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Human Color Perception, Cognition, and Culture: Why "Red" is Always Red

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This article is an overview of color vision and color perception from an evolutionary and anthropological perspective. It is intended for an audience with no prior background in either of these fields of study. This is an effort to provide a general overview of some the more recent significant works regarding color vision and perception, in an evolutionary framework, that is accessible to a general audience. Though it is intended to explain some of the general dynamics of a detailed and complex history, this cannot be considered an exhaustive overview, but a general description of some of the fundamental anthropological and evolutionary understandings of color vision and perception.

The Beginning of Color

The Evolution of the Eye

Color vision is not uniquely human, nor did it evolve in isolation. It is the result of a very deep history within a dynamic world of color and light, which began long before our vertebrate ancestors left the oceans some 370 million years ago. To understand color vision and perception among modern humans, we must first take a glimpse at the ancient history of vision and the workings of the eye. An eye fundamentally "sees" by the use of photoreceptors which convert light into nerve signals. Color vision is due to a certain class of specialized photoreceptors that not only detect light, but detect and distinguish specific wavelengths of light (colors). These color photoreceptors, often called cones, are attuned to different color wavelengths by way of pigments known as photopigments. One of the fundamental components of these photopigments is a type of protein called an opsin, which has the primary role of tuning color photoreceptors to specific wavelengths of light. Though each type of color-specific photoreceptor can detect a limited range of colors, each is most responsive to a specific wavelength of light, referred to as its absorption maxima. For example, many diurnal butterflies have three types of color photoreceptors: an ultra-short wavelength cone which has a maxima at 360nm (tuned to ultra-violet), a short wavelength cone with a maxima at 440nm (blue-violet), and a long wavelength cone at 588nm (yellow-orange). Though the maximum for each of these cones is a specific wavelength (color), each cone type can actually detect colors within a range near the maximum (e.g., the yellow-orange cone can detect yellow-greens, yellows, oranges, and some nearby reds).

There have been at least ten optically distinct eye types identified among modern and ancient animals.[1] However, recent studies on the genetics of opsins have pointed to a common ancestor of color vision.[2] The claim is that the varying types of opsins (which offer the varying spectral types of color photoreceptors) can be traced back to one ancestral type.[3-4] By comparing the genes responsible for the synthesis of opsins, across

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numerous species, this common ancestor has been dated from 500 to 800 million years ago.[2-4] The basis for color vision may be as old as the first primitive eyes. The fossil record itself does not extend much beyond 600 million years; numerous species of Cambrian Period fossils from the Burgess Shale (570 million years ago) show the presence of eyes, some complex enough to suggest an already rich history of the evolution of these organs. The use of opsins to focus photoreceptors to specific light wavelengths was likely already underway by the Cambrian Period.

To perceive and distinguish colors, more than one type of color photoreceptor is needed; color perception is a comparative sensory phenomenon, in which signals from more than one type of color photoreceptor are cross-referenced.[2] Many animals have only one type of color photoreceptor, which does not actually permit the perception of color, but allows a greater distinction of gradients of what we would call grey. These animals are referred to as monochromats. More than one type of color photoreceptor is needed to cross-reference signals, to determine specific colors. Mutations in the genes for the single ancestral photopigment likely gave rise to two distinct "spectrally-tuned" types of photopigments, allowing this cross-referencing process to happen.[2] A small number of amino acid changes (only seven) in photopigments are needed to shift a photopigment sensitivity by 30nm.[2] Monochromats tend to see a range of greys, and are able to identify about 200 discrete gradients.[2] However, dichromats (having two color photoreceptor types) can distinguish around 10,000 colors.[2] The addition of each new photoreceptor spectral type expands the palette of discernable colors at a geometric level. Humans have three cone types and have a palette of around 1,000,000 distinguishable colors—we are trichromats.[2] From a sorted evolutionary history, humans have not come to be the apex of color vision in the world animals—we are only trichromats. Some non-mammalian diurnal vertebrates are tetrachromats. Many fish and birds have four types of photopigments, including a photopigment tuned to ultra-violet.

The Evolution of Human Color Vision

Blue and yellow dichromacy is the ancestral mammalian color vision.[5] The first primitive mammals, around 220 million years ago, are believed to have been nocturnal.[2,5] The proposal is that mammals lost two of the four photopigments that we once shared with our non-mammalian ancestors, given that color vision offers little benefit to a nocturnal lifestyle.[2,5] Within the last 100 to 150 million years, diurnal mammals emerged from the darkness, with only dichromatic color vision—limited to blue and yellow.[5]

Humans and our closest of kin, the Great Apes (Gorillas, Chimpanzees and Bonobos, and Orangutans) and our next closest of kin, the Old World Monkeys (Baboons, Colobus Monkeys, Rhesus Macaques), are the only mammals known to have color vision beyond dichromacy.[6] Trichromatic vision evolved a second time in our neighborhood of the primate and mammalian worlds.[6] Of the two mammalian photopigments we began with (yellow and blue), the medium wavelength photopigment (yellow) diverged to become two separate spectral types: a medium wavelength (green) and a long wavelength (red), thus offering us a greater spectral range, as well as an exponentially greater ability to distinguish between colors.[7] The time of this divergence has been calculated to be about 50 million years ago, which is consistent with calculations for the division between Old and New World Monkeys (60 million years ago).[2,5] These three photoreceptors of humans (and our relatives) are often referred to as blue, green, and red, but they can be more specifically described as: short wavelength (maxima at ~420nm, which is actually blue-purple), medium wavelength (maxima at ~525nm, which is green), and long wavelength (maxima at ~560nm, which is actually yellow).

Some explanation for why this shift to trichromacy happened among our branch of primates has been explained by recent works in genetics. In a recent study, Gilad et al. found that the emergence of full trichromatic color vision among humans and our next of kin corresponds to a significant reduction in our sense of smell.[6] The genes that code for an articulate sense of smell comprise the largest gene family of the mammalian genome.[6] When compared to the genome of other mammals, almost 60% of the genes responsible for the acuity and range in olfactory perception (sense of smell) have been "shut of" in our species;[6] among the Great Apes, 33% of these genes have been "shut off."[6] An interesting exception to this "re-evolution" of trichromatic vision is the Howler Monkey (*Alouatta caraya)*; it is the only New World Monkey to have

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also developed trichromatic vision.[6] It appears that it developed trichromatic vision independently of the Old World Monkeys, though likely for the same reasons. Similar to humans and other Old World Monkeys, Howler Monkeys appear to have lost a significant proportion of their sense of smell (31% of the associated genes have been "shut off").[6] The co-occurrence of the loss of smell and the development of a more fine-tuned sense of vision cannot be definitively explained in a manner of cause and effect, but can be summed-up as a shift in our primary senses—a change to a greater reliance on sight and hearing than smell.

