Photographic Truth in the Age of Digital Manipulation:
A critical evaluation of journal-based image manipulation guidelines

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Mike Rossner's fifteen minutes of fame came in early 2006. In the space of a few months, he appeared in Nature, the Boston Globe, the New York Times, on NPR. As the executive editor of a specialized science journal, how did he get so much press?

Much can be accredited to the South Korean cloning scandal which came to a disturbing conclusion just weeks before. The Hwang Woo Suk case left no part of the scientific community unscathed, and much blame fell on the journals whose peer-review process seemed to have failed. One particular embarrassment came when investigators discovered gross manipulation of the digital photographs that appeared as evidence in Suk's papers, two of which were published (and subsequently retracted) by the prestigious journal Science (Morton 2006).

The press's sudden interest in Rossner stemmed from his longstanding stance against improper manipulation of images which appear in journals like his own, *The Journal of Cell Biology* (The JCB). For years, Rossner had been an outspoken proponent for more regulation of digital images which are used as scientific evidence. Before the cloning scandal, enthusiasm for Rossner's aggressive, editor-centric approach was far from widespread: in at least one case, Rossner and *The JCB* rejected a paper on grounds of image manipulation, and that very paper was later approved and published by a competing journal (Morton 2006). The cloning scandal provided an ideal platform for the advancement of Rossner's approach—in an email to members of his editorial board, Rossner wrote "'Nothing like an international scandal to generate some interest'" (Morton 2006).

With the spotlight on, Rossner described the proactive policies and procedures he co-wrote for his journal a year and a half ago. As reported through the imperfect filter of

the popular press, the guidelines say, "in effect, that nothing should be done to any part of an illustration that did not affect all other parts equally" (Wade 2006).

The articles frequently emphasize Rossner's sleuth-like enforcement methods and tactics. The headline of the piece in *Nature*, "CSI: Cell biology", references "Crime Scene Investigators," the popular TV drama based on police forensics. The story's lead continues the analogy:

> In a cramped office in midtown Manhattan, a forensics expert peers intently at a flickering computer screen. The shadowy image, hugely magnified, reveals a tell-tale dark smear. Something about it, she can tell, is just not right… (Pearson 2006)

Such descriptions of the manual, labor-intensive process abound, and most articles include descriptions of Rossner's next pursuit: an *automated* system for detecting manipulated images.

Specific approach

The narrative above presents many possible subjects for a study of "the scientific establishment": the role of journals or journal editors, the relationship between the popular press and research scientists, the changing nature of evidence, and so on. Yet for those involved, those "pragmatists" like Mike Rossner, these issues are secondary to the problematic nature of the digital image and its potential for modification.

Why does someone like Mike Rossner view the digital image as problematic? Do these justifications hold up under scrutiny? What might be at stake?

By looking closely at journal policies and related articles, we may be able to answer these questions. As this venture is necessarily broad and multi-disciplinary, this paper will focus primarily on the language and justifications provided by Mike Rossner in support of the *JCB* guidelines he co-authored. Without venturing beyond the original

articles themselves, our close reading will find a number of shortcomings and contradictions. The analyses of resampling and "pixel favoritism" will be supplemented by separate documents which provide Photoshop-based demonstrations.

After this initial critical evaluation these primary texts, the Rossner program will be more broadly considered through a selection of history of science texts. Though the articles do not address image manipulation as such, their diverse methodologies and perspectives will be essential to considering Rossner's work in its broader, historical context.

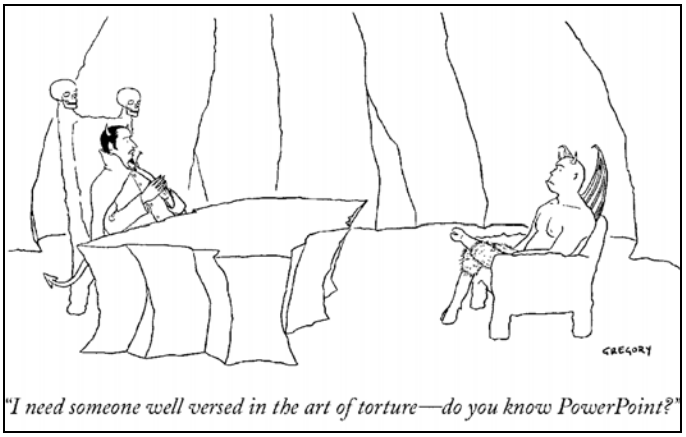
In the first article, "Judgement Against Objectivity," we will investigate the relation of the Rossner program to Peter Galison's historical/theoretical dichotomy of the "mechanical image" and the "interpreted image." The second article, "Do We See Through a Microscope?" will question Rossner's analogies to natural vision, and more importantly, provide a glimpse into the heavily-processed and constructed nature of all scientific images. In the third and final article, "Visual Truth in the Post-Photographic Era", W. J. T. Mitchell will argue against a specific interpretation of the digital image which motivates the Rossner program.

After these three specific textual perspectives, this paper will briefly explore the policies' broader ramifications within the scientific community. This last analysis will motivate an attempt to lay out an alternative interpretation of the digital image, one which avoids the many pitfalls previously identified. This alternative interpretation will be accompanied by a system for preventing inappropriate image manipulation, one capable of replacing the Rossner program in its entirety.

To start, we will consider a piece by Rossner which contains many important pre-cursors to program of image manipulation as laid out in early 2006.

Image-as-Data in "The JCB will let your data shine in RGB"

This earlier article, co-written by Rossner in 2004, announces the transition from a print-based CMYK workflow to a web-based RGB workflow: "With a completely electronic work flow, we have now decided to make the online version of the journal the 'journal of record'" (O'Donnell & Rossner 2004). The article strikes an optimistic, upbeat tone: the Editors of the *JCB* are "pleased to announce" the transition and a New Yorker-style cartoon makes a predictable jab at Power Point:



(O'Donnell & Rossner 2004)

As casual and friendly as these stylistic decisions may seem, they point to an underlying reality that was a likely source of dismay for authors. Along with the full conversion to RGB, *The JCB* shifted many prepress burdens onto authors. This changing work dynamic is most apparent in article's proportions: by word count, less than one quarter of the article addresses the CMYK/RGB transition. The remaining three quarters of the article discusses the submission requirements for digital images.

> In addition to color mode, we have other requirements for the file formats and image resolutions of figure files. In the light of the confusion that we have encountered from authors about these requirements, we'll take this opportunity to explain them. The requirements serve three purposes. They ensure that:
> - sufficient information is present for reproduction of high quality images;
> - that information is not lost or compromised at any step along the way; and

- file formats are compatible with our production software.

(O'Donnell & Rossner 2004)

This passage marks the transition from friendly announcement to delineation of duty. The remainder of the article is a technical tutorial on the basics of desktop publishing and digital workflows. The JCB's implication is clear: learn this, because it's your job now.

As a whole, this article provides an interesting case study in "carrot and stick" digitization. By shifting work, responsibility, and liability to their authors, the JCB editors effectively shift the "balance of power" between journals and authors. To justify this shift, the JCB appeals to scientific values held in common. Why must scientists bear an additional desktop publishing burden? So that "information is not lost or compromised at any step along the way" (see above).

This "data integrity" appeal resurfaces later in the CMYK to RGB article. Again, though the article doesn't specifically addresses image manipulation, it contains strong language on the topic:

> You should be aware of the resolution at which the image was acquired by the digital camera on your microscope. When that file is imported into an image manipulation application such as Adobe Photoshop, you may get an option to set the size and resolution of the image. If the total number of pixels in the file you create is greater than the total number of pixels in your original, the computer has just created image data for you that was not present in the original. (O'Donnell & Rossner 2004)

This admonition against "creating data" is repeated later in the article, in an almost identical context.

