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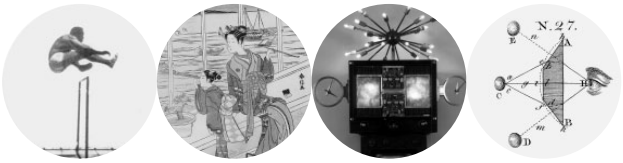

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Jonathan Sterne and Dylan Mulvin

Abstract

This article offers a perceptual history of American color television through a study of the making of the National Television Systems Committee's 1953 color standard. Rather than seeking out an ideal representation of color, the NTSC standard asked what the minimally acceptable level of color transmission might be for home audiences. While exploiting psychophysical research that suggested that normal eyes tended to have a lower acuity for blue, the NTSC also set their aesthetic standards according to rough measures of everyday life. The NTSC thus mobilized a conception of vision essential for modern commercial culture. The authors consider the perceptual engineering of color TV as a path into a neglected but crucial dimension of 20th-century visuality: compression. The history of color TV shows the centrality of compression to the look of many 20th-century visual media – analog and digital – and to the cultures of looking in which they circulated.

Keywords

analog • compression • lossy • new media • perception • standardization

CBS televised its first color show under the new NTSC standards on Thursday, October 8, 1953. According to critic Jack Gould, 'both the color and show were not very good'. (Abramson, 1987: 57–58)

Compared with inventions like perspective, photography, cinema and digital image formats, the development of color television is generally

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considered a minor event in the history of perception. Historians of media have mostly neglected the invention of color TV, and for a wide range of reasons. Compared with other color media, color television did not usher in a major new age of visual experience. Viewed as a formal innovation, it did not transform the aesthetics or routines of visual culture, even if it had a clear impact on production routines in the television industry. Within the domain of television scholarship itself, it is hard to find writers who argue that it radically transformed the experience of viewing for audiences. In the United States (and in many other countries) the same networks and the same regulatory formation dominated broadcast television before and after color television became available. Economically, its impact was probably most strongly felt in the television wing of the consumer electronics industry. Culturally, its significance was probably most strongly felt with advertising and with programming like sports, though historical interest has been so sparse that we don't really know. Although an analogous argument could be made for TV as for film – that color challenged the hegemony of black-and-white as the visual ground for a realist code (Price, 2006; Street, 2010) – color did not produce a considerably higher-definition television image. Despite marketing claims made at the time (see Murray, forthcoming), in retrospect it seems that color TV was not more immersive or more engaging, and did not make any particularly new subjective demands on its viewers.

And yet, if one reads the National Television System Committee's (NTSC) account of its own history, the development of a color television standard for the United States was not only the greatest peacetime achievement of any industrial technical committee, it was also a renegade public service project of cross-industry cooperation that directly contravened the myopic directives of the Federal Communications Commission (FCC), the body that would eventually have to approve the NTSC's work (Fink and NTSC, 1955: 3). When we square this with what the NTSC actually undertook and the reasons for industrial cooperation – short-lived and self-interested as they were – we see something much more pedestrian and familiar. Just as photography and film had progressed from black-and-white to color, the transition to color was an expected progression for the medium of television. But the color TV standard was a compromise, a solution that negotiated industrial desires, regulatory tendencies, existing technical formations, and an emergent consumer culture. Television broadcasting capitalized on post-war wealth and consumer spending, advents in microwave technology, and existing broadcasting monopolies; the NTSC's monochrome and color standards were necessary components in establishing, expanding, and maintaining these features of American commerce and infrastructure. Although broadcasters were meant to wait until January 1954, the FCC approved the NTSC's standard in 1953, and a Halloween broadcast of the opera *Carmen* was staged that same year for CBS. The system was used in the United States for another 56 years until 12 June 2009, when full digital conversion took place in the United States, making it a particularly long-lived technical standard. It is still used in some countries and 'NTSC' is still a color calibration option in many computer operating systems. Unraveling

the history of the NTSC standard reveals how such technical codes are artifacts of a suite of assumptions about human vision and viewer practices, broadcaster and engineer rivalries, and conjectures about the normal subject matter of television. The story of analog color TV does not, therefore, strictly conform to prevailing stories of painting, photography, cinema and (now) high-definition digital images and video. Scott Higgins (2007), for instance, describes how technicolor was first used as a spectacular means of drawing attention, connoting mood, and developing thematic motifs in film. David Batchelor (2000) describes color's denigration as cosmetic and superfluous and Richard Misek (2010) describes how film theorists and historians have erroneously treated color as a surface phenomenon. While these scholars are right to recover a historical significance for color in film aesthetics, theirs is only one possible color history. For analog television in the 1950s, color did not automatically add greater depth and meaning. It was built around the limits of bandwidth, the existing infrastructure and consumer electronics of monochrome television, and contemporary beliefs about the limits of visual perception. Color TV history is thus a history of limits and compromises, not increasing definition or aesthetic saturation.