The Natural World of Color

The Natural Language of Color Among Plants

Our species, *Homo sapiens sapiens*, evolved within a very dynamic world of color. To better understand some of our most fundamental associations with color, we must understand the colors of the natural world that shaped our species. Nature has developed a language of color, which is not only employed in communication within a species, but across species (and even across entire kingdoms of life). When examining the human relationship with color, we have to consider that part of the "hard-wiring" of our species is to understand and respond to this natural language of color. Nature tends to use color for communication for four basic purposes: to attract or repel members of the same species, and to attract or repel members of different species. These communications can be defined with even greater precision:

- (among plants) to attract (a) pollinators or (b) propagators
- (among animals) to attract prey, either by (a) camouflage, or by (b) decoy
- to avoid predators, either by (a) warning, or by (b) camouflage
- mating purposes – (a) attracting the opposite sex (intersexual attraction), or (b) intimidating the same sex competitors (intrasexual competition).

Being an omnivorous species, trichromatic vision offers great advantages to humans. Many plants have developed mechanisms for the propagation of their seeds, namely fruits. There are many plants that have not co-evolved with specific propagators, but instead send out a "general signal" to a range of interested parties—by developing a fruit with both a bright salient color and a strong and recognizable smell. Having a bright color and a rich smell is a way to "hedge bets"—attracting propagators that may have a keen sense of smell but limited color vision, or vice-versa.[8] Fruits (or structures developed to serve similar purposes) tend to have rich, salient colors that contrast with green foliage: reds, pinks, bright oranges, and yellows. Ethylene gas is a component in the strong, "fruity," smell emitted by most ripening fruits—it is a recognizable note common to fresh strawberries and raspberries, fresh melon, ripe figs, and cut apple. There may have been an evolutionary advantage to sight over the sense of smell, perhaps offering our ancestry a greater ability to find fruits from a greater distance by sight alone.

In a strategy similar to fruits, flowers attract pollinators by color, scent, and even shape—both visual and olfactory signals are broadcasted. Many flowers that emit strong odors, and that are colored blue, purple, pink, ultra-violet, yellow tend to be adapted to diurnal insect pollinators —these colors reflecting the range visible to most insects (especially bees (Apis sp.) and their closest relatives).[9] The honeybee (Apis mellifera) has three types of photopigments: an ultra-short wavelength (350nm, ultra-violet), a short wavelength (440nm, blue), and a medium wavelength (540nm, green). Flowers in the range of reds, rich oranges, and bright pinks (and lacking strong scents) tend to be pollinated by birds.[9] Most diurnal birds have the ability to distinguish reds, which insects such as bees do not[9]. Some studies have found that birds that rely on nectar, such as hummingbirds, do not necessarily show innate preferential interest in red flowers over other colors.[9] However, other competitors such as bees have little ability to distinguish the red flowers from surrounding foliage, and thus the red flowers are more available to birds. This is an evolutionary strategy to select birds as pollinators over insects—likely because birds tend to have a greater degree of outcrossing (spreading pollen from one plant to another) than bees (which may only spread pollen from one flower to another on the same plant).[9]

The Natural Language of Color Among Animals

Numerous studies on the relationship between human color perception and food have been undertaken by marketing researchers, food scientists, and perceptual psychologists. With regard to innate associations between color and flavor, the majority of the results are either inconclusive or conflictory.[10-11] However, what can be concluded from these studies is that color associations with food is a conditioned relationship—the product of one's life experience. The majority of tests that claim to demonstrate that certain colors are unappetizing actually demonstrate that uncharacteristic or unexpected colors added to foods makes then unappetizing.[10-11] This suggests that we indeed make associations between colors and expected flavors, however these associations are acquired through experience.[10-11] This can been understood on an adaptive level, given our omnivorous history. It may be beneficial to avail ourselves to novel foods, by not being committed to innate associations and preferences with particular food appearances. Acquired personal associations between certain colors and foods may serve as a protective measure—we may try novel foods, but we develop associations with foods that we consume regularly and know to edible and safe.

There has been a noted difficulty with the use of blues in processed foods, and it has often tested as one of the most unappetizing colors.[12] The generally unappealing nature of blue does not conflict with the conditioned color/food relationship noted above. Given that our color associations with expected flavors, etc. are learned, and that nearly all natural foods are not blue, this aversion to blue foods is the product of a palette with no known natural blue references. What are called "blueberries" in English are not in fact very blue, but a deep indigo-purple. Only a few rare examples of cultural practices of dying foodstuffs blue exist, likely because most naturally available blue dyes are either unpalatable, rare, or unstable. Anthocyanin, which is a common natural pigment in flowers, is responsible for a range of blues, purples, and pinks. It is susceptible to change with acidity—this blue dye is somewhat unstable and readily turns pink in even slightly acidic environments. However, there are certain colors of blue that are naturally associated with food—they tend to appear in the context of decay and mold. Future research in the relationship between the color blue and food may clarify a possible innate avoidance of this color, in terms of instinctive aversions to unsafe foods.

Typee of natural color signaling that could be considered the closest to a natural "universal language" among animals are the colored warnings of venomous bites and stings, or the warnings of a highly developed passive defense: being poisonous to eat. A few examples of this common warning pattern are: the Banded Sea Snake (Laticauda colubrina), Coral Snakes (Micrurus sp.), the Lionfish (also called the Turkeyfish) (Pterois sp.), the Red-Headed Centipede (Scolopendra heros castaneiceps), bees (Apis sp.) and their closest relatives (wasps, yellowjackets, etc.), and Arrow-Poison Frogs (Dendrobates sp., Atelopus sp.). All are either venomous or are poisonous to eat (or even poisonous to touch); their shared color pattern could be considered a vibrant and blatant advertisement of toxicity—a universal display to warn any potential predators. All of the above examples share a similar, somewhat universal, warning display—liberally employing the colors that are most salient to dichromats (yellow) and/or trichromats (red). A striped pattern of black (or white) is a way to provide an intense signal even to monochromats—a pattern that is also salient when only perceived in greyscale. This general pattern of black stripes with red, yellow, or white (or combinations of three or more of these) could be considered as close to a "universal warning" as mother nature offers. This pattern of color is salient at multiple levels of color vision, or even lack of color vision. What is noteworthy about the above examples is that they all share a similar warning pattern, though nearly each example evolved this signal independently. A few examples of similar patterns, which have evolved for very different reasons, should be noted. Zebras also have black and white stripes, and tigers have black on an orange/yellow background. These patterns have different functions—the zebras' stripes interfere with a predators' ability to visually isolate an individual zebra from the surrounding herd. The tiger's stripes serve as "disruptive camouflage"—breaking up the "large cat shape" as it walks through underbrush and grasses.