The article as a whole implies a parallel between "information," "data," and "pixels." Is this language merely metaphoric—pixels are *like* data—or does it make a statement of fact—pixels *are* data? The quantitative language suggests the later: creating

more pixels always creates more data, and therefore the two must have a one-to-one relationship

Regardless of precise semantics, the end result is a compelling conflation of *data manipulation* and *image manipulation*. The former certainly carries more weight of precedent than the latter, and by tying the two together, Rossner and the *JCB* make a strong case against image manipulation of any kind.

This earlier article, though it does not deal specifically with image manipulation, provides a preview of important themes which will reappear in the 2006 article outlining the JCB's new image manipulation policies.

What's in a Theory: the Rossner Program of Digital Image Integrity in "What's in a picture? The temptation of image manipulation"

Momentarily setting aside the policies themselves, Rossner's case for image policing can be quite compelling. Though the popular press may glamorize or sensationalize his work, Rossner is quick to point out that less than 1% of the images submitted are downright fraudulent (Wade 2006). As a defense of the journal-centric approach, Rossner argues that "Journal editors have a responsibility to protect the published record in any way they can…This is one way they can" (Morton 2006). Furthermore, the Rossner guidelines are far from arbitrary—they are the culmination of a long-standing, gradually-developed position against image manipulation (Rossner et al 1998, 2003, 2003). The most latest version of the anti-manipulation program is laid out in the 2006 JCB article titled "What's in a picture? The temptation of image manipulation." Beyond listing the justifications and rationales for a program of image regulation, this piece described the Photoshop-based procedure for detecting

inappropriate manipulation, and it's likely that this "set a thief to catch a thief" novelty was a factor in the popular press's interest.

Rossner and Yamada begin their 2006 article with a 21st century truism ("It's all so easy with Photoshop") that also cites the 2004 article above (Rossner & Yamada, 2006). Already, the authors provide Photoshop with dual roles. Having only read the article's title and this first line, readers are plainly aware that improper image manipulation will be the article's topic. Yet the reference points to Photoshop's functional, non-controversial role in journal assembly. Similar to Photoshop's duality, the article itself becomes a two-pronged endeavor like the CMYK to RGB article: it will both educate and announce the specific rules and guidelines of the *JCB*.

Before listing specific guidelines, the article lays out a theory of data exchange which will motivate the upcoming rules. Readers are first informed that while traditional darkroom modifications "required considerable effort and/or expertise," digital image editing is now "very simple, and thus tempting" (this claim will be examined in detail the later section "Mitchell vs. Mitchell") (Rossner & Yamada, 2006). The introduction also takes pains to outline the dangers of improper image manipulation. These dangers fall into two broad categories: dangers to the livelihood of the researching scientist (external), and dangers to the scientific community (internal).

Although "[t]here are different degrees of severity of a manipulation," the listed external consequences are only of the extreme variety. In the first paragraph, the article states that improper image modification is a form of "scientific misconduct," as defined by the "US Government." This unsourced definition of "scientific misconduct" refers vaguely to "fabrication" or "falsification" of "research" or "research results" (Rossner &

Yamada, 2006). Without examining the definition, the authors employ its terms in a negative example of image manipulation:

> For example, showing a figure in which part of the image was either selectively altered or reconstructed to show something that did not exist originally (for example, adding or modifying a band in a polyacrylamide gel image) can represent falsification or fabrication.
>
> (Rossner & Yamada, 2006)

Having established a link between image manipulation and "scientific misconduct," the authors declare that "the scientific community takes strong action against perceived scientific misconduct" and warn that "being accused of misconduct initiates a painful process that can disrupt one's research and career." These external threats—the "scientific misconduct" label, the specter of the "US Government," the "scientific community"—suggest a threat to the individual scientist. Together, they create an almost menacing tone.

The authors then justify their new policies in ways which make assumptions about the internal practice of science. In a section titled "Why is it wrong to 'touch up' images?" various aspects of image use are proposed. One such passage speaks directly to readers, stating that "your colleagues" expect "basic scientific honesty," which is then defined as "an accurate representation of what you actually observed" (the problematic "what you actually observed" will be examined further in the "Hacking and Microscopes" section beginning on page 20) (Rossner & Yamada, 2006).

Readers are also informed that "an image usually carries information beyond the specific point being made." This phrase adopts a curious double meaning: on one hand, image modifiers might "deprive you and your colleagues of seeing other information that is often hidden in a picture or other primary data." Here, "information" refers directly to

directly observable aspects of an image, and examples specific to cell biology are provided. The second meaning of "information" is vastly different:

> The quality of an image has implications about the care with which it was obtained, and a frequent assumption (though not necessarily true) is that in order to obtain a presentation-quality image, you had to carefully repeat an experiment multiple times. (Rossner & Yamada, 2006)

This association between image quality and experiment repetition becomes a recurring theme. Later in the article, the editors condemn the juxtaposition of tracks from different gels: "As it was with gel photographs, it is unacceptable…Rerun all of the samples on the same gel!" This chastising tone re-appears at the conclusion of the article, which condemns "sloppy work":

> Just because the tools exist to clean up sloppy work digitally, that is no excuse to do sloppy work. If you would have redone an experiment to generate a presentation-quality image in the days before the digital age, you should probably redo it now. (Rossner & Yamada, 2006)

Divorced from context, these "sloppy work" statements are not especially noteworthy, but as they come from journal editor to article authors, they are quite exceptional in the assertion of expertise and judgment over the peer-review process.

Having laid out the basics of a justification, the JCB article goes on to review various image modification policies among cell biology journals. The provided examples progress from least to most stringent, with the JCB at the end. Rossner finds this variation in guidelines "surprising," but never explicitly states why the laxer, "less comprehensive" guidelines are insufficient. Since 1992, The Molecular and Cellular Biology journal guidelines state that "images can be manipulated for better clarity" but "a description of the software/hardware used should be put in the figure legend(s)." In addition to requiring a note in the legend, The Journal of Cell Science declares that:

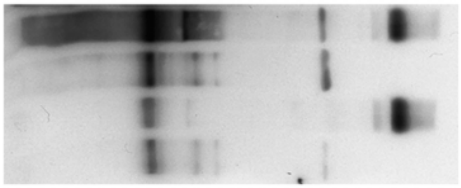
> Image enhancement with computer software is acceptable but there is a danger that it can result in the presentation of quite unrepresentative data as well as in the loss of real and meaningful signals. During manipulation of images, a positive relationship between the original data and the resulting electronic image must be maintained. If a figure has been subjected to significant electronic manipulation, the specific nature of the enhancements must be noted in the legend or in the Materials and Methods. (Rossner & Yamada, 2006)

Finally, the Journal of Cell biology presents its criteria, which is, in their own language, "by far the most comprehensive":

> No specific feature within an image may be enhanced, obscured, moved, removed, or introduced. The grouping of images from different parts of the same gel, or from different gels, fields, or exposures must be made explicit by the arrangement of the figure (e.g., using dividing lines) and in the text of the figure legend. Adjustments of brightness, contrast, or color balance are acceptable if they are applied to the whole image and as long as they do not obscure or eliminate any information present in the original. Nonlinear adjustments (e.g., changes to gamma settings) must be disclosed in the figure legend. (Rossner & Yamada, 2006)

The remainder of the article goes on to outline and justify each point of the guidelines, using examples specific to cell biology.

