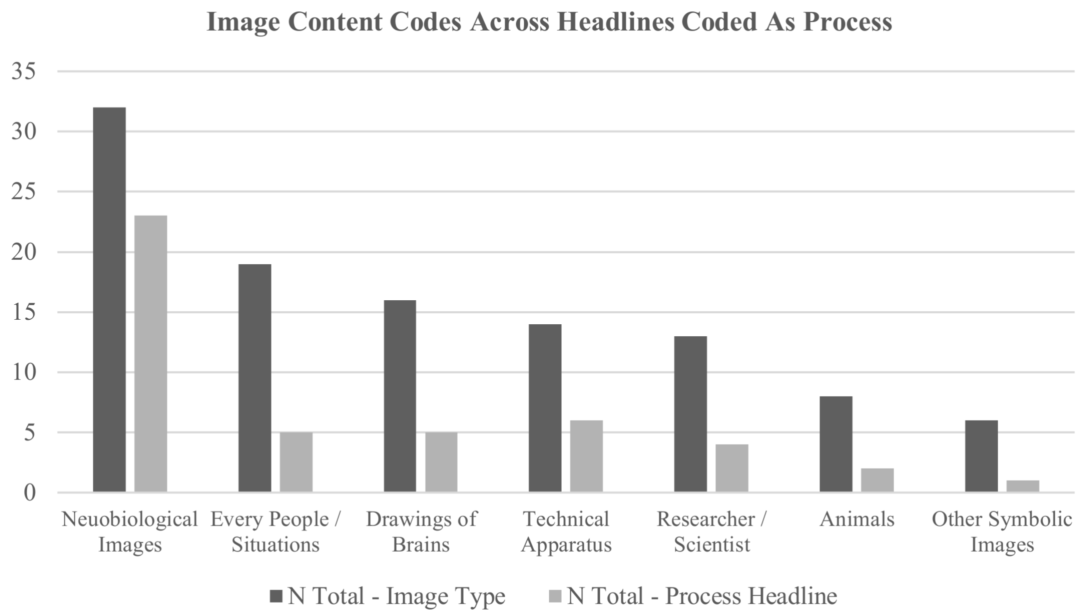

Figure 1. Image content codes × news headlines discussing brain processes.

stressing function) highly tentative. For one, not every neurobiological image featured in the news is made with an fMRI. Although an important method, microscopic images with digital overlays and MRI images are also circulated widely and seen across the sample. Thus, thinking about the shapes, colors, and inter-relations of the particular elements pictured inside of the images — as opposed to which machine constructed the image or what part of the brain an image shows — offers an investigation led by visual semiotics [Kress and Van Leeuwen, 2006]. This approach moves beyond a simple view of this study's findings as reflecting the activity-based nature of a functional brain image.

The two characteristic examples, indeed, look radically different. They are constructed with a different technical apparatus and made through different processes. What they have in common, however, is an aesthetic thematic, i.e. a representation of light-as-life or heat-as-life, a strength of contrast, and a structural symmetry, better articulated as pleasability. Set against black backgrounds, they both crackle with — is it life, energy, or oxygen? The audience is left to wonder if a flash or bubble is "really" there in the flesh or if the image illustrates an implicit force, like magnetism, which has been imposed overtop of the image. As viewers, I hope to show, we cannot always be sure. The images are "blurry" even if they are "clear".

Both examples discussed below originate from the particular neuroscience lab being discussed in the article; both images were featured immediately below a headline stressing the activity of neurons. To create a systematic discussion for the qualitative close reading, I have drawn specifically and only from three "image elements" developed from social semiotic analyses of images, including 1) framing, 2) inter-relationality of lines, and 3) lighting [Kress, 2003; Kress and Van Leeuwen, 2006; Wilson and Landon-Hayes, 2016]. This keeps the analysis concise. I then offer reflections, proposing that digital image manipulation is valuable for scientists and media institutions precisely because it serves both interests well: blurry images attract audiences with vibrant displays but also foreground areas of concern, allowing neuroscientists to emphasize the neuronal processes central to the argument for the proposed discovery.

Characteristic example 1

The image in Figure 2 looks to be from outer space. A glowing green network, an alien thing, alive and spreading out to shock passerbyers, like a deadly jelly living deep in the bottom of the cold Pacific. The image is featured below the following headline: "Brain is ten times more active than previously measured".