In this article, we recount the NTSC's technical challenges as a way of rethinking color television's place in the history of 20th-century media and visual culture. Considered from the vistas of high culture and high-definition aesthetics, one can certainly understand why color TV seems like a minor event. But considered as part of the history of compression, it is a fascinating story. As with telephony before it and digital compression for JPEGs and MPEG videos after it (MacKenzie, 2008; Mills, 2011), the assumed gaps and absences of an imagined viewing subject were directly and explicitly engineered into color television transmission. By tracking media history in terms of compression, rather than verisimilitude, we bring into relief a different set of relations between perceiving users, technical standards, and media infrastructures, relations built around limits and contingencies rather than ideals of immersion and plenitude (Sterne, 2012: 4–7). Of course, media technologies have been entangled with psychophysics since before its formalization as a science (Crary, 1990; Cubitt, 2011; Hui, 2012; Kittler, 1999), but our interest is specifically in how media systems economize signals – how they produce the possibility of a surplus – through encoding assumptions about the limits of human perception.

Color television is part of a longer history of the entanglements between perceptual science and the economics of communication infrastructures, a process called *perceptual technics*. Perceptual technics is 'the application of perceptual research for the purposes of economizing signals. Perceptual technics did for perception what ergonomics did for work' (Sterne, 2012: 19). The NTSC built on Bell Labs' work on telephone transmission in the 1910s and 1920s, which posited the existence of *necessary frequencies*, essential to the reproduction of sound and image, and *surplus frequencies*, technically possible for the system but not necessary for aesthetic effect. Communication engineers rendered communication infrastructures more

efficient by applying perceptual technics to create and then operationalize the distinction between necessary and surplus signals (see also Mills, 2010). The increased efficiency could be used to carry more signals, as it was with phone lines, or it could be used, as in the case of color television (and later in the case of MPEG and digital ISDN lines) to deliver new kinds of signals that previously could not fit into the available bandwidth. As Geoffrey Bowker and Susan Leigh Star (1999: 323) explain, 'as sets of classification systems coalesce into working infrastructures they become integrated into information systems'. In the same way, perceptual technics use measurements of the limits of human perception to classify signals that transmit images and sounds through an infrastructure, thereby transforming the operational character of the infrastructure. Where Bell's phone lines could carry one phone call before the application of perceptual research to telephony, they could theoretically carry four afterward. Where analog television infrastructure was designed for a certain size of monochrome signal, perceptual technics provided a way for it to carry a multiband color signal that would otherwise be much larger. Color TV is an especially poignant case of perceptual technics, since, as Carolyn Kane (2014: 59) writes:

> A colored TV image *occurs* through the act of watching TV. The multicolored images are ephemeral; they exist in the subjective perception of each viewer, when viewed close up, a color CRT screen reveals a matrix of tiny red, green, and blue *dots*, or *trace points*, which, like an Impressionist painting, form an "image" only when one steps back and takes in the whole. Given that this so-called "image" is only a series of rapid electronic scans, any "whole" can only be partial and ephemeral. (Emphases in original)

Color TV is thus a perceptual technology in the deepest sense: a technical formation that requires a set of perceptual operations on the part of its subjects to 'work' at all. The 'colorness' of the color TV picture thus lies somewhere between the inner workings of the camera, the broadcast infrastructure, and the set on one hand, and the inner psychophysical life of viewers on the other.

We read NTSC reports and related documents to both show how color television works but also how it helps us to think through the role of perceptual technics in visual culture more broadly. Analog color television worked because it incorporated the supposed limitations of its viewers into its technical standards and infrastructure. In so doing, it also economized its viewing subjects' limits as a kind of financial lubricant for efficient transmission. Our aim is not to develop an apparatus theory of television (Morse, 1990), because the ideological effects of this imagined televisual gaze for its subjects are not the primary concern or effect of the technical standards. True to its roots in information theory and psychophysics

(Shannon and Weaver, 1949), the NTSC's model enforces a rigorous distinction between content and channel (though it might be possible to postulate some ideological side effects for viewing subjects). Rather, our argument is that color television is a major node in compression history, and that compression history is at least as important as a history of verisimilitude for understanding the perceptual and infrastructural politics of media in the 20th and 21st centuries.[1] Although our analysis is based on the US color TV system and the American context, we argue for its broader theoretical consequences, in part because even though the specific standards are different, it is likely that histories of other nations' color standards were also developed through perceptual technics.

The NTSC in Context

The technical history of television stretches back into the 19th century and color television experiments just as far. As Carolyn Kane (2014: 56–57) notes, color reproduction was a goal for television from its very beginning and color standardization was one of the defining features of television for much of its history. The NTSC system is only one of many possible color television technologies, and with significant advances in phosphor and disk-based color technologies before it (see also Abramson, 1987). Accordingly, it is perhaps inaccurate to reflect on television in the 1950s as a 'new medium'. Although American TV was still novel as a nationally available service in the 1950s, its basic infrastructure and industrial protocols were already stabilizing, and massive changes were already seen as unfeasible. Yet television's future was never fully determined. 'There is a moment', Pingree and Gitelman (2003: xii) remind us, 'before the material means and the conceptual modes of new media have become fixed, when such media are not yet accepted as natural, when their own meanings are in flux'. This is a familiar refrain, built on histories of media artifacts and practices as negotiations over power, authority, representation, and knowledge (Marvin, 1988). The evidence of this negotiation is apparent when examining the 15 years it took to settle the standard for color broadcasting. Existing histories characterize this period as one of power plays between industry players and televisual protocols. While William Boddy (1990) frames it in terms of industry competition within the United States, Andreas Fickers (2007, 2010) chronicles the role of international standards fights in the formation of European color television. Susan Murray's (forthcoming) new work expands this narrative to further examine industrial competition, but also to consider color's role in advertising and in TV culture more broadly. Where these authors have provided rich industrial and cultural histories, we situate color TV in relation to the history of perception and infrastructures.