Much of the proffered examples of image manipulation use blots and gels. In many ways, this category of images provides a simplest case scenario. The digital image has a non-technically mediated, first-hand perceptual analog (again, refer to "Hacking and Microscopes" on page 20).



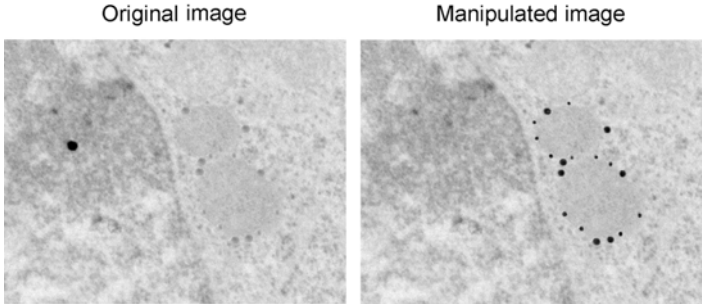
Sample gel image (Rossner & Yamada, 2006)

These images present few problems, because the informational content of a blot exists in only a few dimensions: band location, band intensity, and band labeling. Because of this

simplicity, “reading” the informational content of a blot or gel requires relatively less interpretation.

The article goes on to describe practices which qualify as “gross” or “subtle” misrepresentation. The former includes removing or inserting bands, and duplicating a single band to represent more than one trial or gel. The latter includes selective brightness/contrast adjustments and “cleaning up the background.” On this subject, the article makes a strong claim against using “the tool variously known as ‘Rubber Stamp’ or ‘Clone Stamp’”: “don’t do it” (Rossner & Yamada, 2006). The editors both threaten—“This kind of manipulation can usually be detected…because it leaves telltale signs”—and effectively second-guess their authors: “what may seem to be a background band or contamination may actually be real and biologically important and could be recognized by another scientist.” The unqualified tone of these statements clearly places the judgment of authors and peer-reviewers beneath that of editors, and they gloss over clearly acceptable uses of the tool in question. In the case of gels, removing dust specs reduces distractions without in any way obscuring data, real or imagined.

The next section characterizes the guidelines as they apply to micrographs: photographic images which reproduce the visual image created by a microscope. The first example shows an image in which certain features were manually shaded with a paint brush feature.



Micrograph sample images (Rossner & Yamada, 2006)

The justification for impropriety is slim: “This type of manipulation misrepresents your original data and is thus misconduct.” The editors provide two alternative methods of highlighting features: arrows and pseudocoloring (the latter requiring a note in the legend). Though ostensibly acceptable, neither of these alternatives is without problems.

Arrows are an improvement only in that they announce their presence by being clearly distinct from the image itself. Unfortunately, arrows have significant limitations. As indexical signs, arrows can only direct, never describe. They indicate either direction or the quality at some point: “look at this thing here.” Arrows also cover “irrelevant” portions of the image. How big to make an arrow, where to place it—these decisions may seem insignificant, but in the language of Rossner, they may “obscure” parts of the image. Applying the same, editor-knows-best logic employed in the gel examples, we have no reason to conclude that the contributing authors are capable or trustworthy enough to preserve “background” that “may actually be real and biologically important and could be recognized by another scientist” (Rossner & Yamada, 2006).

Pseudocoloring provides the informational richness that arrows lack, but still falls prey to logical inconsistencies. Though readers are told that it “does not alter the brightness of individual pixels,” it is offered as an alternative to an otherwise inappropriate “enhancement” of a “specific feature” (to use Rossner’s language). Though pseudo-coloring doesn’t alter “brightness of individual pixels,” the implicit message is that it does alter the overall *perception* of the image—perhaps more so than changing the “brightness of individual pixels” in the first place. Here we have run into an essential crux of the image modification problem: the complex relationship between objectivity

and interpretation (considered at length in the “Judgment Against Objectivity” section below).

The admonition against nonlinear adjustments is the least justified of the various requirements. In full, the guidelines say only that “Nonlinear adjustments (e.g., changes to gamma settings) must be disclosed in the figure legend” (Rossner & Yamada, 2006). These manipulations are described as both useful and problematic. On one hand, nonlinear adjustments are unlike linear adjustments in that “the same change is not made to each pixel.” The assertion that ‘all pixels must be treated equally’ is not as straightforward as it sounds. Rossner earlier stated that brightness and contrast adjustments are acceptable within bounds—but it’s not clear that even these basic adjustments ‘treat all pixels equally” (see “Pixel Favoritism” on page 36).

On the other hand, “nonlinear changes are sometimes required to reveal important features of an image”. The article then endorses certain non-linear techniques (“background subtraction” and “digital masks”) which contradict the previous admonitions against both nonlinearity and whole-image adjustments. These contradictions are meekly acknowledged at the conclusion of this section: “Standards and guidelines in the field will continue to evolve, but full disclosure will always be the safest course” (Rossner & Yamada, 2006).

The article’s shortest section addresses misrepresentation of a microscope field. The restriction described here prohibits the merging of images into one image which represents a single microscope field. In a parallel to the earlier discussion of stamp tools, this section emphasizes the editors’ ability to discover manipulations, a claim emphasized by an accompanying graphic.

A new heading announces a discussion of resolution. More than any other part of the article, this section seeks to educate the reader, much like "The JCB will let your data shine in RGB". Parallels in phrasing even suggest that the later was copied from the former, or that the two share a single source. The language of "information" remains largely the same, with an identical prohibition against "creating data" by upsampling. More importantly, the article now addresses downsampling:

> It is acceptable to reduce the number of pixels in an image, which may be necessary if you have a large image at high resolution and want to create a small figure out of it. Reducing the resolution of an image is done in Photoshop by sampling the pixels in an area and creating a new pixel that is an average of the color and brightness of the sampled ones. Although this does alter your original data, you are not creating something that was not there in the first place; you are presenting an average.
>
> (Rossner & Yamada, 2006)

This new description of down sampling continues the pixel-as-data convention applied before, only now the attitude towards said data has changed. Whereas the implication before was that data must be maintained unchanged, the editors now adopt the stance that data "averaging" is acceptable. In other words, despite the fact that the number of pixels has decreased, original data has been neither created nor destroyed. This claim of fundamental asymmetry between upsampling and downsampling is deeply problematic on a number of levels. Though the article uses the terminology "sampling" and "average," the reality is that resampling a photograph is significantly more complex. A variety of resampling methods exist, three of which come standard with Photoshop: bicubic resampling, bilinear resampling, and nearest neighbor resampling ("Choosing and Interpolation Method" 2002). Though Photoshop differentiates the three on a "good, better, best" basis, this scale relies on assumptions about which image qualities should be retained. In the demonstration provided ("9 dots" on page 35), the differences between

the three methods is striking, and it becomes quite clear that the "good, better, best" distinction does not hold up in all cases. Furthermore, the proposed asymmetry between upsampling and downsampling falls apart as well, as both deviations from the original image introduce image anomalies which obscure some aspects the image and its data content.

Having finished describing the specifics of image manipulation, the article gives a short gloss on "Other Data Management Issues." As the "primary rule of good scientific practice," authors are admonished to keep original images and record instrumentation settings: "In fact, some journal reviewers or editors request access to such primary data to ensure accuracy" (Rossner & Yamada, 2006). This procedural reminder concludes as the editors re-unite image manipulation with other varieties of data misrepresentation which they "have not addressed": selective data acquisition, hiding negative results, etc. This discussion points to a major lacuna of the journal-centric perspective: if image modification is so similar to other forms of data misrepresentation, why aren't these other forms of data manipulation policed by the JCB in a similar fashion? Though Rossner never answers this question, there are some who may answer it for him (see "Mitchell vs. Mitchell" on page 25).