Humans have independently developed a similar pattern of color and contrast to attract attention. The most recognizable uses of this pattern are on safety labels and signs, and even taxicabs. Most of us recognize the reflective yellow and black stripes used to label dangerous parts of equipment, dangerous areas, and other warning signs. The traditional design of taxicabs employs the same pattern—a yellow background with a black and white checkered band across the midsection. The independent development of this pattern by humans demonstrates our sensitivity to certain natural universals of color and perception.

Though the above warning pattern could be considered a lingua franca message—understood across numerous species of the animal kingdom, there are also "specific languages" of color within a species. We see color signaling by numerous species of birds, fish, cephalopods (octopi, squid, cuttlefish, etc.), some diurnal reptiles, and insects, in which the signals of color convey messages to members of their own species. The most common purposes for these signals are to display fertility or sexual receptivity, or as displays to compete with members of the same sex for mates. Many of these "species-internal messages" which are signals for mating, fitness, and fertility are only understood by other members of the same species. The number of iridescent spots a peacock has on his tail is a message only understood and appreciated by the peahen—the number of spotted tail feathers a peacock bears is understood as a sign of fitness to the peahen, and males with more of these spots mate more often.[13]

Humans are not separate from the animal world, in terms of color and communication. In fact, humans may have evolved some color variations across the skin for the sole purpose of communication. Population skin color is the direct product of latitude (and thus sun exposure)—populations that have had a significant history near equatorial latitudes have darker skin pigmentation as an adaptation to significant exposure to sunlight. It has been noted that though the skin color tends to be uniform—from the ankles to the scalp—there are notable exceptions: the palms of the hands and the bottom of the feet. The palms of the hands are exposed to at least as much sunlight as the inner thigh or outer ear canal; however, palms, fingertips, and fingernails remain notably lighter than the rest of the skin and even seem to resist tanning.[14] One proposal is that this lightness is due to communication needs—that the hands have played a significant role in gestural communication for a long period of human history.[14] Lighter colored palms and fingers, contrasted against the darker skin of the body, provides more salient signaling devices. If this proposal is correct, our own hands are a testament to the role that gestures have played in the history of human communication.

The Human World of Color

The First Human Colors

Our species is defined as "anatomically modern" as of 100,000 years ago; at this time, humans physically appeared the same as we do today. However, it was only 50,000 years ago that we could be described as "behaviorally modern"—humans began to behave technologically and culturally like people today.[15] Artifacts from 50 thousand years ago display the beginnings of art, the use of complex tools, and even the signs of cosmology.[15] This period could be considered an incredible pan-human renaissance. A remarkable finding is that the first art to appear was polychromatic[15].

In human cognitive development, the signs of art and color appeared simultaneously. There is no evidence of a "monochromatic phase" in early human history—use of color appears to have been a legitimate channel of communication from the very beginning of art and symbolism.[15]

It is likely that at this time in human history, the distinctions between colors may have been quite small in number. Though several distinct colors were employed in Paleolithic cave art, this does not require that each of the colors was given its own specific name or recognized as canonically different from others. The colors of cave art can be described as the product of mimesis—simply copying what one sees, which does not necessarily require having a name for what one sees. Modern linguistic evidence substantiates this possibility—though small in number, there are cultures today which have only two basic color terms. The Jalé in Highland New Guinea have only two basic color terms: hóló, which could be glossed as "brilliant," and sing, which could be glossed as "dull."[16] The term hóló appears to encompass the colors that we call white and yellow, and likely covers the lighter ranges of blue and green; the term sing names black and red and likely the darker ranges of blue, green, purple, and brown.[16] Among the Tangma of New Guinea, the two basic color terms are mola and muli. The term mola encompasses the "brilliant" colors white, red, and yellow,[16] and muli encompasses the "dull" colors black, green, and blue.[16] Along with Jalé, three other Damian family languages (New Guinea) have been found to be two color term systems also.[16] These limited systems do not reflect a physical impairment of color vision across the population, but appear to be the product of adaptive need (or lack of need). In simple terms, their cultures and environments have not provided significant pressures which would warrant the distinctions between certain colors.

Basic Color Terms and Perception

In their study, Berlin and Kay set a foundation for current understandings of the relationship between color perception and language. They compared basic color terms collected from 20 languages (from several distinct, unrelated linguistic stocks), and further supplemented their comparison with basic color terms from 98 languages previously collected by other linguists and ethnographers.[16] Their comparison focused on basic color terms. These can be defined as a class of words which canonically identify colors, which (a) are not composed of names of other color terms, (b) cannot be classified as a subset or variant of another color term, (c) are not specific to a particular object or substance, (d) and which are known and clear to all speakers of a language.[16] The English language has 11 basic color terms: black, white, red, green, yellow, blue, purple, orange, grey, pink, and brown.[16] Some examples of what are not basic color terms are: blonde (this term is specific to hair color), chartreuse (this term is not used or known by all speakers of English), blue-green (this term is composed of two other basic color terms), brownish (this term is a derivation of a color term), scarlet (this can be considered a specific color within/below the broader basic color term, red).[16]

To elicit basic color terms from informants, they used a Munsell color chip chart, of 329 color chips (320 chips of 40 equally spaced hues and 8 degrees of brightness, all at maximum saturation, and 9 chips of neutral hue).[16] Basic color terms were elicited from informants, then the boundary of each term was identified, and then the focus of each term was identified.[16] The focus of a color term is what the informant determines to be the single best exemplar of that basic color term. For example, an English speaker will offer red as a basic color term, then will determine which color chips are considered red and not-red (the boundaries of red) and then decides which specific chip (within the broad field of what they defined as red) best exemplifies red—which chip is "the reddest of the reds".[16] These foci were originally used by Berlin and Kay to refer to the different levels of term systems—a two color term system is called black and white; a three term system is black, white, and red.[16]

Berlin and Kay identified a pattern in the way languages develop new color terms, which suggests an evolutionary progression. This progression occurs in a regular and systematic order.[16] The most fundamental distinction is between black and white—all languages have this distinction, there is no "one color term system."[16] If a language has only two basic color terms, the spectrum is divided along the lines of "brilliant" and "dull" colors (also called "warm" and "cold" colors; called "black" and "white" in the Berlin and Kay study) as exemplified in the Jalé terms above. If a language has only three basic color terms, the spectrum is not divided along the lines of brilliant, dull, and intermediate. The novel third color term is actually a distinction of red (the focus of this color term is what we would call red in English). Red is the first color to receive recognition aside from the other colors.[16] This may be linguistic evidence for the salience of red and its importance to human survival.