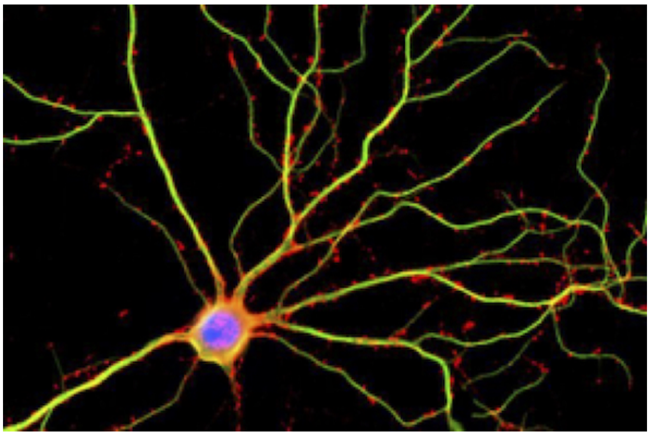

Figure 2. Credit: Shelly Halpain / UC San Diego, with permission.

Analyzing an image like this and explaining its aesthetic appeal is a complicated matter but, as Kress and Van Leeuwen [2006] note, made more accessible through "inventories of major compositional structures which have become established conventions in the course of the history of visual semiotics" [p. 1]. Accordingly, Kress and Van Leeuwen offer a "grammar of visual design" that examines structural features common to Western art and utilizes 1) lines that divide the image into segments to create in/balance or implied action, 2) relations made apparent between the elements of the image through connections or gestures, coupled with 3) examination of how light is used to foreground or background features. Although other approaches are also suggested in Kress and Van Leeuwen's "grammar", these appear most fitting for an exploration of scientific images absent human figures.

Seeing the image, first, as a set of compositional lines is a process of uncovering conscious and unconscious cultural meanings, noting how the segments of a picture can relate to recurrent ideas about bodies and nature, i.e. up being "elevated" or "good" and down being "base" or "lowly", etc. The image, herein credited to Halapin, can be understood, in like manner, as constructing some aesthetic appeal because of its specific divisions; this is noted through the lines superimposed onto Figure 3.

As Kress and van Leeuwen note, image segments can tend toward interpretative gestures, with the top segment typically representing a "heavenly" or "ideal world", the bottom representing "the real" or "common" world, the left

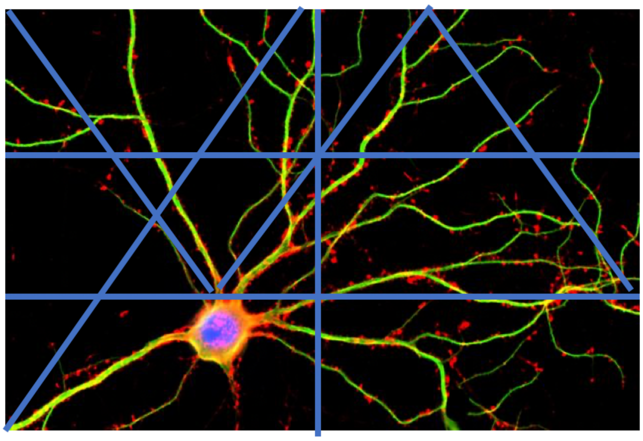

Figure 3. Halapain image with superimposed lines for aesthetic analysis.

representing "what is given", and the right "what is new" [p. 192–196]. Taking this framework, the image implies a neuron growing — dendrites reach toward new realms and may suggest an "ideal" — for the growth of the neuron, for the brain, or for scientific findings — in extending upward from the cell body. Likewise, the image also implies movement. The extension of dendrite arms from left to right and out toward the top of the frame offer a visual implication: the thing is alive with motion and activity; what the neuron does is novel or, perhaps, never-before-seen.

Relations between image elements — between the glowing pink orb of the cell body and the electric tentacles striking out into black space — recall the flow of power. Indeed, the image is not unlike ones documenting electricity. The image reminds of Tesla's crackling electrical ball caught in a vacuum. The red splotches add to the effect. Popping along the green lines, the splotches suggest sudden activity or heat, as in heat maps. In this way, the image is situated as significant in being visually hot. The neuron is firing. And it thereby seems to have its own agency.

The bright lights and colors of the image add to its life-likeness. For Kress and Van Leeuwen [2006], light intends to show "salient elements" [p. 47] and compose differentiation as well as "three-dimensionality" [p. 259]. The way that the dendrite arms stretch into the background, reaching into empty space, composes differentiation between the strong force of the neuron and the empty spaces of the brain — or is it the mind? No mental activity can occur without the spark of the dendrite. Everything about the image, in fact, screeches with vibrant life.