The article concludes with an upbeat narrative of broad intentions and cooperation within the scientific community:

> We hope that by listing guidelines and publicizing examples of transgressions, all of us can become more vigilant, particularly in guiding junior colleagues and students away from the tempting dangers of digital manipulation.
>
> (Rossner & Yamada, 2006)

This almost moralizing tone ("transgressions," "tempting dangers," etc.) begins to suggest the usefulness of a more historic, multi-disciplinary perspective. Not

coincidentally, this need is fulfilled by Peter Galison, an eminent historian of science who specializes in scientific imaging. Of his many writings on this subject, Galison's "Judgement against Objectivity" provides a uniquely appropriate lens with which to re-consider the Rossner program of image manipulation.

"Judgement Against Objectivity": Mechanical Objectivity and its Enhancement

Though the previous analysis has accused the Rossner program of faulty logic and incomplete justification, at least one important passage clearly expresses a specific methodological attitude. Near the end of "What's in an Image," the editors declare that "Data must be reported directly, not through a filter based on what you think they 'should' illustrate to your audience." The dichotomy of "direct reporting" versus "illustration" is decomposed and contextualized in Galison's 1998 essay "Judgment Against Objectivity."

Surveying a broad array of imaging technologies, scientific fields, and source materials, Galison describes changes in the definition and meaning of the "objective image" over the last two centuries. The essay further focuses on what Galison sees as a 20th century transition from the "mechanical image" to the "interpreted image." The former is situated in its late nineteenth, early twentieth century context:

> Taking place against the background of the mid-nineteenth-century romance with manufactured objects, image technologies instantiated the valued ability to produce identical things. The modernity of manufacture, the dynamics of control, the scientific labor management all figured in the nineteenth-century mechanical image. Self-denial, self-restraint, and supervision were the moral correlates of such production, and they reinforced and affirmed both the social and epistemic rightness of this new way of re-presenting nature. (Galison 1998)

This brief excerpt more than adequately describes many aspects of the Rossner program. The "dynamics of control" and "supervision" apply exactly, and these impulses relate

directly to the 19th century "moral correlates." From the analyses of the JCB articles above, we see that Rossner frequently uses moralizing language and themes, often with distinctly Calvinist overtones: manipulation is a "temptation" in part because it allows one to do "sloppy work." Both supervisory and moral aspects are merged in the admonition cited above:

> We hope that by listing guidelines and publicizing examples of transgressions, all of us can become more vigilant, particularly in guiding junior colleagues and students away from the tempting dangers of digital manipulation. (Rossner & Yamada, 2006)

One can almost see the "straight and narrow path" along which wise, elder scientists guide the young and gullible.

This "moral culture of the scientist" was directly linked to a contemporaneous technological culture. "Objectivity," Galison tells us,

> …had nothing to do with truth, and nothing to do with the establishment of certainty. It had, by contrast, everything to do with a machine ideal: the machine as a neutral and transparent operator that would serve both as instrument of registration without intervention and as an ideal for the moral discipline of the scientists themselves. (Galison 1998)

That Rossner embraces this techno-centric "machine ideal" is clear: recall his continuing efforts to automate the now-manual image-screening process. For Rossner, automation is both labor saving and legitimizing—an automated image screening process would hermetically seal the cycle of the scientific image (never mind the inevitable necessity of a judgment-making human mind).

Having established the surprising link between Rossner and Galison's "mechanical objectivity," we can consider potential implications as they relate to the future of image manipulation standards. We will first consider one alternative to the "mechanical image," that which Galison refers to as the "interpreted image." Having

evaluated an alternative perspective, we can then ask why the Rossner program arose in the first place, and what its future course might be.

For Galison, "mechanical objectivity" and "the mechanical image" are historical entities which lose ground to the "interpreted image" in the early twentieth century. "Interpreted images" include hand drawings, subjective categorization, and, most important to this paper, manipulated mechanical images (photographs, X-rays, etc.). These images "built interpretation into the very fabric of the image," and Galison quotes the 1950 preface to a medical atlas which boldly declares that "Accuracy should not be sacrificed to objectivity" (Galison 1998). The confidence of this statement hints at a different self-perception of scientists, one both empowered and emboldened. Galison describes the differences as such:

> ...the *interpreted image* is produced not by a moral culture of neutral, self-abnegating bureaucrats, but by self-confident experts, who trust the trained eye more than the automatic conveyance of pictures…the technocratic objectivist became a transparent medium for nature to image itself, and the trained expert created images that brought conditioned experience and judgment to the edification of initiates.
>
> (Galison 1998, original italics)

What accounts for this transition in the scientist's role? Galison proposes and rejects a number of potential explanations. A photography-based technical determinism ignores historical context, as "objective" drawings existed well before the camera. Exploring Wittgenstein and "conservative critics of science studies," Galison rejects two opposing political interpretations as "ahistorical and backward." (Galison 1998). The best explanation may ultimately rely on placing the scientist in a much broader social context. In the writings that accompany "mechanical images", Galison sees "a certain defensiveness, a nervousness before the charge that the phenomena were not actually out

there, but instead were the mere projections of desires or theories." For Galison, this tone of scientific insecurity comes as no surprise, given that

> [The] last decades of the nineteenth century were, institutionally, years of transition, during which the persona of the scientist was itself shifting…In this period of rapid institutional expansion and reformulation of the role and proper comportment of the scientist, it is perhaps not surprising that while these new investigators aim for the durable results of exactness, they were still defensive about their new status. (Galison 1998)

Thus institutional insecurity is posited as a necessary historical condition for "time-specific, hard-won, and contingent category" that is "mechanical objectivity."

Having now identified a historical analog and an alternative conception of image making, how does this directly affect the Rossner program? To be sure, the eerie parallels of moralizing language and tone provide a stinging if superficial criticism. More importantly, Galison's arguments provide a historical narrative which undermines the positivistic implications of the Rossner program. By its existence alone, the "interpreted image" category provides a challenge to the Rossner program, which posits a monolithic and necessary attitude toward image making. Furthermore, since Galison describes the "interpreted image" as a more self-secure and sophisticated notion of image-making, it becomes a compelling competitor and forces Rossner to defend what looks to be an outdated notion of image-making.

Though compelling in its parallels, Galison's article is unlike to persuade a figure like Rossner himself. For a more robust and directly relevant critique, we might turn to an author whose focus on technically-mediated image production more directly corresponds the specific claims of the JCB.

Hacking and Microscopes

Returning to Rossner's original article, we find that a number of his claims and justifications rely on references and analogies to natural human vision. For one, the majority of example images provided are of blots and gels, two kinds of images which simply record an example of unmediated sight. At a later point, Rossner demands of his authors that "each image you present is an accurate representation of what you actually observed" (Rossner & Yamada, 2006) In these cases, Rossner is appealing to our everyday intuitions of human vision, and implying that anything other than "plain seeing" constitutes an example of improper manipulation. Unfortunately, "plain seeing" may not be quite so plain, especially when it comes to the sophisticated products of modern scientific imaging. To further investigate the failure of vision analogies and constructed nature of images, we will look at Ian Hacking's 1981 article "Do We Look Through a Microscope?"