The usual story of color at the NTSC highlights its role in negotiating industrial conflict. There were actually two different NTSCs, one for black-and-white television, and one for color. The first NTSC was established in 1940 and

was assembled to 'study monochrome television and to reach agreement on a single set of standards from among the many proposals then before the FCC' (Fink and NTSC, 1955: 1). The FCC approved the Committee's recommended standards and television service was available beginning 1 July 1941. After the Second World War put an end to the development of television broadcasting and manufacturing, the FCC had to re-approve the standards at the war's conclusion. Although CBS immediately petitioned the FCC for the commercialization of color broadcasting, the Commission declined their request and monochrome television took off in March 1947.

Or so the story goes. Another description of the NTSC's genesis is found in the record of the American Senate's Commerce Committee, in which David Sarnoff states:

> If [the Chairman of the FCC] and his commissioners would sit down with the industry, we can forget technicalities and hearings and lock the engineers and executives up in a room and tell them to stay there until they come out with an agreement. (quoted in Boddy, 1990: 34)

Perhaps because of the locked-door conditions of the first NTSC, the American standards for monochrome broadcasting were far from perfect and terrestrial broadcasting using the NTSC standard was inferior to other international standards. The FCC was aware of these shortcomings during the first NTSC and also recognized the difficulties in modifying the system once a standard was approved. Pressure to commercialize broadcasting in the United States trumped desires to update and refine existing standards. With a federal election approaching, politicians took a new interest in color TV. In the US Senate, republicans accused the FCC of putting Americans out of work with its dallying on a standard, while the democratic White House pushed for a unified standard, fearing the Republicans would make hay out of the delayed approval of TV.

Like other technical standards, decisions about color were steeped in political maneuvering within the TV industry, motivated especially by the competition between RCA and CBS (Murray, forthcoming; Seldes, 1956). When the second NTSC reconvened itself in 1950, it was against the wishes of the FCC, which had recently approved a CBS color system that would not work with monochrome sets. This second NTSC, led by the executives and engineers at RCA, likely recognized (and hoped) that the non-compatible CBS system – approved less than three years after the monochrome standard – would face debilitating challenges. Sure enough, after NBC failed to get an injunction from the Supreme Court of the United States against CBS's standard, the Office of Defense Mobilization cancelled all color television manufacturing, claiming that the Korean War took priority. Replaying a script from the Second World War, the US government suspended the technical development of television to help support a war.

CBS's incompatible color standard also won few allies in the press. By 1956, in an essay entitled 'Problems of Power I: The politics of color', the critic Gilbert Seldes (1956: 255) wrote of

> the requirement that whatever was sent out in color could be received in acceptable black-and-white on the thirty million sets already bought by the public. The technical name for this was 'compatibility,' and it was a good name because the lack of compatibility is in many communities grounds for separation if not divorce.

Compatibility protected 'the public from the chaos of two receiving-systems operating in different ways'. NTSC documents also reflect this sentiment: by November 1954, when the color standard had just taken effect, 31 million monochrome receivers had already been sold (Fink and NTSC, 1955: 2). For a color system to be worthwhile it would have to be 'backwards compatible' with already-purchased monochrome sets. Forcing viewers to buy a new set or an adapter to continue participating in the broadcasting system was seen as untenable – a lesson that was moderately heeded during the recent conversion to all-digital broadcasting. As Matthew Fuller (2005: 96) writes, standardization implies 'the necessity of relations' among institutions, technical protocols, practices and people. By insuring interoperability, standards work as a mode of governance within media systems, encoding industrial and social relations within technical protocols (Sumner and Gooday, 2008). Color standardization was the means by which government regulators could secure commercial stability, producers could secure aesthetic practices, and manufacturers could establish an interoperable system of television sets and accessories.

If the first NTSC was convened as a hostage negotiation between the industry's engineers and executives, the second NTSC became the FCC's Stockholm Syndrome: at the moment of standardization, the regulators submitted themselves completely to the will of industry actors. Even though the color NTSC organized itself without government sanction or approval, the FCC ultimately accepted the Committee's proposals as the only viable color system. In addition to outmaneuvering the government, the NTSC's approval also signaled RCA outmaneuvering CBS. The Committee honed RCA's dot-sequential technology, which allowed for the development of a monochrome-color compatible system. In making that choice, and despite some efforts to the contrary, the color NTSC would fail to solve the shortcomings of its monochrome predecessor. The resulting color standard was widely considered inferior in comparison to international standards like PAL and SECAM. Among the standard's many derogatory nicknames, 'No True Skin Color,' is especially evocative of its failures.