Most of these three-color term languages exist in Melanesia, Australia, and Africa.[16] An example of a three-color term language is Tiv, a Bantoid language from Nigeria.[16-17] In Tiv, the three basic color terms are: ii, which encompasses all greens, some blues, and some greys; pupu, which encompasses very light blues, light greys, and white; and nyian, which encompasses red, some browns, orange and yellow.[16-17]

An interesting note about red, as one of the most fundamental color terms, is that numerous examples of the words for red appear to be derived from the word for "blood."[16] In Mid-Grand Valley Halyhalymo: mepmep 'red' and mep 'blood;'[16,18] in Nasioi: esereng 'red' and ereng 'blood;'[16] in Queensland Aboriginal: oti 'red' and oti 'blood.'[16,19] At least in some examples, the early distinction of red may be related to the cultural significance of blood, human or animal.

The stages of complexity (and acquisition of novel color terms) among color term systems identified by Berlin and Kay can be summed as follows:

- Two-term systems distinguish black and white (as all languages do) and divide the spectrum along the lines of brilliant and dull colors.
- Three-term systems distinguish black, white, and red and divide the spectrum along lines similar to the two-color system above, yet isolating red and similar colors (yellow, orange, some browns) in a discreet category.
- Four-color systems tend to distinguish blue and green as their own discrete category, though they do not distinguish between blue and green. There are a smaller number of examples in which yellow is distinguished as a fourth color term before blue/green. Similarly, there are also a small number of examples in which blue/green is then the fifth color term developed. There are no identifiable examples of the simultaneous acquisition of yellow and blue/green, both appear to be acquired in separate stages.[16]
- Five-color systems distinguish between black, white, red, blue/green, and yellow; they are found in a large number of languages, in Africa and the New World (a large percentage of New World languages are five color term systems).[16]
- Like the previous stages, six-term languages bear all of the distinctions of the previous stages, with an additional distinction: differentiating between blue and green.
- Seven-color-term languages contain all previous distinctions (black, white, red, green, yellow, and blue), with the addition of brown.
- Systems with eight or more terms tend to acquire the remaining terms almost simultaneously: orange, pink, grey, and purple. The maximum number of color terms identified for any language is eleven.[16]
- There is ongoing analysis and consideration for a few twelve-color term systems. Russian and several other Slavic languages appear to have two basic color terms for what is referred to as blue in English; in Russian, these are goluboy, which encompasses light blues, and siniy, which encompasses the dark ranges of blues.[16] There is still debate about the etymology of these words and whether or not they fit the criteria of basic color terms.

Another correlation noted by Berlin and Kay is that of general cultural complexity (complexity of social order and complexity of technology) and the complexity of color term systems.[16] This correlation can be described in terms of a direct relationship between color and technology. Though a society may have arisen in a very color-rich environment, it appears that the complexity of interaction with the environment, and the related technologies employed by the culture, dictate what color terms are necessary (how specific one needs to be about colors). That is not to say that societies with only two or three basic color terms have no other words that refer to colors—most have rich vocabularies of terms for colors, however, they tend to be case-specific (used for only particular substances or only in specific contexts). The number of basic color terms simply demonstrates that distinctions between certain colors are not universal, and that greater specificity among color terms is not entirely requisite for human survival. The pattern of acquisition of color terms (the predictable nature of the acquisition of additional color terms) does demonstrate a universal in the prioritization or ranking of colors and their relative salience with respect to one another.

The Hering Elementary Colors and Perception

Another line of study which has offered insight into human color perception was initiated by Ewald Hering in 1878; he generated the foundation model for understanding color perception beyond the retina of the eye. Hering proposed opponent-process theory, which explains much of color perception in terms of how signals from the eye are transmitted and perceived. The opponent-process model considers that though the eye has three types of color photoreceptors (blue, green, and red), the signals sent to the brain travel along three channels: one that transmits light and dark, one that transmits red and green, and one that transmits blue and yellow.[20] With regard to the color-specific channels, each channel transmits only one of the two colors at any given time. When the red-green channel is excited, red is perceived; when this channel is inhibited, green is perceived; when the signal is balanced between excitation and inhibition, the result is achromatic—no color is seen. This process is identical for the blue-yellow channel. This model explains why red and green are not perceived simultaneously, and why blue and yellow are also reportedly imperceptible together. These four colors are considered unique in terms of this model—they are not composed of other colors. The specific unique colors can be identified by, for example, testing differing types of red—the red that does not have any perceptible traces of the other unique colors (such as red with some detectable traces of yellow) can be considered unique. Colors such as purple and orange can be considered binary—they are perceptually composed of other identifiable colors (namely, red and blue, red and yellow). The four unique hues combined with black and white (the achromatic colors of the light-dark channel) are termed the Hering Elementary Colors.

Though the Hering Elementary Colors can be considered meaningful in terms of some of the mechanical aspects of light perception, they do not readily parallel basic color terminology data (and the underlying cognitive processes that shape these data). There has been the assumption that the (chromatic) Hering Elementary Colors are perceived as equally distinct from each other. However, a study by Berlin et al. has revealed that the four (chromatic) Hering Elementary Colors are not perceived as equally salient or distinct from each other.[21] Red and yellow are perceived as qualitatively more "alike" than either is to green or blue, and the qualitative relationship between green and blue is closer than the relationship between red and yellow.[21] This dynamic is exemplified in the pattern of color term acquisition identified by Berlin and Kay (see above). As a novel color distinction (a novel basic color term) is made, the next "most distant" relationship will dictate which color will be distinguished next. It is likely due to the salience of red (in other terms, that it has a greater total distance from the other three colors) that it is the first to be recognized—though in simpler color term systems, it is merged with yellow in the earliest stages. This red/yellow set is the first to be distinguished. In the majority of examples, the blue/green partnership is the next to receive distinct recognition. Then, the next most distant relationship, red and yellow, separates and yellow receives distinction from red. Then, the closest relationship between these four colors, blue/green, is finally severed and blue becomes distinct from green.

Summary

Human color vision and perception begins long before human history, and even long before the history of vertebrates. Recent evidence suggests that the basis for color vision may be between 500 to 800 million years old. Our first mammalian ancestors, between 220 million and 100 million years ago, lost much of the full color vision appreciated by other vertebrates, given that they had taken to the safety of nocturnal life. The more recent ancestor of humans and their next of kin "re-evolved" full color vision, giving us a world of full color, instead of the limited blues and yellows of other mammals. This ability to see a greater volume of colors coincided with the loss of much of our sense of smell—committing us to a greater reliance on our eyes than many of our fellow mammals. The new ability to see red gave us and our next of kin a great advantage—greater ability to see fruits, as well as the warning colors of nature. The earliest examples of human art demonstrate the use of color. To humans, the use of color as a channel for communication is as old as art. Though humans have the ability to see a great range of colors, comparisons of human languages demonstrate that we do not necessarily all make the same distinctions between colors, nor are all of these distinctions necessary for our survival. However, distinguishing red from other colors is one of the first, second only to a fundamental division between black and white. Though color distinctions may vary among populations, they are varied in a predictable and regular fashion, which may reflect human perceptual universals.