As part of a larger philosophical dialog on realism, Hacking explores the physical reality and social use of modern and pre-modern microscopes. Though he eventually leaves the philosophical questions unanswered, Hacking provides us with a number of salient examples with which explore and complexify "image," "seeing," and "mediation."

Even before exploring the technical specifics of microscopy, Hacking makes an important point which mirrors a criticism of Rossner found above.

> One should be especially wary of the word "image" in microscopy. Sometimes it denotes something at which you can point, a shape cast on a screen, a micrograph, or whatever. But on the other occasions it denotes as it were the input to the eye itself. (Hacking 1981)

The implied differentiation between direct perception and perception of an image appeared in the above analysis of pseudocoloring. In that specific case, Rossner conflated Hacking's two meanings of "image" (see page 13).

Most of Hacking's article discusses the vagaries and varying techniques of visible light microscopes. Even in this "simplest case" branch of microscopy, Hacking points out a number of counter-intuitive realities within microscopic vision: light transmission instead of light reflection; diffraction gratings; phase-contrast microscopes; interference microscopes; and so on. Each of these technologies provides a unique hurdle in defending the claim that an operator "plainly sees" through the microscope, and Hacking is quick to point out that these hurdles are often coincident in one machine. Furthermore, given that each presents unique problems of false images, one must often compare images from multiple devices before "seeing" can be trusted (Hacking 1981). In one specific case, Hacking describes how two "unrelated chunks of physics" are required to confirm the presence of "electron-dense bodies" in red blood cells (Hacking 1981).

Just barely touching on electron and acoustic microscopes, Hacking destroys the common interpretation that we "see" through a microscope. Instead, "*We can use any property of light that interacts with a specimen in order to study the structure of the specimen*. Indeed we could use any property of *any kind of wave* at all." (Hacking 1981, original italics). That this relation can be trusted relies not so much on the faculties of our human vision, but "a line of thinking" which "reveals that the image must be *a map of interactions between the specimen and the imaging radiation*" (Hacking 1981, original italics). This "map of interactions" phrase is perhaps Hacking's most salient point for our discussions. By using the language of mathematical transformations, Hacking reveals how processing and conversion are central to image making. Again, note that this is accomplished without relying on imaging technologies which require intensive computer processing, like a scanning electron microscope or an MRI.

Having undermined the common notion of "seeing through a microscope" Hacking uses his concept of "mapping" to construct a more accurate characterization:

> When an image is a map on interactions between the specimen and the image of radiation, and the map is a good one, then we are seeing with a microscope. What is a good map? After discarding or disregarding aberrations or artifacts, the map should represent some structure in the specimen in essentially the same two- or three-dimensional set of relationships as are actually present in the specimen. (Hacking 1981)

As a criterion for appropriate image-making, this description succeeds at incorporating complexities of image, vision, and technological mediation ignored by Rossner.

In addition to providing an alternative interpretation of vision and microscopic imaging, Hacking also speculates on how such misleading concepts persist, even among the professional scientists and lab technicians who use microscopes:

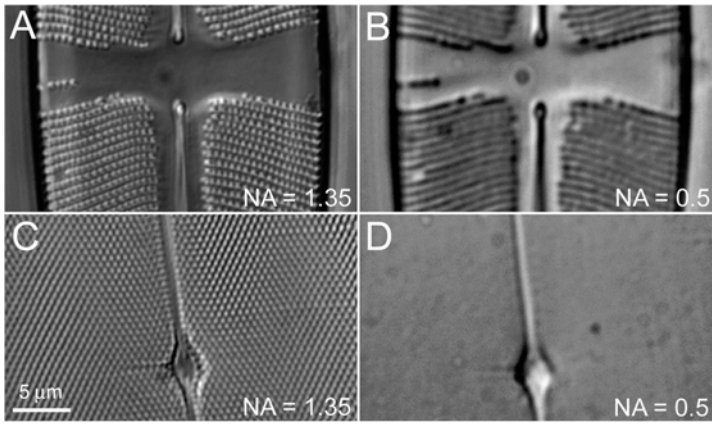
> It may seem that any statement about what is seen with a microscope is theory-loaded: loaded with the theory of optics or other radiation. I disagree. One needs theory to make a microscope. You do not need theory to use one…Hardly any biologists know enough optics to satisfy a physicist. (Hacking 1981)

Beyond explaining the persistence of "seeing through a microscope," this characterization may also explain the various logical lacunae in Rossner's program against image manipulation.

By unsettling the relation between plain vision and microscopic images, Hacking's article provides a compelling and science-specific argument for the constructed nature of the scientific image. From Rossner's perspective, image manipulation contaminates an otherwise objective, veridical, and direct representation of nature (hence the analogies to seeing). Put another way: the assumption necessarily underlying any strict policy against image manipulation is that 'images are *captured*, not *produced*,' and it is this very assertion that Hacking undermines.

Ironically, the JCB itself provides proof and extension of Hacking's claims. In 2006, the JCB published a feature article entitled "Seeing is believing? A beginners' guide to practical pitfalls in image acquisition." Hacking's modest claims about image construction in optical microscopes become super-sized in the realm of contemporary, high-tech microscopy. The article begins by deflating a myth of the direct and objective image: "Imaging can be thought of as the most direct of experiments. You see something; you report what you see. If only things were truly this simple" (North 2006). In phrasing and underlying content, this deflated myth almost exactly mirrors passages from Rossner: "Data must be reported directly, not through a filter based on what you think they "should" illustrate to your audience," or the admonition to present "an accurate representation of what you actually observed" (Rossner & Yamada, 2006).

Through a series of examples, readers are shown how an image's end use all but determines the conditions under which it is created. A series of compelling examples further this point, one of which is reproduced here:



> Differential interference contrast (DIC) images of two different diatoms…In all cases the focus was adjusted to give the best possible image…Thus it is NA [numerical aperture], not magnification, that determines the resolving power of the objective lens. (North 2006)

Between Hacking and "Seeing is believing," it becomes very difficult to argue that scientific images are not mediated, processed, and constructed. If one agrees to this

claim (as Rossner must at some level), it becomes more difficult to vilify digital image manipulation as such: if the images are mediated, processed, and constructed during their creation, why not mediate, process, and construct images after their creation?

Rossner never addresses this question, and this silence may be indicative, according to the last critical perspective we will examine.

Mitchell vs. Mitchell

Published in 1992, *The Reconfigured Eye* became an instant classic among academics of all stripes. Developed at the Harvard Graduate School of design and written by William J. Mitchell, *The Reconfigured Eye* provides a nearly exhaustive consideration of then-emerging digital image technology. Beyond merely cataloging, the book offers a compelling narrative of the future, alluded to in its subtitle: "Visual Truth in the Post-Photographic Era." The uncertainty of "photographic truth" dominates *The Reconfigured Eye*. Much of the book focuses on the theoretical and practical problems posed by the transition from traditional photographs to digital photographs.

Already, the mission and tone of *The Reconfigured Eye* parallels that of the Rossner program. As a long-time editor who has grappled first hand with digitization, there's little doubt that Rossner was personally exposed to the text—a 1998 article on digitization co-authored by Rossner cites *The Reconfigured Eye* as a resource (Rossner et al. 1998).

Throughout the book, Mitchell makes a number of well-argued guesses about the future of photographic culture. In one of the book's more elegant passages, Mitchell declares that

> The currency of the great bank of nature has left the gold standard: images are no longer guaranteed as visual truth—or even as signifiers with stable meaning and value—and we endlessly print more of them. (Mitchell 1992)

The bleakness of the digital image future is reconfirmed by the book's many visual aids. Flipping through *The Reconfigured Eye*, readers are assaulted by a comprehensive historical catalog of photographic manipulation.