On some palpable level, it is hard *not to imagine* a function for the activity in the image. Whatever function is proposed in the text may be visually aided by semiotic associations present here. The black background, for instance, is reminiscent of empty outer space and suggests a semiotic related to space adventure, a visual frontier metaphor recurring in science [see: Ceccarelli, 2013] that helps perhaps to position the dendrite as actively entering the new. The pink and orange ball of light — featured like an alien planet or space vehicle — illuminates the darkness, bringing the light of human life, or of rationality, to the unconquered or unexplored lands of the brain. The image might, then, help to situate the scientist as a daring innovator or maybe a laboratory astronaut who discovers previously hidden worlds right inside the labyrinth of the brain. The association between space exploration and neuro-interrogation may seem far-fetched, but that a neuroscientist could capture this image at all likely weighs in on the credibility of the interpretation; indeed, this image seems to show a neuron doing something breathtakingly new and important.

Semiotically, the image, I am arguing, reinforces the headline proclaiming the brain to be "ten times more active than previously measured". Interestingly, the image features only one neuron and not the entire brain. Other brain images could very well demonstrate activity across a whole brain and, presumably, better evidence the claim. The neuron acts, however, as a synecdoche for the whole brain's activity. The scientist seems to be saying not only that the study finds its grounding in looking at the activity of some individual neurons, but that presumptions about inactive brain areas are the result of wrongly visualized dendrites, i.e. past studies missed important flickerings of life. The image is evidential. The article is, likewise, positioned as a critique of past neuroscience. The image heightens the message and the profile of the lab. As the article states, "the UCLA team discovered that dendrites are not just passive conduits. Their research showed that dendrites are electrically active in animals that are moving around freely, generating nearly 10 times more spikes than somas" [Gordan, 2017, para 4]. Put simply, the image is beautiful, performative, and demonstrative. It shows what scientists believe a neuron can do as well as how dendrites are more alive and exciting than anyone ever realized. The coloring and sharpening contributes something palpable to this work, as does the framing of the image, as does the way that the neuron sparks with a flash of light. If the "Natural" reality of pink, blue, green, and red neurons floating in a black space ever seem doubtful to the viewer as an image of the meaty "natural" brain, then the image is not entirely of realism but of the (digital) imagination — or do neurons really glow pink and green? To many viewers, it is going to be blurry.[7]

Characteristic example 2

The second image, seen in Figure 4, appeared next to the following headline: "This is your brain on God: spiritual experiences activate brain reward circuits". Like the previous image, we confront another pitch-black background, but this time, we see a medical scan of a soft grey brain dotted with blobby digital overlays. In the center of the cloudy tissue, the blackness and emptiness peeks through, creating hollow spaces. Viewed as an artwork, the brain's dark core might suggest something of the fragility of material existence or our own human ignorance, which neuroscience only confirms, or cannot overcome. However, this is no museum show-piece. This is a laboratory image used in the public communication of a neuroscience finding about "reward circuits" and their relationship to spiritual thinking.

As ghostly pale as the brain appears in this image, we see the scientific convention of grey scale inadvertently generating a feeling of dead flesh dotted in select areas by the luminescence of the heavenly presence of mentalizing — bright blue and yellow digital additions glow like floating apparitions. The digital blobs indicate, presumably, important areas of neuronal activity but also suggest life amid matter;

[7]Note: it is the nature of semiotic, and indeed artistic, analyses of images to make claims about the persuasive power or "pleasability" of images outside of reception studies. The qualitative approach relies on the "grammar" of visual design and the critic's own expertise.

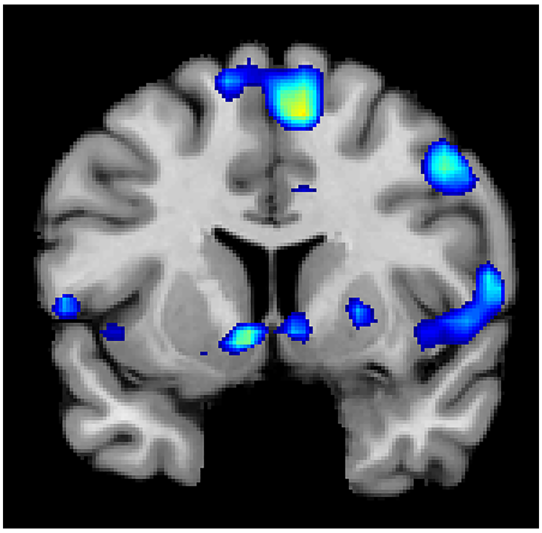

Figure 4. Credit: Jeffery Anderson, with permission.

the cool, soft glowing orbs pop across the winter stage of the brain's inactivity and meaty texture.