References

1. R. D. Russell, "Evolution of eyes" Current Opinion in Neurobiology **10**: 444-450, 2000.
2. J. Neitz *et al.,* "Color Vision: Almost Reason Enough for Having Eyes," Optics & Photonics News Jan: 26-33, 2001.
3. J. Nathans *et al.,* "Molecular genetics of human color vision: The genes encoding blue, green, and red pigments," Science **232**: 193-202, 1986.
4. C.W. Oyster, The Human Eye: Structure and Function. Sinauer Associates, Inc. Sunderland, MA, 1999.
5. G.H. Jacobs, "The distribution and nature of colour vision among the mammals," Biological Reviews **68**: 413-71, 1993.
6. Y. Gilad *et al.*, "Loss of olfactory receptor genes coincides with the acquisition of full trichromatic vision in primates," PLoS Biology **2(1)**: 0120-0125, 2004.
7. L.T. Sharpe *et al.,* Color Vision: From Genes to Perception, Cambridge University Press, New York, NY, 1999.
8. P. Sumner and J.D. Mollon "Chromaticity as signal of ripeness of fruits taken by primates," Journal of Experimental Biology **203**: 1987-2000, 2000.
9. M. Rodríguez-Gironés and L. Santamaria "Why are so many bird flowers red?," PLoS Biology **2(10)**: 1515-1519, 2004
10. H.R. Moskowitz, "Taste and food technology: Acceptability, aesthetics, and preference," Handbook of Perception, Via: 158-193, 1978.
11. L.L. Garber *et al.,* "Placing food color experimentation into a valid consumer context," Food Quality & Preference **14(1)**: 41-43, 2003.
12. T. Hine, The Total Package. Little, Brown and Company, New York, NY, 1996.
13. Amotz Zahavi and Avishag Zahavi, The Handicap Principle: A Missing Piece of Darwin's Puzzle. Oxford University Press, 1997.
14. G. Hewes, "The current status of fhe gestural theory of language origin," Origins and Evolution of Language and Speech **280**: 482-504, 1976.
15. R. G. Klein and B. Edgar, The Dawn of Human Culture. John Wiley & Sons, New York, NY, 2002.
16. B. Berlin and P. Kay, Basic Color Terms: Their Universality and Evolution. University of California Press, Berkeley, 1969.
17. P. Bohannan, Social Anthropology. Holt, Rinehart, and Winston, New York, NY, 1963.
18. M. Bromley, "The linguistic relationships of grand valley dani: A lexico-statistical classification," Oceania **37**: 286-308, 1967.
19. W.H.R. Rivers, "Introduction and vision," Reports on the Cambridge Anthropological Expedition to the Torres Straits, (A.C. Haddon ed.), Vol. II, part 1, 1901.
20. E. Hering, (translated by L.M. Hurvich and D. Jameson) Outlines of a Theory of the Light Sense. Harvard University Press, MA, 1878, 1964.
21. B. Berlin *et al.,* "Merrifield color term evolution: Recent evidence from the World Color Survey," Presented at the 84th Annual Meeting of the American Anthropological Association, Washington D.C, 1985.

From the Editor's Desk

Book reviewers needed!

Many current and forthcoming books cover subjects of interest to our membership. We would like to publish more reviews, and to do that effectively we need to enlist the help of members who are well qualified to write them. We do not offer an honorarium to reviewers, but each reviewer is entitled to keep the book after writing its review.

If you are interested in participating in the review process, please drop me a line describing your particular interests and expertise. We'll forward to you the publisher's description(s) of books in your field and have a book sent to you only if you express interest in writing its review. Typical review length is 1,000 to 1,500 words.

With sincere appreciation,
Vivian Walworth, editor
(vwalworth@comcast.net)

To the Editor:

I am writing these observations shortly after returning from this year's outstanding IS&T/SPIE Electronic Imaging meeting in San Jose, CA. For me a highlight of the meeting was the Human Vision Conference banquet, organized by Conference Co-chairs Bernice Rogowitz, Thrasyvoulos Pappas, and Scott Daly. The featured after-dinner speaker was Professor Stanley Klein of UC Berkeley, who addressed issues at the interface of science and religion in a most entertaining and thought-provoking fashion.

Klein's thesis, following Einstein, is that modern science and liberal theism are natural, intellectually-compatible allies necessary to each other. In other words, science can define problems and propose solutions; religion, where compatible with science, can provide the motivation and the value construct in which the potential of science for the good of humankind and the planet can be realized. Scientists must also have a spiritual life, lived in community. As used by Klein, liberal theism refers to any religious viewpoint, regardless of cultic tradition, which posits the reality of the divine, but rejects as essential to its belief system any literally "revealed truth," paranormal phenomena, or miraculous intervention. Liberal theistic communities are characterized as accepting of and compatible with each other, regardless of the traditions from which they may have evolved (Judaism, Christianity, Islam, etc.) and whose ritualistic expressions they may continue to use.

I could flesh out Klein's thesis with a couple of examples from my own life experience. First, in the 1960s I had the privilege to be working in Washington, DC, at the time Dr. Martin Luther King, Jr., led his famous March on Washington. (Coincidentally the Human Vision lecture was delivered on Martin Luther King Day this year!) While I completely supported the aims of the March, I didn't see any need to take part personally. My logic, or lack thereof, was quickly challenged by fellow members of the faith community in which I participated, and with their encouragement I became an active supporter of the civil rights movement. Second, in recent days my wife and I attended an interfaith memorial for victims—dead and surviving—of last December's Indian Ocean Tsunami. From this experience of immersion in gamelan orchestration, Buddhist chanting, Ojibway drumming, and the music of Johan Sebastian Bach, accompanied by words of encouragement from rabbis, pastors, and imams, we came away motivated to increase significantly our monetary commitment to Tsunami relief efforts. In other words, the experience of ritual, prayer, and meditation focused our thoughts and translated into concrete, useful action.