However, because the NTSC was a massive undertaking that allowed for the very early standardization of television technology and broadcasting infrastructure, it was a signature moment in the technical history of information compression, a moment that crystallized existing research on the perceptual technics of electronic media. The second NTSC had a slightly different challenge: to develop a broadcast standard for color television that would be ready for American broadcasters, advertisers and

audiences *when they wanted it*. According to Sue Murray (forthcoming), this readiness was not only, or not merely, technical. Even as Americans purchased new televisions in the late 1950s that were equipped for color reception, the cultural acceptance lagged. While NBC pushed forward with color programming – having invested heavily in the eventually approved NTSC color system – it was at first widely panned by critics and did not have anything near widespread consumer adoption until the late 1960s. In part, this was the result of other networks being slow to start regular color broadcasts and the high expense of sets. In 1964, only 3.1 percent of US households had a color TV, and it wasn't until 1965 that CBS and ABC joined NBC in having a large number of regular color broadcasts (Steinberg, 1980).

Negotiating Infrastructural and Human Limits

The NTSC on color television gathered 315 people to serve on its various panels, doubling the size of the first NTSC. The Committee worked for 32 months before deciding on a standard, the aforementioned dot-sequential system, in July 1953. In the existing monochrome system they had six megahertz – the standard width of a channel for American broadcasting – in which to fit two image signals and one audio signal. On top of the technical limitations, the Committee was also freighted with cultural and aesthetic concerns, chief among them the faithful reproduction of skin tone (Fink and NTSC, 1955: 17). As the NTSC report on subjective aspects of color television put it: 'Most critical of all is the tolerance for flesh color (because of trained memory of observers for this characteristic, and the connotation of flesh color with emotional states)' (p. 94). Seldes (1956: 256) echoes this point:

> Electronic color is in itself more delicate than Technicolor and more true to life; when the system goes wrong, the picture becomes laughable and the effect is all the worse because the right picture has been so amazingly right. And, to be sure, the pervasive sense that television is 'real' makes sea-green faces and red butter too disturbing.

Unspoken but clearly central was the articulation of flesh color and the politics of race in the United States in the early 1950s. As Lorna Roth (2009: 112–115) has shown, both American and European color TV relied on 'Shirley' cards that were used for calibration of white skin tone – to the exclusion of all others. Over time, the various 'Shirleys' used for white-skin-tone calibration reflected changing standards of skin beauty. Just as white supremacy was facing its most serious challenges in the United States in close to a century, whiteness as an aesthetic category was being directly encoded into the palate of American color television. This is a topic we explore more fully elsewhere (Mulvin and Sterne, forthcoming).

Whereas monochrome television's points of reference were film and grayscale media like newspaper photographs, color television was tasked with maintaining the sharpness of the monochrome image while introducing a new semiotic register in the televisual field. The NTSC undertook a prolonged testing plan that used color slides and a single filmstrip to determine the acceptable levels of interference in the television signal. Their unit of measurement was the *just-noticeable difference*, one of the pillars of perceptual measurement, formalized in Gustav Fechner's 1860 book *Elements of Psychophysics* (Fechner, 1966[1860]). Drawing on insights of Ernst Heinrich Weber about relative feelings of pressure on the skin, Fechner devised a mathematical formula to describe quantities of sensation in terms of their felt intensity, as distinct from quantities of light or sound as measured by instruments (what psychologists would today call a stimulus). Fechner assumed that the just-noticeable difference was a constant quality, and in so doing, posited a logarithmic relationship between measurable stimulus and sensation. In other words, each time the intensity of a sensation like brightness increases, greater and greater quantities of the stimulus (in this case, luminosity) will be needed to increase it further. From the standpoint of perceptual intensity, the Weber–Fechner law yields diminishing returns as the stimulus increases. From the standpoint of communication engineering, the Weber–Fechner law opens up a host of opportunities for efficiency in the form of signal conservation and compression, precisely because of the assumption of diminishing returns as signal definition increases. The historian of psychology Edwin Boring wrote that Fechner's book 'brought sensation, the representative of impalpable, immaterial, unextended consciousness, under the requirements of measurement' (Boring, 1961: 242). But as Alexandra Hui (2012: 3–21) has recently argued, Fechner's work was actually rooted in German romanticism. Although Fechner's approach still defines modern psychophysics today (and certainly did in the 1950s), it is largely stripped of an original romantic context in order to serve the needs of an objectivist science: 'the *habitus* of the engineers and technicians, who believed in the rationality of their profession and neutrality of their behavior as men of science and technology' (Fickers, 2010: 99).

When the NTSC wrote that the technical basis of their color standards lay in 'the science of color measurement (colorimetry)' (NTSC, 1951–1953a: 42), they placed themselves as heirs to the tradition of 19th-century psychophysics in its modified objectivist form. For our purposes, psychophysics was at once a product of a particular intellectual and institutional history, and a set of propositions about the world that worked pragmatically for the engineers building color television – and eventually, for its users. We leave aside the question of whether the psychophysical models of color perception were the best or correct constructs of human vision for all time – certainly the study of visual perception has changed greatly since the 1950s. What mattered was that for the NTSC engineers, psychophysics' description of visual perception – as it stood in the 1950s – was 'within the true', to use a phrase from Foucault and Canguilhem. That is, any proposition about perception had to fulfill 'some onerous and complex condition before it can

be admitted within a discipline, before it can be pronounced true or false' (Foucault, 1972: 224). Psychophysics provided a theory of perception and a method for studying it. By separating the process of perception from what was perceived, it also excluded a range of questions that would be difficult to operationalize in an experiment or negotiate in a technical standard. Or rather, it offered no direct way to engage with aesthetic questions, even though it operationalized a set of aesthetics in order to test viewing subjects. The assumed subject of color television was always at least partly a psychophysical subject.