The center positioning of the image is typical of a vertical slice of brain, cut down the middle, with a "hear it is" kind of obviousness. In this way, the image fits the nuanceless headline: "This is your brain on God". The textual frame suggests the intention of universalizing and "neuro-essentializing" the image, i.e. encouraging the viewer to equate "subjectivity and personal identity to the brain", to see this brain as fully constitutive of spiritual experience and, accordingly, of the religious person [Racine, Bar-Ilan and Illes, 2005, p. 160]. But it does so only through making an evidential implication in the follow-up phrase in the headline, i.e. "Spiritual experiences *activate* reward circuits".

The composition of lines exposes an aesthetic expectation — or what Kress and Van Leeuwen [2006] call semiotic "pattern" — in images likely to be understood as visually pleasing [p. 45]. That is, as seen in Figure 5, the image breaks down into perfect thirds working from top to bottom and also directs the viewer upward in a pyramid shape, lending balance within a strongly grounded center-based composition. Looking toward the top segment associated with "the divine", we encounter the brightest round blob, as if God Himself is inspired to manifest there. The orientation may emphasize the impact of a neuroscience study seeking materialist correlations to spiritual belief. Likewise, at the bottom of the image, at the lowly base of the brain, we find abstract grey shapes, scarcity, a visual cue suggesting that nothing very spiritual emerges from the mucky "reptilian brain" of the cerebellum [Bell, Han and Sawtell, 2008].

Reviewing relations between elements of the image, the two halves of the brain mirror each other. Like a Rorschach ink blot aiming to test emotional stability and outline one's personality type, the image, equally, positions neuroscience in the role of psychological interrogator [Exner, 2002]. As in Rorschach tests, the bias of the person viewing the image (or the patient thinking about God in the neuroscience study) as well as the psychologist (or the neuroscientist who must interpret the import of the patient's interpretation) play a central role in deciding what this

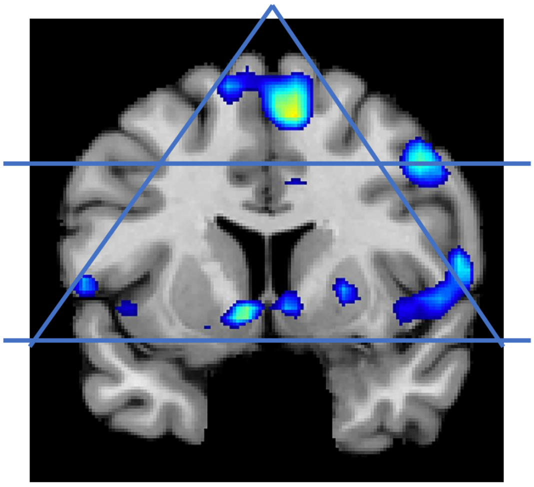

Figure 5. Jeffery Anderson image with superimposed lines for aesthetic analysis.

image says for neuroscience and whether the patient is sane, spiritual, happy, or presents "normal" functioning. That the bright little spots sit along the lines that divide the image into thirds may imply a relationship of balance, i.e. the neuro interpreter, we imagine, moves from seeing emotional reaction in lower central regions of the brain to cognitive, deliberative decision-making happening in the upper frontal lobe, concluding that attunement with God is fully immersive, completely expected in evolutionary development, or even beautiful. Whatever the case, the image foregrounds how relationality among blobs is dependent upon what can be known from specific correlations made from verbalized mentalizations to regions of the brain and ultimately determined by those with disciplined, expert knowledges.

Considering light and color, we see a cool image, even cold along the edges. The choice not to use red or pink to represent neuronal firings may be one about the subject matter — the experience of God need not look so angry. The softer blue tones produce a calmness and might insinuate objectivity for a neuroscientist entering into a controversial topic likely to be carefully scrutinized by religious observant and atheist alike. Additionally, the choice not to harden the edges or make too bright the tissue lends a fuzziness to the medical aspects of the photographic-like image of the organ, which draws more attention to the crisp, bright areas of digital activity. Indeed, the relation between the grey tissue and the bright neuronal firings suggests that the neuroscience tool measures only what activates.