Discussion among attendees of Klein's talk raised the issue of intellectual honesty or integrity; was he calling on people to give lip service to an ideology to which they could not honestly assent? We didn't have time to talk through this issue to any point of resolution, but it has been addressed admirably by Erich Schumacher, the former head (1960s) of the British Coal Board and one of the founders of the sustainable growth movement. The principles of the latter were laid out in his famous book *Small is Beautiful*, but my interest is more with an earlier book of his—titled with obvious reference to Maimonides' medieval treatise—*A Guide for the Perplexed*. His thesis here is that in order to make sense of our life experiences and learn how to respond to them, we need to use a set of assumptions, just as we usually need a set of assumptions to interpret the data from a laboratory experiment. These assumptions may or may not be true, and as new data become available the assumptions may need to be rejected or revised. Every one of us makes and uses such assumptions in life, whether we realize it or not. In religion, the set of assumptions—whatever they may be—is called "faith" and the process of testing them against reality, revising them, and thereby growing in understanding is called "the spiritual life." A life lived in this way, consciously reflected upon, is thus an example of the scientific method in action; hence the compatibility of science and (liberal theistic) religion.

In my experience the practice of science provides excellent discipline for the spiritual life, helping keep the latter grounded in reality. As rational people we don't make assumptions in science, religion, or any other aspect of life because we have been convinced by some external authority that they are true, but because they may be useful to us as a starting point—and only as a starting point—in understanding the data of life experience. Admittedly, the wisdom of those who have gone before us may help us select assumptions that may prove of value in our undertaking. In science we find this wisdom in the literature; in things spiritual we may look to Plato or Aristotle, Jesus or Mohammed, Lao Tze or the Buddha.

To my hearing, Klein was specifically asking us to make those assumptions which can lead us into situations (community participation, liturgies, etc.) that provide us with the direction and motivation we need to employ our scientific expertise for the good of the planet and of humankind. Without making the right starting assumptions these things just won't happen.

My thanks go to Drs. Rogowitz, Pappas, and Daly for arranging the Human Vision Conference banquet and for providing this wonderful experience for all of those present.

—M. R. V. Sahyun

David Q. McDowell, Editor

This issue of Standards Update touches on a number of recent activities of CGATS, TC130, TC42, and CIE.

PPML/VDX

ISO 16612-1, *Graphic technology—Variable printing data exchange—Part 1: Using PPML 2.1 and PDF 1.4 (PPML/VDX-2005),* was approved at the DIS level with no negative votes. This means that it can go directly to publication once all comments have been resolved.

However, there are still some pieces missing that are needed to facilitate the implementation of this standard.

One of the most important pieces, being developed by CGATS/SC6/TF2 (the CGATS committee working on this standard in parallel with the ISO effort), is the definition/identification of reference characterization data specifically for variable data printing.

Preliminary gamut testing indicates that three reference color characterization data sets are adequate to define the data exchange for high speed digital printing devices.

The proposed gamuts and their descriptions are:

1. Reference color characterization data set 1 (largest color gamut)—Grade 1 substrate (white point) and typically high gloss image characteristics;
2. Reference color characterization data set 2 (intermediate color gamut)—Grade 1 substrate (white point) and typically low gloss (satin) image characteristics;
3. Reference color characterization data set 3 (small color gamut)—based on Grade 5 substrate (Grade 5 white point) CGATS TR 001 data set.

At this point the next step is to define the internal color characterization data appropriate for gamuts 1 and 2.

In addition TF2 is working to complete a set of application notes to help developers and advanced users in software development and implementation.

In support of the Application Notes, TF2 is also developing a series of test suites to help both developers and users evaluate and test applications. These will include tests of both PPML/VDX functionality and color management.

PDF/X

The current PDF/X standards (ISO 15930-4, *Graphic technology Prepress digital data exchange using PDF—Part 4: Complete exchange of CMYK and spot colour printing data using PDF 1.4 (PDF/X-1a);* ISO 15930-5:2003 *Graphic technology—Prepress digital data exchange using PDF—art 5: Partial exchange of printing data using PDF 1.4 (PDF/X-2);* ISO 15930-6:2003 *Graphic technology—Prepress digital data exchange using PDF—Part 6: Complete exchange of printing data suitable for colour-managed workflows using PDF 1.4 (PDF/X-3))* as their titles show are based on PDF version 1.4. Adobe has recently released version 1.6 of the PDF specification.

CGATS/SC6/TF1 (the CGATS committee working on the PDF/X standards in parallel with the ISO effort) has taken on the task of preparing a proposal, to be submitted to ISO TC130, of the features that should be incorporated in the next revision of the PDF/X standards.

This group met in early February 2005 and their discussions resulted in the following recommendations, which will form the basis for the proposed revision.

Development in a single new part

Parts 4 (PDF/X-1a), and 6 (PDF/X-3) of ISO 15930, published in 2003 were intended to differ only in a few areas, notably around colour spaces. Subsequent to publication it has been found that other small discrepancies crept in during the editing process. While the differences found are not a cause for concern, they highlight the additional work and risk required to publish separate parts for PDF/X-1a and PDF/X-3. In addition, the bulk of the PDF/X-2 standard (15930-5) is defined by reference to PDF/X-3. CGATS therefore will recommend that all three conformance levels be folded into a single part, to be published as ISO 15930-7.

Renaming of PDF/X-1a to PDF/X-1

Input to the CGATS meeting shows that the majority of users do not understand why PDF/X-1a has the letter 'a' at the end, and that simplifications would assist implementers. CGATS therefore will recommend that the CMYK-only conformance level in this revision be named PDF/X-1 rather than PDF/X-1a.

PDF Version

The initial proposals for this revision suggested that it should be based on PDF 1.5 (the 2003 parts are based on PDF 1.4). That was based on assumptions about the publication date of the PDF Reference version 1.6 from Adobe Systems. Version 1.6 was published, earlier than expected, in late 2004. CGATS therefore will recommend that the new work be based on PDF 1.6

Monochrome PDF/X-1 files

Previous versions of PDF/X-1a have required monochrome files to be encoded using CMYK output intents. A job that will be printed in black ink only, or in black with one or more spots, must currently be encoded either with a CMYK output intent, or as a PDF/X-3 file. CGATS will recommend that PDF/X-1 be extended to allow greyscale output intents as well as CMYK.

Optional content (layers)

The PDF 1.5 reference introduced structures defining optional content within a PDF file. Commonly known as 'layers', these are powerful and flexible features designed for many use cases, amongst them regional versioning of printed material. A single PDF file may be supplied that includes all the data for multiple variants of the output, e.g., a brochure to be published in both English and German. The groups of optional content all carry names, allowing the file recipient to configure his production workflow in such a way that the same file can be processed twice to generate two different printed outputs, e.g.,one in English and one in German.

While the flexibility of the PDF layering structure can lead to unexpected output in the context of graphic arts, it is relatively easy for the PDF/X standard to place limits on the use of those options that would lead to variable output.

CGATS will recommend that optional content be permitted in PDF/X, subject to the addition of suitable restrictions.