The NTSC's colorimetry measured color perception in terms of hue, brightness, and saturation. Whereas the monochrome television signal only required brightness information, color television had to also reproduce hue and saturation. By combining the features of the television production system – its use, for instance, of red, green, and blue, and not yellow – with existing psychophysical research, the Committee sought to exploit psychophysical understandings of the human perceptual apparatus to reduce bandwidth use. This meant transmitting only the lowest necessary amount of the three colors in the signal; the Committee only had to know how much of each color was needed to satisfy the at-home viewer. Since psychophysical theories of the eye suggested that human sensitivity was normally much higher for green than for red, and even less sensitive for blue, the image only needed to transmit a small amount of blue information and slightly more for red to achieve an image that was adequately sharp. The 'low acuity for blue', then, referred to the viewers' reduced ability to perceive changes in sharpness when blue is added to the image. This knowledge, combined with the eventually approved dot-sequential system, allowed the Committee and the American broadcasting system (and much of the world to follow) to fit both a color and monochrome signal in the limited bandwidth available, bandwidth that had previously been allocated entirely for the monochrome signal (NTSC, 1951–1953a).

Panel 11 of the NTSC was tasked with adapting psychophysical testing and the assumed viewer conditions and applying them to the problem of compressing the television signal. This Committee spent its time testing themselves and test audiences to determine the acceptable level of flicker, fuzziness of the image, noise in the picture, and problems in color reproduction. Because the panel's work predated practical video recording, they worked with the Eastman-Kodak company to develop representative slides and a film strip to test these factors. The slides themselves are remarkable for their depictions of idealized middle-class life and whiteness in the 1950s: a young woman holding a kitten; another smiling from behind a net; boys canoeing and playing tug-of-war; potted flowers with a dark background. Their subjects evidence the connection between the technical ambitions behind advances in televisual representation and what Michael Schudson would later call the 'capitalist realism' of advertising – idealized pictures of life 'as it should be' (see Schudson, 1984; we discuss the images in greater depth in Mulvin and Sterne, forthcoming). Within the official language of the engineers, the

content of the slides and the film were subservient to their more technical features. They were meant to depict both commonplace subjects (interiors and exteriors, families, physical activity) and a range of formal properties that a television system would need to reproduce (relations between foreground and background, different kinds of patterns, light and darkness). The fact that these subjects and properties were deeply connected to a particular ideological strand of the visual culture of the time was essentially a given; it was the technical considerations that mattered most. When the Committee first proposed using slides from Eastman Kodak, they stated:

> Since the results of the Panel 11 tests depend on the nature of the equipment or the characteristics of the particular slides used, the Eastman Kodak company has offered to select a set of 24 kodachrome pictures (some being 'average' pictures and some being 'exceptional' pictures). (NTSC, 1951–1953b: 3)

The Committee stated that the images would serve as 'test subjects'. There were, of course, two subjects being tested: the subjective test viewers (often the engineers themselves) and the equipment. The only element shared across laboratories and testing environments was the set of color slides produced by Eastman Kodak. They were the common denominator of both color information and aesthetic quality.

A year into testing, the engineers requested information from Eastman Kodak on the optimal viewing conditions for the slides. Brightness of the images was obviously key, Eastman Kodak replied, but also recommended a completely dark room and a matte screen: 'Ambient light of the same color temperature as the projector light is usually not disconcerting, but daylight would certainly change one's opinion of the color quality on the screen' (NTSC, 1951–1953b: 2). Though the content of the images was meant to reproduce an imaginary vision of future television programming, the test conditions were meant to reflect an ideal laboratory site. While these conditions were chosen for their reproducibility across laboratories, they were quite distinct from the viewing conditions for most American viewers. Ambient light during the day and artificial light at night in the average living room would mean that color images might look quite different for the average viewer than the laboratory subject. The difficulties that some high-definition sets still exhibit with color reproduction under ambient light shows the durability of this separation between artificial lab conditions and the lived experience of television watching. In essence, the ideal subject of television had to be considerably less attentive to color quality than the laboratory subject would be.

Inside these laboratories, the color television image was composed of two factors: its luminance and chrominance, or brightness and color level. Changes in the images' brightness or color levels would bear on the bandwidth requirements of the signal and the subjective perception of the viewer. Since, from the perspective of color perception theory, the green

portion of the signal contained the most information about the image, the monochrome signal was derived from sampling the brightness of green content frame-to-frame. Making sure that the system could reproduce green properly was therefore an integral part of the testing process. As a 1951 paper by MW Baldwin explained: 'the green component is the critical one in the additive 3-color picture'; it was 'just about as critical as the single component is in the monochrome or black-and-white case' (p. 1174). Beyond a certain threshold, the system's ability to reproduce blue (and to a lesser extent, red) became forms of surplus capacity. Reproducing green in the test images was important enough that in 1953 Eastman Kodak was required to produce new slides with additional green content (NTSC, 1951–1953a: 4). By this late point in the Committee's process, seeing green was the surest means of detecting value in the image, by determining where detail could be lost at the lowest cost to the perception of the image.