The slightly out-of-focus greyness of the brain juxtaposed with the pixelated digital glow also implies an epistemological function — an identification of action during a specific test of spiritual thinking and, consequently, evidence for new knowledge. As the credit line under the image explains, "An fMRI scan shows regions of the brain that become active when devoutly religious study participants have a spiritual experience, including a reward center in the brain, the nucleus accumbens" [Dicou, 2016, credited to Jeffrey Anderson]. However, once reading the text of the article, we discover that 19 Mormons were encouraged to "feel the Spirit" when listening to quotations of Mormon pastors and familiar religious passages. We then learn that the image also evidences the claim that correlations to meditating on “the Spirit” offers different results than other studies of religious experience, for example, with eastern religions [Dicou, 2016, para 10]. The phrase, “Here is your brain on God”, suddenly transforms and becomes somewhat deceptive, something closer to “Here is your brain on Mormonism”, or rather, “Here is your brain reacting to specific stimuli in a time and place if you have a specific cultural background associated with the Mormon Church in Salt Lake City”. The image can then be re-seen as floating in tension with the overblown headline and can move from the realm of the totalizing and objective to the realm of the individualized and subjective.

However, if the headline is taken at face-value, then the image might well evidence “spirituality” writ large as a discovery of specific configurations of brain activity. Those configurations, of the upper and midbrain, of left and right sides, aids the neuroscientist in making an argument for what this all means. The image itself, although playing an evidential role, does not offer any obvious interpretation to a lay reader, nor is the image very cohesive, insofar as the digital blobs do not quite “fit” over the grey shapes underneath, compromising the view that this is produced from any rote mechanical impulse. The image in this way requires both a neuroscientist and a computer.

Of course, the image helps to build a case that “reward circuits” are activated by spiritual experience and, thus, feelings of spirituality can be rationally explained by evolutionary science. Yet, at the same time, a semiotic analysis shows how this image looks a little “blurry”. It leaves the audience requiring quite a bit of expert guidance, and it also fits within semiotics patterns of images meant to be aesthetically pleasing, adding some curiosity about its mechanization and, perhaps also, its generalizability when juxtaposed against the article’s text. Further, and perhaps because of its lovely structure, the image seems a little “spiritual” itself. At least once the title is considered, the image appears as an exaggerated or simplified depiction of something called spirituality. What that blue glowing blob *is* exactly and whether it is “inside” the brain as “spirituality” or something else, something coming from the image creation process, something more than oxygen or enhancement, remains blurry to the viewer.

Discussion

Watching computers organize the work of laboratories, Bowker and Star [1999] argue that scientists must adjust images and persuasive approaches according to new technologies; thus, they expect that notions of objectivity will shift in kind through a “convergence” effect [p. 82]. Yet, Beaulieu [2001] in her analysis of brain atlases stresses that computational tools keep up the same old appearances. The elements of the image, she explains, are pulled from a database and algorithmically designed to “merge and blur so as to appear seamless” [Beaulieu, 2001, p. 665]. The “seamlessness” sustains the objectivity of the scientific image. That is to say, if Bowker and Starr suggest that expectations may change with new technologies and practices, then Beaulieu suggests that neuroscientists stay on the traditional objectivity path through digital integration. However, the images in this study shed doubt on the “seamlessness” of some neuroscience images. The coding of headlines indicates that studies foregrounding neuron actions tend to display images easily identified as hybrid digital composites. Thus, although “seamlessness” is likely still valued in many arenas, the sample here shows enough aesthetic punch to wonder about the requirements for scientific objectivity when interpretations of brain functioning are in question.

The neurobiological images in the sample are not perfectly seamless. They, rather, can appear "blurry", or a little creative, a little distanced from mechanization, and a little seductive to the eye, at least with respect to semiotics and the "visual grammar" of Western images. There remains a question then as to whether audiences will always read them as images of Nature or if audiences will instead see them as strategically enhanced objects intending to attract or persuade in favor of particular viewpoints. These sparkling images, of course, could communicate some sense of objectivity if they are read by audiences as totally produced "as is" by machines. But it is often difficult to tell whether they have been creatively punched up by the laboratory or by an artist, or by some collaboration. Audiences have no way of knowing. Understanding how these images are made is a complex matter difficult to articulate, even for advanced students of neuroscience. Further, when viewed in tandem with the popular texts that they accompany, as communicative conglomerations [Im, Varma and Varma, 2017], these images might be understood as visualized arguments or enhancements made by scientists acting as rhetors.