Transparency

All previous parts of ISO 15930 prohibit the use of PDF transparency structures in PDF/X, either explicitly or implicitly (through

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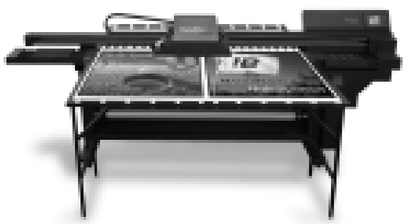
NEW PRODUCTS

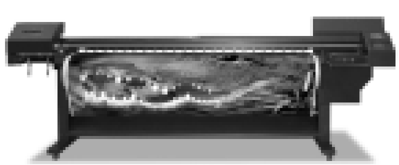
William M. Aitken, Editor

The **DisplayMaker 72UVR** is **MacDermid ColorSpan's** first 72-inch wide-format flatbed UV printer. This high-performance 600-dpi printer has flatbed / roll fed features using UV-curable ink technology at an affordable price. UV-curable ink technology is the latest in advanced printing options offering you the versatility of printing directly to just about any rigid or roll fed material up to ¼" thick.



Display Maker 72UVR

New to the **"Gator"** family is the **DisplayMaker 98SX, "ElonGator"**. A 98" wide-format solvent version of the award-winning DisplayMaker **72S**, with the capability of printing up to 98.5 inches (2.5 meters) on both roll-fed and optionally on rigid media by adding flatbed tables. This printer is designed for bigger runs with faster print speeds (up to 700 square feet per hour) using 16 piezo-electric printheads, for more output per inch on elongated media and multipurpose extensive format applications. It's a grand format printer without the grand format price. More information at www.macdermid.com.



DisplayMaker 98SX

IC INTRACOM has added a Network IP Camera that supports wireless transmission based on the IEEE 802.11b standard to its INTELLINET ACTIVE NETWORKING Professional Series line.

The Wireless Network IP Camera allows users to view live, full-motion video from anywhere on the Internet or a computer network using a standard web browser. Unlike conventional PC web cameras, it has a built-in CPU and can transmit high-quality video images for security, surveillance and other types of monitoring in homes, offices, banks, hospitals, nursing homes, amusement parks and many additional applications. The camera can be remotely managed, accessed and controlled by any PC or notebook computer and supports up to 100 simultaneous users.

The Wireless Network IP Camera offers all of the advanced features available in other INTELLINET ACTIVE NETWORKING Professional Series cameras. These include exceptional image quality, direct image access, an enhanced application program interface (API) and user-based frame rate control. In addition, users can specify the time interval for internal clock synchronization for time-critical security surveillance applications.

For maximum flexibility, open standards including TCP/IP networking, SMTP e-mail, HTTP and other Internet protocols are supported. In addition, the camera can function in a mixed operating system environment.

The Wireless Network IP Camera (model 550703) will be available in February at a manufacturer's suggested retail price of $499. High- and low-resolution photos and more information are available at www.icin tracom.com.

Carl Zeiss has introduced the new **AxioCam MRc5** high-resolution, color digital camera with 5-megapixel CCD sensor, FireWire, high dynamics, and great flexibility in read-out modes. In addition, the AxioCam MRc5 offers brilliant, true color, high-quality images rich in detail at an amazing price/performance ratio. It is perfectly designed to suit applications in pathology, histology, cytology, as well as, biology and materials research and testing.

The AxioCam MRc5, 5 megapixels, 36-bit RGB color depth camera is based on a new generation of innovative CCD sensors. Because of the increased pixel density and significantly higher image resolution, these sensors produce color images of exceptional brilliance and needle-sharp details. The camera features a dynamic range of 1:1300, with the 12 bit digitization to ensure loss-free image dynamics and to guarantee high performance when working with difficult specimens (e.g., reflecting surfaces in materials microscopy).

AxioCam MRc5 offers exceptionally fast live image acquisition. The frame rate can be freely selected, providing an ideal ratio between speed of data transmission and resolution that the specimen requires. Maximum electronic signal processing guarantees minimal interference, thus providing excellent signal-to-noise ratio.

The FireWire interface allows direct connection to the laptop. The camera is completely integrated with the operating software to ensure that you have a powerful and upgradeable digital imaging system, which includes image acquisition and processing functions. For more information contact Carl Zeiss MicroImaging, Inc., Thornwood, NY 10594, 800-233-2343, www.zeiss. com/micro or email at micro@zeiss.com.

PhoTags, Inc. has introduced **V3.0 of their Active Captions** photo-messaging and management technology in their **Digital Photo Suite**. Capabilities include acquisition of images from any source, organization of images quickly and easily, editing enhancing and sharing. The software allows creation of Digital Photo Albums which can be viewed, printed and burned onto CD for viewing on PC's or DVD players. Calendars, greeting and postal cards can be easily created from your images, including both sides of a 4"x6" postal card. External editing software can be launched directly from the application, applied and then returned directly to the application when finished. Active Captions allows inserting captions, shapes, frames, keywords, photographer identity and categories in the JPEG photo file so data are always part of the photograph and not in a separate linked database. The stored metadata do not impact the photograph and, along with select EXIF data stored in the image file, can be searched directly from Windows at any time. More information at www.photags.com or www.active captions.com.

Concord Camera demonstrated WiFi for digital cameras at Photokina 2004, called **WIT® (Wireless Image Transfer**). The showcase demonstration was a 2"x2" device that plugged into the digital camera USB port and downloaded images to a PC using IEEE 802.11b and 802.11g wireless protocols. Downloads are as much as 1500 times faster than GSM (GPRS) and 20 times faster than Mobile G. The technology enables a 4 MP image transfer in 1/10s or video clip transfer at up to 54Mb/s. The company is evaluating both a stand alone device and one integrated in a digital camera. More information at www.concordcamera.com

Epson introduced its **PhotoPC L-410** 4Mpixel camera last summer. The camera will capture up to 3 frames/sec at maximum resolution up to the capacity of the optional memory card. The camera features 3x optical and 3x digital zoom, a 1.5" LCD and Print Image Matching II compatibility for direct printing on enabled printers. A Print Image Frame button on the back of the camera allows the user to add a frame to any image. The camera can be operated in fully automatic point and shoot mode or in manual mode. While it has 16MB memory built in, the camera also accepts Secure Digital (SD) memory cards up to 512MB. Power is supplied by a CR-V3 battery or can use 2-AA alkaline, NiCd or NiMH batteries. An AC adapter is available. Street price is estimated at $399USD. More information at www.epson.com.

Standards

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selection of PDF version). Many current design applications are capable of producing PDF files containing such structures, and they are in widespread use by designers.