Perceptual Technics and Television

The entire color TV system was therefore built on a key assumption: there were quickly diminishing aesthetic returns to reproducing and broadcasting lots of blue, or any content that perceptual theories suggested that viewers were unlikely to notice. These aesthetic choices also had economic meaning in terms of conserving that most precious commodity, bandwidth. But it also went further than that. The NTSC not only asked what information was superfluous, they also sought to establish the minimum, necessary information for acceptable color reproduction in the signal. As Donald G Fink explained in 1951:

> *A television system should never be called upon to reproduce an image that is 'more than pleasing.'* This seemingly trivial limit on the required excellence of a television system has profound influence on the cost of rendering the service and the amount of radio spectrum space required. It implies that the system should not have capabilities beyond the reproduction of a satisfactory (pleasing) image, since such capabilities cost dear, in money and in spectrum resources. (p. 1125. original emphasis)[1]

A year later, Knox McIlwain (1952: 910) echoed Fink's conclusion: 'certainly it is wasteful to transmit information which the eye cannot see.' Although Fink attributes his orientation to color photography, this line of thinking almost exactly echoes Bell Labs' attitudes toward speech transmission developed during the 1910s. Bell pursued basic research into hearing to understand the minimum amount of signal the phone system had to pass in order for speech to be intelligible at the other end. This set of questions not only shaped the development of modern psychoacoustics, but also formed an important intellectual basis for cybernetic information theory some decades later (Mills, 2010; Sterne, 2012). Once Bell technicians knew the

baseline needs for hearing, they could design filters that allowed multiple calls to run on a line. By the end of the 1920s, they had technology that would allow four calls to traverse the same line where previously only one had, allowing AT&T to theoretically quadruple its infrastructural capacity, as well as its potential for billing. Through these techniques, AT&T not only incorporated the capacities of its users into its infrastructure, but built its infrastructure to take advantage of their *incapacities*.

In response to a survey question about the specifications for a color TV picture, the NTSC report quotes a Professor AC Hardy, who suggests that knowledge of social practice can go even further than knowledge of perceptual science:

> I propose to answer this group of questions as the head of a household rather than as a scientist. In my own experience with black-and-white television, the ambient illumination seems to depend to a large extent on whether my wife wishes to knit or crochet while watching the program or just relax and watch the program. The quality of the illumination depends upon whether my son is in college or home on vacation. Between us we have one fluorescent desk lamp and one tungsten desk lamp. Sometimes he takes one to college and sometimes the other, and the rest of the family manages to get along with the residue. I can believe that there will be people who will take color television as seriously as some now take high fidelity in sound recording. I believe, however, that it will always be a small group, and that most people will learn to like even bad color. (Fink and NTSC, 1955: 86)

The viewing subjects of color TV were imperfect and distracted subjects in a variety of social spaces, not the ideal, immersed, fully engaged subjects of cinema, art, or print. This is a significant point, because so much visual culture theory is derived from objects – such as visual art and cinema – and subjective situations that are treated as high culture or *as if they are materials of high culture*, and analyzed through a logic of attention, engagement, and immersion. At least in its treatment of color, the larger history of visuality tends to gravitate toward a history of verisimilitude (though this tendency exists elsewhere in the field as well). In other words, visual culture studies – and the larger history of perception – may have found little of interest in color television precisely because it has remained insensitive to the cultural, technical, and perceptual problems that shaped the design of color TV.

Television is quite different from other visual and audiovisual media, in part because of its historical relationship with radio. While radio provided important points of household (Czitrom, 1982; Meehan, 1993), local (Berland, 2009), national (Hilmes, 1997; Verma, 2012), and international identification, a new generation of radio historians has shown that everyday radio listening was considerably more distracted than had previously thought to be the case (Goodman, 2009; Russo, 2010). By the 1930s, radio engineers writing about television already assumed that TV would be caught up in the same routines of everyday life that radio had been, and thus, it would

not always command undivided attention (e.g. Dinsdale, 1932). Even as today television takes on an increasing share of the high culture mantle (or at least high-middlebrow – see Newman and Levine, 2012), classic work in television studies has shown how viewing subjects and texts operate quite differently from those in contexts like film, art, and print. Cultural historians like Lynn Spigel (1992, 2009) and Anna McCarthy (2001, 2010) have shown the degree to which domestic and public viewing of television worked differently from other media, and was often caught up in uneven flows of attention, engagement, and distraction, a point echoed in Rick Altman's still-classic (1986) study of television sound. All of these points are probably well known to readers in television studies. But taken together, they challenge the assumptions and periodizations that still organize prevailing histories of visual culture and color, most of which focus on the richness and definition of color production, and which presuppose an attentive viewing subject.