When set against accessible descriptions of image modification tools, Mitchell's ultimate message echoes Rossner's: though the change in photographic technology doesn't completely determine "visual truth," it certainly makes image manipulation more "tempting" and therefore likely. Traditional image manipulation is "technically difficult, time-consuming, and outside the mainstream of photographic practice" and while Mitchell never says so explicitly, it's clear from the juxtaposition that we are believe that digital manipulation is "easy, quick, and increasingly in ordinary." This dichotomy is shared by Rossner, who begins his essay with "It's all so easy with Photoshop…" (see above). Implicit to the arguments of both Mitchell and Rossner is the assumption that once the technical bar is lowered, an increase in manipulation will inevitably result.

Another Mitchell finds this logic deeply flawed. William J. *T.* Mitchell (henceforth WJTM) argues against Mitchell's alarmist tendencies in a paper entitled "Realism and the Digital Image." As a "scholar and theorist of media, visual art, and literature," he argues against the narrative of "easier manipulation, more manipulation." Along the way, WJTM provides a number of observations and insights which will prove useful for constructing an alternative system of image manipulation management.

WJTM begins by reminding readers about those images which become fraudulent or misleading well before the shutter clicks. There is little disagreement on this issue, as both Mitchell and WJTM provide numerous examples of "pro-filmic" image creation.

Writing more than ten years after Mitchell, WJTM begins with a personal ethnography of digital photography. WJTM uses Photoshop to create fake images "once a year," for the family Christmas card (WJTM 2006). Even these playful endeavors are doomed to become a "fading print and a digital archive," as they're frequently vetoed by his wife and children. WJTM contrasts the rarity of this manipulation to the ordinariness of his daily Photoshop use. On a day-to-day basis, WJTM uses Photoshop for the functional "'optimization' of images": "crunching them down for screening or transmitting over the internet, fattening them up in .tiff format to produce highly saturated color prints" (WJTM 2006).

Though quite unscientific, WJTM's provides the auto-ethnography as representative of a compelling argument against Mitchell's alarmist tendencies. By examining digital photography in its now-everyday application, WJTM points out that "the photographic image"—digital or chemical—is deeply embedded in social practice. To de-emphasize this fact is a "fallacy of misplaced concreteness, a kind of vulgar technical determinism that thinks the ontology of a medium is adequately given by an account of its materiality and its technical-semiotic character" (WJTM 2006). WJTM professes to prefer Raymond Williams's account of media as "'material social practices,'" a concept which takes into account "skills, traditions, genres, conventions, habits, and automatisms, as well as materials and techniques" (WJTM 2006). This criticism of Mitchell seems right on target, for though *The Reconfigured Eye* mentions socially constructed safeguards against digital image manipulation (in photojournalism, for example), these examples are not extended or developed enough to overcome the over-arching tone of technological determinism. Rossner's 'slippery slope' language similarly over-emphasizes the technological aspects of digital imaging. The neglect of

social practice is most apparent in Rossner's imagery of seasoned scientists "guiding junior colleagues and students away from the tempting dangers of digital manipulation" (Rossner & Yamada, 2006). As one specific example of manipulation suggests, it is more likely that junior scientists are guiding senior scientists in both the use and regulation of image modification (Morton 2006).

At the same time, WJTM suggests that digital images will not simply fill the shoes of traditional photographs. Digital images will make a difference, but it is a difference which "has to be understood as a complex shift in many layers of photographic and image-culture" (WJTM 2006). As to which direction this might shift, WJTM suggests that Mitchell "has things exactly upside down":

> Instead of making photography less credible, less legitimate, digitization has produced a general "optimization" of photographic culture, one in which better and better simulations of the best effects of realism and informational richness in traditional photography have become possible.
>
> (WJTM 2006)

These better-than-chemical arguments proceed from different perspectives, many of which relate directly to the evaluation of and possible alternatives to the Rossner program.

One stated advantage of digital photography is its ability to provide images richer in information. WJTM notes that Mitchell frequently cites such "technoscientific" examples—for example, the image/data manipulation which provided elevation views of Venus's volcanic landscape (WJTM 2006).[1]

As it relates to providing evidence, another advantage of the digital image cited by WJTM relies on its implicit extension of photographs' characteristic immaterially. Beginning with a discussion of imaging in the two Gulf Wars, WJTM points out the

[1] Curiously, both WJTM and Mitchell fail to mention the significant scientific controversy surrounding the images, which use an exaggerated vertical scale to emphasize geographic features. A brief review of this controversy appears in Edward Tufte's *Envisioning Information* (1997, Cheshire CT: Graphics Press.)

unique lifestory of the Abu Ghraib photographs. While the digitization of the photographs had no negative effect on their reception as authentic evidence, WJTM does see their digital-ness as having had, in one important respect, a positive effect, that of "circulation and dissemination":

> If the Abu Ghraib photos had been chemical based, it would have been very difficult for them to circulate in the way they did. They could not have been copied so readily, or transmitted world-wide by e-mail, or posted on websites. (WJTM 2006)

WJTM goes on to describe this advantage of digital photography in terms that mimic biology: the circulation of images is "rapid, virulent", and has an ability to "'break out' of whatever boundaries have been established for their control." This migration and movement includes repurposing, which, in the case of Abu Ghraib, gave them their final and most compelling meaning.

Having challenged and dissembled the "problem of the digital image," WJTM goes on to speculate as to exactly why such a notion exists in the first place. In the transition from digital to film, WJTM sees a number of broader trends and "mythic narratives." Deceit, disembodiment, de-realization—not coincidentally, these very themes suggest deeper connections between the popular press's association and fixation on both the Korean cloning scandal and the Rossner program of image authentication.

Recommended Course of Action

Returning once again to the unfortunate case of the Korean cloning scandal, we are reminded that fraudulent image manipulation is not to be simply ignored. Despite the preceding critical examination of the Rossner program, there can be little disagreement over the motivation behind establishing guidelines: to paraphrase Rossner himself, *every*

member of the scientific community has a responsibility "to protect the published record in any way they can." (Morton 2006).

Having identified a number of serious shortcomings in the Rossner argument, there remains a certain question of urgency—is there sufficient reason to abandon the guidelines as they stand now?

This paper began with a summary of the extensive press coverage Rossner and his program generated in early 2006. In the specific case of *Nature*, these articles reached an audience comprised largely of research scientists and those in positions of science-related policy making. When legitimized by a prestigious publication and explicitly linked to examples of scientific fraud, the Rossner program begins to look very appealing. That this positive press is affecting the practice of science is certain—in January of 2006, *Science* began using Rossner's guidelines and screening processes for their images.

The stakes of the Rossner program are increased by its pan-disciplinary language and application. When abstracted away from this original context and qualifying language, the guidelines become increasingly obtuse and divorced from actual imaging processes. A particularly compelling example can be seen in one graphic which accompanies the piece on Rossner which appeared in The New York Times. It depicts a sweeping astronomical image of deep space and swirling galaxies. Clearly created by the New York Times staff, the graphic includes a series of digital manipulations which are "discovered" and condemned on the basis of the Rossner program. The absurdity of comparing the two disciplines is apparent even within the context of the graphic: a small "note" beneath the graphic stipulates that "In a widely accepted practice, the colors in images from space are routinely modified to show what the human eye can't see" (Wade 2006). This note grossly understates the role of image processing in astronomy, and

makes clear the problems of assuming that any scientific digital image can be treated like any other.