The reasoning behind prohibition of transparency in previous parts of PDF/X was that different workflows, using products from different vendors (or even different products from the same vendor or different versions of the same product), are capable of producing different printed results from the same PDF file. That leads to a lack of predictability.

Over the years, since the introduction of PDF transparency (in PDF version 1.4), the variability of output has reduced steadily. CGATS now believes that, by the time 15930-7 is published and products creating and consuming it are available to users, that variability will have reduced still further.

Rather than passively hope for such a reduction, however, CGATS is also actively developing a program designed to drive down that variability:

- Adobe will be urged to issue an Adobe technical note describing all the transparency blend modes that are not fully documented in PDF version 1.6.
- Representatives from a number of RIP vendors will work together to develop as complete a set of unit test files as possible. It is expected that Adobe will be able to provide reference output from those test files (as electronic raster files). The test files and reference output will then be made available to encourage vendors to develop their products towards a common rendering.

The least technically sophisticated or most conservative print sites may be unable or unwilling to accept files requiring colour management. In the same way, CGATS believes that those same sites will probably be unwilling or unable to accept files containing live PDF transparency. CGATS therefore will recommend that PDF transparency continue to be prohibited in PDF/X-1, but that it be allowed in PDF/X-3.

It is planned that the proposed draft text for ISO 15930-7 will be submitted to TC130 at the May 2005 meeting in London and will be entered into DIS ballot shortly after that meeting.

New Parts for ISO 22028

ISO 22028, *Photography and graphic technology—Extended colour encodings for digital image storage, manipulation and interchange*, is a key imaging standard being developed by TC42. *Part 1: Architecture and requirements* was published in 2004.

JWG 23, the Joint Working Group of TC42 and TC130, which developed Part 1 has two new parts ready for ballot as ISO Technical Specifications. These are *Part 2: Reference output medium metric RGB colour image encoding (ROMM RGB)* and *Part 3: Reference input medium metric RGB colour image encoding (RIMM RGB).*

Both of these image encoding spaces have larger gamuts than most RGB gamuts. Their definitions follow the requirements outlined in Part 1. It is hoped that additional encodings, useful in photographic and graphic technology applications, will be defined using the principles outlined in Part 1. Where their definition is not specifically related to other standards, it is suggested that they can become additional parts of ISO 22028.

Image Quality Standards Published

The following 3-part standard, prepared by TC42, is in the final stages of publication. This standard represents a significant step in the standardization of image quality evaluation procedures.

- ISO 20462-1:2005, *Photography—psychophysical experimental methods for estimating image quality—Part 1: Overview of psychophysical elements under development*
- ISO 20462-2:2005, *Photography—Psychophysical experimental methods for estimating image quality—Part 2: Triplet comparison method*
- ISO 20462-3:2005, *Photography—psychophysical experimental methods for estimating image quality—Part 3: Quality ruler method*

These standards may be ordered from www.iso.org or www.ansi.org.

New CIE Publications

The following recent CIE publications may be of interest to the imaging community.

- *Colorimetry* CIE 15:2004 (3rd edition) ISBN 3 901 906 33 9
- *A Review of Chromatic Adaptation Transforms* CIE 160:2004 ISBN 3 901 906 30 4
- *Chromatic Adaptation Under Mixed Illumination Condition when Comparing Softcopy and Hardcopy Images* CIE 162:2004 ISBN 3 901 906 34 7
- *Proceedings of the CIE Symposium '04 on LED Light Sources: Physical Measurement and Visual and Photobiological Assessment 7-8 June, 2004 Tokyo, Japan* CIE x026:2004 ISBN 3 901 906 36 3
- *The Effects of Fluorescence in the Characterization of Imaging Media* CIE 163:2004 ISBN 3 901 906 35 5
- CIE Standard S 012/E:2004 *Standard Method of Assessing the Spectral Quality of Daylight Simulators for Visual Appraisal and Measurement of Colour*
- CIE Draft Standard DS 014-1.2/E:2004 *Colorimetry—Part 1: CIE Standard Colorimetric Observers*
- CIE Draft Standard DS 014-2.2/E:2004 *Colorimetry—Part 2: CIE Standard Illuminants*

Details and ordering information are available at www.cie.co.at.

For suggestions (or input) for future updates or standards questions in general, please contact the author at mcdowell@npes.org or mcdowell@kodak.com.

Upcoming IS&T Conferences

April 25-28, 2005 IS&T Archiving 2005
Washington, DC *General Co-chairs: Robert Buckley and Franziska Frey*
Early Registration Deadline: March 26, 2005

May 9-12, 2005 DPP 2005 (co-located with GRAFIVAK 2005)
Amsterdam, The Netherlands *General Chair: Ramon Borrell*
Early Registration Deadline: March 26, 2005

May 23-26, 2005 IS&T/CSIST 2005 Beijing International Conference on Imaging: Technology and Applications for the 21st Century
Beijing, China *Chairs: David Weiss, Rong-Qian Wen, and Pei-Jie Xia*
Early Registration Deadline: March 31, 2005

September 18-23, 2005 NIP21: 21st International Congress on Digital Printing Technologies
Baltimore, Maryland *General Chair: Rita Hofmann*
Call for Papers Deadline: February 28, 2005

September 18-21, 2005 Digital Fabrication Processes (co-located with **NIP21**)
Baltimore, Maryland *General Chair: James Stasiak*
Call for Papers Deadline: February 28, 2005

November 8-11, 2005 CIC13 Color Science and Engineering: Systems, Technolgoies, Application Scottsdale, Arizona *General Co-chairs: Po-Chieh Hung and Michael Brill*
Call for Papers Deadline: April 1, 2005

For a more complete listing of imaging conferences, visit www.imaging.org

Other Meetings

March 6 - March 10, 2005
Smart Structures and Materials/ Nondestructure Evaluation for Health Monitoring and Diagnostics Joint Conference San Diego, California. Sponsored by SPIE, spie@spie.org; 360/ 676-3290.

March 17 - March 20, 2005
Photo Imaging Expo 2005 Tokyo, Japan. Sponsored by Fiji Sankei Business, +816-45-861-0075.

April 20 - April 22, 2005
Ink Jet Printing Developers Conference 2005 Geneva, Switzerland. Sponsored by IMI, devcon@imieurope.com; +446-1223-235920.

April 24 - April 27, 2005
Inter Society Color Council's Symposium on Automotive Color and Appearance Issues Cleveland, Ohio. Sponsored by ISCC, iscc@compuserve.com; 703/318-0263.

May 8 - May 13, 2005
AIC Colour 05 Granada - 10th Congress of the International Colour Assn. Granada, Spain. Sponsored by AIC, aic05@ugr.es; +346-958-208650.

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