Here, we build on a growing thread in visual culture studies to consider media in more derisory, everyday forms, and to relativize notions of high aesthetics and contemplation. Jonathan Crary (2001: 13) writes that 'capitalist modernity has generated a constant re-creation of the conditions of sensory experience, in what could be called a revolutionizing of the means of perception.' According to Crary, values of attention (as opposed to distraction) arose in the context of new media and expressive forms of the late 19th and early 20th centuries. Crary problematizes the 'ideal of sustained attentiveness as a constitutive element of a creative and free subjectivity' (p. 2). Similarly, in their introduction to the idea of 'useful' cinema, Haidee Wasson and Charles Acland (2011) argue for a historiography of film that attends to 'functionality' as well as 'beauty' (p. 2) – 'to do something in particular' (p. 3). While they are particularly interested in cinema beyond entertainment, their point applies well to color reproduction in analog television: it operated within a specific institutional context, governed by ethics and imperatives of which beauty, immersion, and definition were only minor threads. Acland's history of the idea of subliminal influence in *Swift Viewing* (2011) tracks popular consciousness of the fact that media often operate at or beyond the threshold of conscious perception. His subjects are obsessed with the possible effects of what might be barely seen in a frame of a film or advertisement. At the exact same time that subliminal influence took off as an idea in American culture, the NTSC's engineers were moving in the opposite direction, using studies of perception and subjective tests to determine what parts of the signal their subjects would not miss. Anxieties about the subliminal were about supplementarity, what else might have been inside the signal. Perceptual technics turned this logic on its head, mobilizing its viewers' measured perceptual limits to supplement the carrying capacity of infrastructures.

Color Television, Compression History and Visuality

As a protocol built around compression, analog color television was a major modality of visual culture in its own right for decades. But it also did much

to set the terms on which the material form of today's fleet of online images and image standards would be composed and the presuppositions around the nature of looking that would be built into them (alongside other media that had to negotiate issues of compression, like telephony and radio, and in different registers, photography and cinema). Beyond images, fonts like Verdana are also designed to negotiate the low resolution of video screens and the known limitation of readers (Coles, 2012). Color TV's politics of infrastructural and visual limits anticipated the material condition of online images today. In his analysis of online video codecs, Adrian MacKenzie (2008: 54) writes that

> many of the complications and counterintuitive orderings of the MPEG-2 codecs arise because they try to negotiate a fit between network bandwidth constraints (a commercially marketed service), viewing conventions (the rectangular frame of cinema and television), embodied perception (sensation of motion, light and color) and cultural forms (fast-moving images or action). They respond to the economic and technical need to reduce the bandwidth required to circulate high-resolution digital pictures and sounds.[2]

All of these issues are present at the birth of color TV: from the management of sensations of motion, light, and color, to the negotiation of network bandwidth constraints and the rendering of cultural forms. As MacKenzie writes, protocols for transmission 'deeply influence the very texture, flow, and materiality of sounds and images … at a phenomenological level'. They lie 'quite a distance from commonsense understandings of perception' (p. 48), especially, we would argue, the still-common humanistic assumption that subjects' faculties are fully available to them at any given time and that the goal of mediatic representation is to reproduce reality in some kind of sensory plenitude or completeness. Sean Cubitt (2011: 30) extends the argument:

> Digital outputs have a much reduced color gamut compared either to normal human vision or to older color technologies like oil paint … the mathematization of color, which began with Newton in the seventeenth century, resulted in its commodification at the end of the twentieth.

We take his point, but push it back half a century. Everything that MacKenzie and Cubitt say about the mess of visual standards online today was being worked out in the emerging standards for color television in the 1950s.

By the early 1970s, the digital transmission of images was already a popular engineering challenge. In one of the first comprehensive anthologies on work in this field, from 1972, the transmission of NTSC-based images was a recognizable reference (Bhushan, 1972). This was not only because of the pervasiveness of the standard but because of a shared use of perceptual

technics in solving the puzzle of how to code color images for limited bandwidth. In Huang and Tretiak's 1972 volume on image compression, Abhay K Bhushan recognizes what the color NTSC had determined years before, that 'efficient coding schemes for transmission of color pictures require only a fractional increase in channel capacity over that required by monochrome transmission' (p. 699). The reason, as we have discussed, is the recognized 'psychological redundancy' and 'the limitation of the human eye to color detail' that animate engineering decisions in the design of visual media. This limitation, writes Bhushan, pointing to the NTSC, 'forms the basis of current practical picture codes such as standards for color television systems' (p. 699). It is not a controversial statement to say that images are encoded with knowledge of human perception. Art historians steep themselves in color theory and artists toy with the optical effects of halftone photography and lithography. Yet the history of the NTSC standard, and its adoption as a practical touchstone for digital processing compels a re-reading of what kinds of encoded knowledge we recognize in the objects of visual culture.