Another worrying aspect of the Rossner program is that it has gone almost completely unchallenged. This may be due in part to its unusual place within scientific procedure. The science press which carried Rossner stories is large and broad while the intellectual space for debating journal procedures is small and extremely-specialized. This asymmetry inevitably leads to an institutional bias in favor of new and press worthy programs like Rossner's.

An important exception to this trend appeared in the February issue of Harvard Focus, a news journal of the Harvard Medical School. In it, journal editors voiced concerns with the Rossner program, and defended the lack of explicit policies. A former editor at *Nature* re-framed the debate effectively:

> …people now tend to collect large amounts of data, perform sophisticated analysis, and present the analyses rather than the raw data. At what point do you hold people's feet to the fire and make them present all of the data, not just the postanalysis data and interpretation? (Morton 2006)

By framing the question in terms of raw data and analysis, this question points directly at a viable alternative to the Rossner program.

Harnessing the Digital Image

To begin the search for an alternative image management system, we might look first for a representative image, a uniquely difficult sort of image which incorporates the various pitfalls identified above. This ideal image would be of non-visible phenomena, one which requires extensive processing both during and after acquisition.

This bill is neatly filled by Functional Magnetic Resonance Imaging (fMRI). Less than fifty years old, fMRI imaging has proved vastly useful in both clinical and

research fields, yet many claims attributed to it remain highly controversial. Much of this controversy stems from the necessity of extensive (and sometimes subjective) image processing. As a result, fMRI images are a frequent a locus of debate, even among proponents.

In 2000, The National Institutes of Health opened The fMRI Data Center (fMRIDC), a virtual space which provides "a public repository of peer-reviewed fMRI studies and their underlying data" (fMRIDC 2006). According to their literature…

> The objective of The fMRI Data Center is to create an environment that will benefit the fMRI research community. The Center will achieve this ambitious goal by:
>
> -Providing access to a common data set that everyone can use in order to develop and evaluate methods, confirm hypotheses, and perform meta-analyses.
>
> -Increasing the number of cognitive neuroscientists who can examine, consider, analyze and assess the brain imaging data that have already been collected and published…
>
> -Providing *all* data necessary to interpret, analyze, and replicate these fMRI studies. (fMRIDC 2006, original italics)

Because fMRI necessarily relies on extensive processing, the "underlying data" promise should be read not as a promise to "pure data," but rather as an opportunity to make transparent the extensive processing and manipulation it goes through: a section heading entitled "meta-data" lists over forty different processing parameters which must be included along with the complete pre- and post-processing data sets.

By harnessing the reproducibility of images and data sets, the fMRIDC radically alters fMRI image economies. Rather than bypassing peer review with a set of rigid guidelines, the fMRIDC places judgments back in the hands of reviewers (perhaps even more reviewers, given the unfettered accessibility). Given the possibility of this increased scrutiny (which does not end after publishing), submitting authors might even

be more careful with their processing decisions than if they were simply "passing a test" like the one encapsulated in the Rossner program.

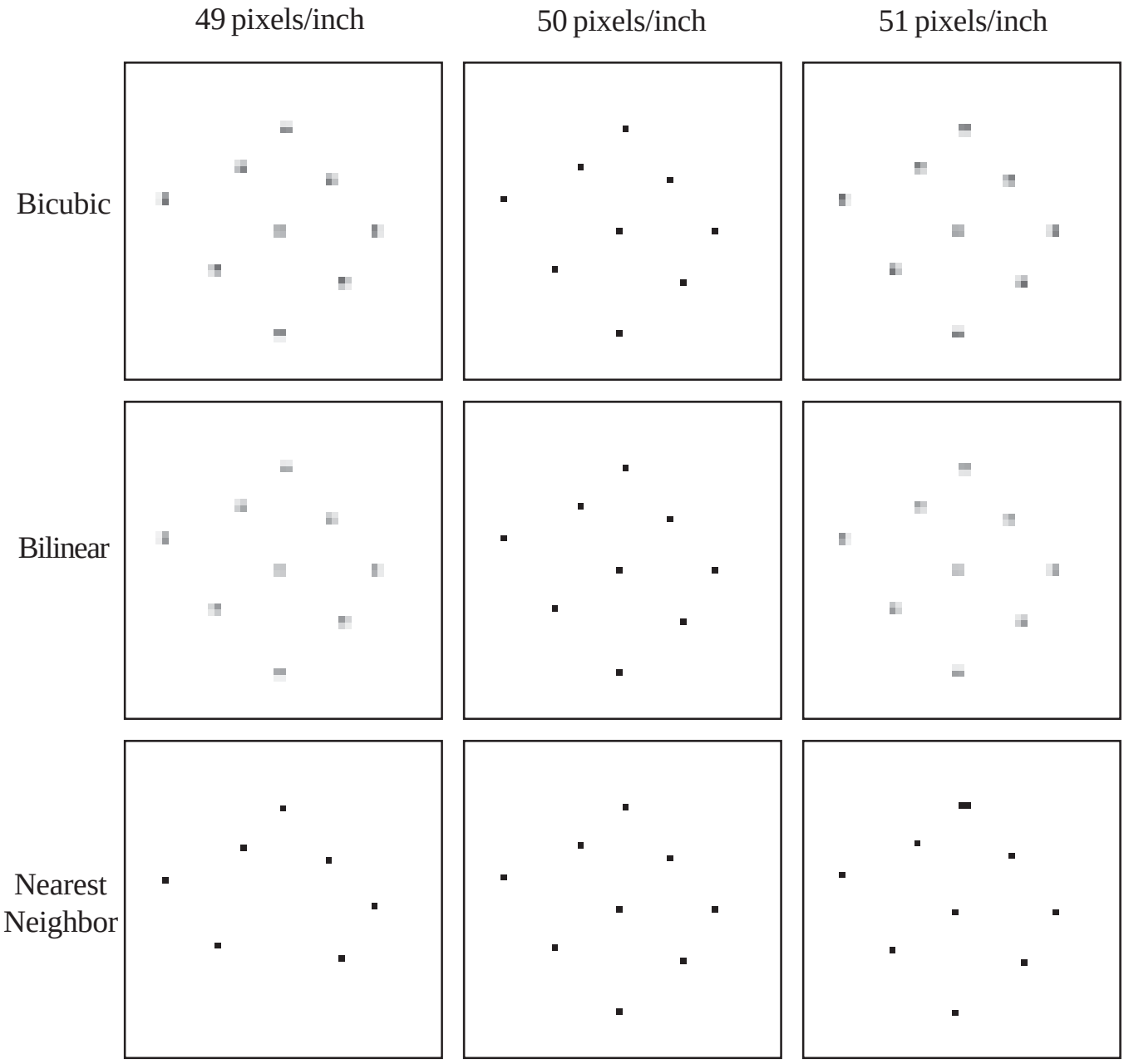
By relying on the social structure and social practices of science, the fMRIDC provides an image-sharing mechanism not unlike the Abu Ghraib situation discussed above by WJTM. To take the analogy further, the fMRIDC model increases the probability and possibility of something analogous to "reappropriation—although in the scientific context it might be termed something like "intellectual cross-pollination."