Whether the specific images discussed in the characteristic examples are understood by popular audiences as evidential of the main line of argument or performative of a scientist's innovative theory, or somewhere in-between, is a question for later reception studies. But what can be said now is that articles having headlines promoting newly discovered brain activity associate with laboratory produced images that have bright digital aesthetic appeal, demonstrating action. As a result, the objectivity of the image can be called into question. Indeed, as the coders note, these images are clearly laced with visual choices: bold colors, strong contrasts, and structural framings that place them at a distance from the de-aestheticized scientific image captured automatically and without prejudice.

One way to understand the epistemic and communicative functions overlapping is to say that such bold images make explicit how scientists "think with data" and, in that sense, represent what Manovich [2015] calls a "data society" manifesting in neuroscience practices and communications [p. 2]. A visual culture of data selection and digital manipulation expands into all aspects of the contemporary neurosciences. In a data society, decisions are made, indeed must be made, only *through* collecting, sampling, and curating data. The role of the researcher is to look at computational options and to test out various visualizations, to add highlights, and to make comparisons, until one appears clearer or more salient than the others, per the audiences held in the image-maker's mind. Space-like, wondrous, glowing neuroscience images, likewise, imply that neuroscientists cooperate with computers to make their interpretations come to life and to reach other scientists as well as various publics. Computers serve as unabashed, as opposed to hidden or unaddressed, support systems for cognitive tasks in some areas of the neurosciences.

The concept of scientific objectivity may be at a crossroads. The laboratory produced images from this sample are inextricable from the digital curation process where scientists foreground image features with enhancement tools to formulate ideas about what is happening in brains. As such, for image historians, the sampled images harken back to “natural history illustrations, hand-drawn anatomical tables, symbolic reproductions, creative imagery”, which were used to illustrate “theories and principles” to other scientists as well as to non-expert audiences [Rigutto, 2017, p. 1]. Such images have existed in the trades craft of scientific production for a long time, having an explanatory function that is also decorative [p. 1–2]. Yet, unlike a hand-drawn neuron, these digital images retain aspects of scientific objectivity by being situated as real scans even while having software features and imprints of strategic inquiry. The result is a digitally enhanced image purporting to show the “real” or “natural” action of neurons while being gorgeous with high gloss colors or contrast layers; the conclusion, accordingly, is that similar images, and specifically ones focused on demonstrating (or asking the viewer to imagine) brain movement/function, can be a “blurry” visual production that combines evidential purposes with a popular “add on” ornamental function.[8] Such images, then, are not far from design practices used by media outlets [see: Rodríguez Estrada and Davis, 2015]. Blurry images make interpretations of objects known but also make more known the digital processes deployed. What results is an image not cleanly independent of the cognitive routines of scientists “thinking with” data.

Conclusion

Future research could examine how blurry images are received by multiple audiences, whether and when viewers understand them as creative productions or whether such images sustain ratings of objectivity and scientific credibility compared to others. Examining when and why neuroscientists feel the need to visualize the brain’s action using digital effects or energy-like colors or black outer-space-like contrasts and color schemes might also expose something of the neuroscientist’s *imaginary* for the brain — or how neuroscientists want to see the brain or want the public to imagine the brain. Additionally, the influence of “fake news” on scientific images, and scientific communications broadly, warrants some future research. Scholars might determine how media skepticism alters perceptions of science in the news in addition to how scientists adjust visual persuasive strategies, if at all, to address circulating fears of digital manipulation.

Although blurry images in this study are not likely to have been created as a direct response to any “fake news”, the broader inculcation of what digital media can offer regarding image manipulation may eventually impact and change the presentation of the brain in popular neuroscience. Accordingly, researchers might look for trends in the types of brain images circulated. Knowing whether controversial or “breakthrough” stories about neuronal action align with specific kinds of digital enhancement and visual appeal can better unwind how neuroscientific choices and practices are changing. As Pauwels [2006] notes, the nature of the represented referent often has something to do with scientific image practices, and since many images having digital enhancement in this sample pair with headlines about brain functioning — and yet are not exclusive to images made from fMRI machines — something about the intractability of signifying the referent may be at play (3). Future research may well find that these cases benefit greatly, even need, digital overlays but then eventually rewrite ideas of scientific objectivity. In brief, the intermixing of art and science in scientific images in a

[8]For more discussion on combinations of purposes in scientific imagery, see: Frankel and Depace [2012].

digital age rife with deep concern about how to know whether something is real or credible stages a new, important area of research in the public understanding of science. The question now is whether scientific objectivity matters as much as scientific credibility, trustworthiness, or persuadability.

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