Here, we tip our hats to Marshall McLuhan, who nicely rendered the aesthetic stakes of compression during the heyday of analog TV. In his classic essay 'Media hot and cold', McLuhan (1964: 22) repeatedly cites television as a paradigmatic *cool* medium: 'a hot medium is one that extends a single sense in "high definition." High definition is the state of being well filled with data.' Cool media are *low definition* 'because so little is given and so much has to be filled in'. With the television image, he writes, the eye must 'act as hand in filling in and completing the image' (p. 29). While we leave aside the more psychologistic and deterministic implications he draws from the distinction,[4] McLuhan's description of the low-definition condition of television in 1964 was certainly apt. Derived as it was from the everyday experience of watching black-and-white images flicker on cathode ray tubes and hearing sounds emanate from tiny monaural speakers with cheap transistor amplifiers, McLuhan's description of television as *cool* might well have felt ontological to the end user of 1964. As Michael Z Newman and Elana Levine (2012: 100) explain: 'one unavoidable difference between cinema and television at that time was to be found in their pictures – both in their size and their quality.' Today, the range of television experiences available to the average person reveals television's coolness as a specifically infrastructural and industrial condition, a technocultural articulation (Balsamo, 2011; Slack and Wise, 2006). Amanda Lotz (2007) hails high definition television (HDTV) as a replacement for the 'long inferior NTSC television standard'. She argues that HDTV 'particularly contributed to a technological revolution in the quality of the television experience' (p. 50). But it is not lost on us that Lotz's language restates the advertised aspirations for color television in the 1950s, and further that the aesthetic denigration of a formerly low-definition image is part of the advertising rhetoric for HDTV today. As Newman and Levine (2012: 104) argue: 'much of the cultural legitimacy lent to television by the rise of flat-panel HDTV sets is a product of the gender and class value ascribed to

the technology.' They show how new advertising and journalistic discourses around HDTV articulated it to masculine, high-tech, and high-culture values, while promoters and journalists described the older analog NTSC standard in low-tech, feminine terms. While we agree with Newman and Levine about the gender and class terms of legitimation discourses around television, we also question the assumption of aesthetic superiority of 'hotness' and high definition in terms of the cultural history of technology. Progress toward greater definition is only one possible aesthetic theme in the cultural history of media technologies. In other words, the neglect of color TV, and other lower-definition media like it, reveals a certain bias among media historians that may mirror that of the electronics industry. Coolness in television – especially color television – was an aesthetic that tuned perception to the limits of transmission infrastructure, and tuned transmission to the then-understood limits of perception (for more on McLuhan, coolness and video, see Kane, 2014).

By excavating the decisions that constituted that imagined subject, we place color TV in the longer history of compression in the 20th century. Color TV's history reveals the shape of vital connections between the aesthetics of television and its infrastructural conditions. Color TV employed and then expanded concepts of perception that Bell labs had developed for the transmission of speech through telephony, and it set terms for the discussion of visual technologies that would resonate in later standards for the digital image. Color TV was not the first, the last or the greatest instance of perceptual technics, but the nature of color TV's significance to perceptual history lies as much in its operational standards as in the much more studied aesthetic domains of narrative, programming and representation.

We close with a methodological point on the study of visual culture. Readers will note that we routinely reference the history of sound in our history of color television's visuality. This is neither accidental nor polemical. From Fechner to telephones to computers, many of the central ideas about perception and media in the 19th and 20th centuries were worked out in the auditory realm before they were realized in the visual realm. If Frances Dyson (2009: 3) is right, and 'sound technologies laid the groundwork for notions of immersion and embodiment, the primary figures that characterize new media', they have played an equal or greater role in developing constructs of compression and perception that are essential to the operational routines of new media devices and their infrastructures. We do not have a single, robust explanation for why this is the case, and most of the extant explanations work better as assertions than drawn-out arguments (for a range of explanations, see Attali, 1985; Ernst, 2011; Serres, 1982). But regardless of *why* sound often precedes image in the history of communication technology (though certainly not always, as historians of painting and photography might remind us), historians of visual culture who wish to generalize about perception must think transversally across histories of technologies, culture and sensation. In doing so, they will not achieve a falsely holistic or relativistic account of all the senses, for the

senses are a multiplicity more than they are a totality. Rather, this is the old lesson of cultural studies about context and conjuncture (Grossberg, 2010). To understand the specificities of the visual register in the broader flow of history, we must necessarily reach beyond visuality to find the forces that produce and condition it.

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Notes

1. We suspect the same claim could be true for 19th-century media and earlier, but to make that argument properly would require a different article.
2. In a footnote to this passage, Fink clarifies that his notion of pleasure is drawn from psychophysics, as 'giving pleasure in general' and not 'the emotional reaction to particular program material'. Although this distinction warrants some scrutiny, our own bandwidth limitations for this article require that we pursue it elsewhere (Mulvin and Sterne, forthcoming).
3. Though we can only take this so far. The operational dynamics are of course different in a digital environment. As MacKenzie (2008: 52) points out, the discrete cosine transform (DCT – on which online video is based) handles the sequencing of images in a manner wholly different from film or TV. See also Sean Cubitt's (2011) discussion of cathode ray and digital imaging technologies.
4. McLuhan's own notion of *definition* is quite unclear from the essay and his categorizations occasionally seem arbitrary. Scholars of the voice, for instance, would dispute his description of speech as cool and low definition (Cavarero, 2005; Dolar, 2006); scholars of radio would likely dispute his description of radio as hot and high definition (Goodman, 2009; Russo, 2010; Verma, 2012).

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