Applying the fMRIDC model to journals presents no insurmountable hurdles. Virtually every journal of repute now publishes online, and in the specific case of the JCB, the online version has become the "journal of record." Furthermore, most journals have embraced the expansive possibilities of publishing online, a decision evidenced by burgeoning of features variously labeled "supplementary materials," "supplementary figures," etc. These pre-established "supplemental" structures could easily serve as a repository for the pre-processed, pre-manipulated versions of images featured in the main text. By providing original images for full inspection of each reader and reviewer, authors are able to process, interpret, and enhance as much as they suspect will be tolerated in the judgment of their peers. Rather than limiting the use of Photoshop as an interpretive tool, the new system would encourage the use of Photoshop as an image viewing and image analyzing tool.

Most importantly, the above proposal does not rely on complex or problematic interpretations of digital images. What is the relationship between pixels and data? Which image modification tools are appropriate? What is the relationship between down sampling and up sampling? Just as scientific images free the scientist from inadequately describing with "a thousand words," so would an open system of image manipulation

regulation free the scientific community from a tangle of well-meaning but inadequate regulations placed on the images themselves.

9 Dots: A Resampling Demonstration

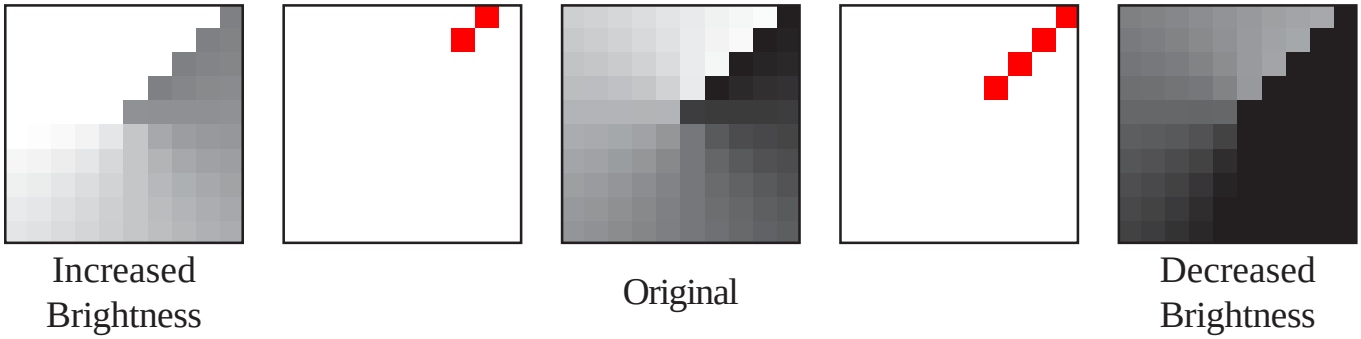


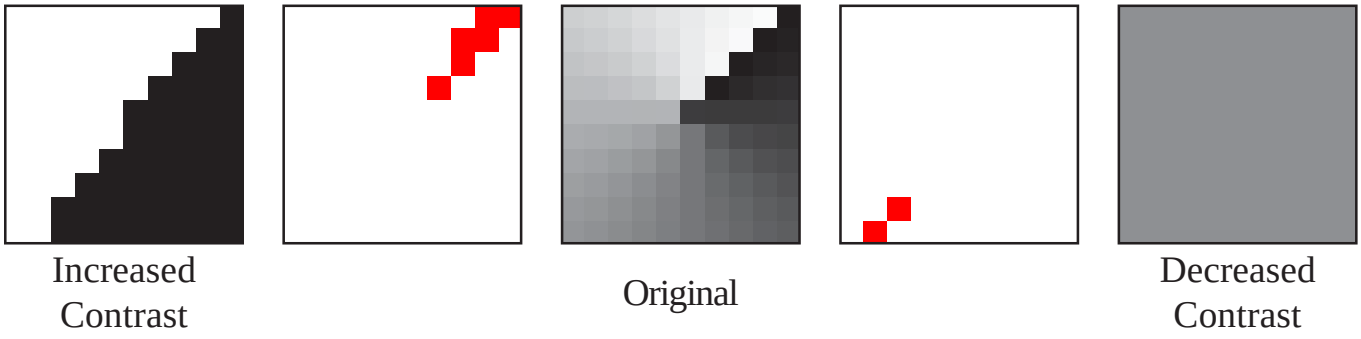
Adobe Photoshop describes interpolation and re-sampling as follows: "When an image is re-sampled, an interpolation method is used to assign color values to any new pixels it creates, based on the color values of existing pixels in the image. The more sophisticated the method, the more quality and detail from the original image are preserved…**Nearest Neighbor** for the fast but less precise method. **Bilinear** for a medium-quality method. **Bicubic** for the slow but more precise method, resulting in the smoothest tonal gradations.

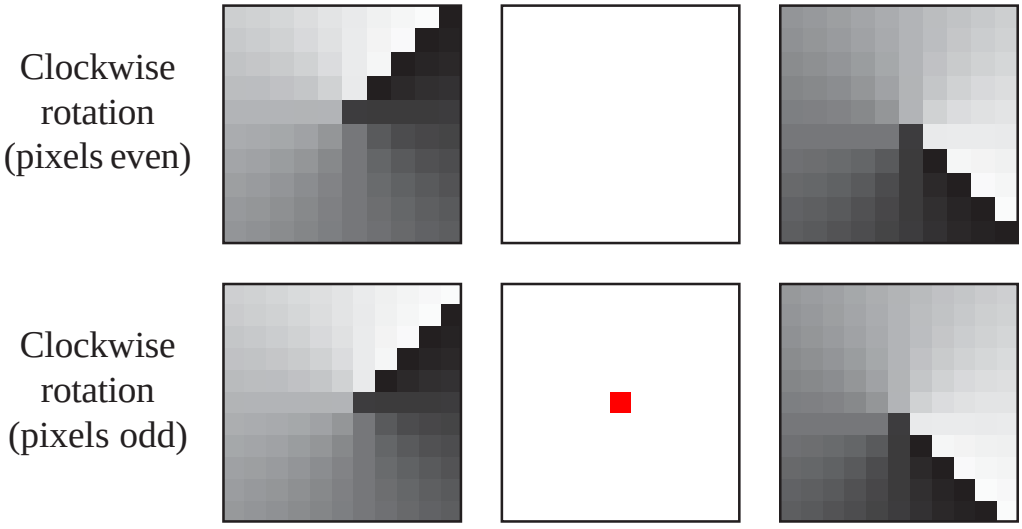
For this demonstration I created an original grayscale TIFF file, 1" x 1" at 50 pixels/inch resolution. I painted 9 black, single-pixel dots in an informal, non-orthogonal grid. I copied this original image 9 times and independently re-sampled each copy. To preserve image sizes, and resolutions, I placed all images into 2" x 2" frames in Adobe Pagemaker. This completed file was printed into an Adobe PDF using Adobe Distiller.

As you can see, each interpolation method presents problems, and choosing between them is not simple.

“Pixel Favoritism”







One key guideline in the Rossner program is a prohibition against what I have called “pixel favoritism.” “Linear” adjustments are acceptable while “non-linear” adjustments are not. The difference between the two is that in the latter, “the same change is not made to each pixel.”

Brightness and contrast adjustments are deemed “linear” and therefore acceptable (within limits), but do they avoid the “pixel favoritism” stigma?

For this demonstration I created an original grayscale TIFF file, 1" x 1" at 10 pixels/inch resolution. Using an automatic gradient tool, I created a smooth field of grayscale values. I copied this original image and applied the listed adjustments to each copy. The red and white intermediary images highlight those pixels unchanged by the listed adjustment.

As you can see, the specter of “pixel favoritism” persists even in “linear” adjustments.

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