Animated films present a unique set of challenges and questions to scholars examining films from a cognitive perspective. When the confines of the real world don’t exist as they do in live action films, the filmmaker is confronted with creating the entire narrative space from scratch (Buchan, 2011; Buchan, 2006). How do animators manage this seemingly enormous task? This question certainly predates film; creating space and life in visual art has been a subject of intense study by artists, historians, photographers, and psychologists alike. While the goal may be to create an extremely realistic visual space, the option given to visual artists and animators alike is to abandon tenets of realism in favor of an alternative perspective on the visual world. Animation alone can bring life to inanimate objects, defy laws of physics, and create visual effects impossible in live action film.

Animation and color have coevolved since their respective inceptions. Color has been both a distinct challenge as well as a space for exploration for animators throughout animation’s history. Scientific discoveries regarding the perception of color also influenced its use in art and animation, making color an ideal target for further exploration in a cognitive context.

This chapter will pose and answer three questions. First, what exactly is color and how is it defined? Second, how has color been used by animators throughout the history of animated film? Finally, how does our cognitive experience of color shape the viewers’ cognitive experience of a film? The final question will address a specific population of animated films (animated films geared for children), and how the use of color in these films strategically differs from other types of films.

WHAT IS COLOR?

Color is a concept that philosophers, artists, and scientists have historically spent a great deal of time exploring and quantifying. Physiologically, our perception of color results from varying wavelengths of light being reflected onto the retina, which in turn are processed by cells called photoreceptors. The relative responses to light spectra by these cells are what generate our ability to see and distinguish between colors. Anomalies in photoreceptor cells can cause deficits in the ability of an individual to see color, though in some unique circumstances, these anomalies allow individuals to more finely discriminate between colors (Neitz, Kraft, & Neitz, 1998; Jordan & Mollon, 1992; Nagy, MacLeod, Heyneman, & Eisner, 1981).
Quantifying Color. Attempts to categorize color vastly predate our understanding of the physiology of the eye, but Isaac Newton’s *Opticks* (1704) is pivotal in its introduction of his color wheel for understanding color theory. The ordering of the colors around his color circle (and in subsequent iterations by other color theorists) is based on the order in which the colors are refracted out from the prism, uniting violet and red to close the radial axis (see Figure 1). Thus the ordering of the colors on the color wheel is not arbitrary, but based in the physics of light. Newton also introduced the notions of primary and secondary colors, and notes that opponent colors on the color wheel combine to create a neutral light color.

Despite that it has evolved over time and exists in varying forms, the color wheel continues to play an important part in both the artistic and psychological understanding of color. Notably, it is useful for defining several metrics of color, namely hue and saturation. Hue refers generally to named colors, and corresponds to the sectors of color into which color wheels are typically divided. Examples of hue-based descriptions include ‘blue-green,’ ‘red,’ and ‘pink.’ Saturation is another important color variable, and generally refers to how bright or potent a color is. Pastel colors (which are closer to the center of the color circle) are relatively unsaturated. Very saturated colors (which are referred to as ‘bright red’ or ‘bold blue,’ for example) lie along the outer edges of the color circle. Luminance is another variable important for discussing color. Luminance refers to how light or dark something is; when discussing color in particular, it refers to how much black is contained within a particular color. Unlike hue and saturation, luminance can be independent of color; in other words, black-and-white images contain no hue or saturation information but do contain luminance information. Because luminance is not a variable unique to color stimuli, it is not represented on the color wheel, but nonetheless it is an important variable when discussing color. These terms, including how they are mathematically quantified, will be revisited later with data.

The color wheel is not the only color quantification system to define colors using the metrics of hue, saturation, and luminance. One of the most noted color-classification systems, and the one still most reliably used in psychophysiological testing, was originally developed by Albert Munsell, and also uses these color parameters. Munsell compiled and organized a tremendous set of finely-grained discrete colors now known as Munsell colors or Munsell chips (Munsell, 1912; Munsell, 1919). One important component of the Munsell color system is that it emphasizes that color perception is dependent on the physiology of the human eye. For example, humans can more identify many more discrete levels of yellow than blue at high values, whereas the reverse is true at low values. In other words, one can argue more light yellows exist than dark yellows, whereas color wheel representations suggest that all color values exist equally in our visual environment.

While the study of how we physiologically perceive color is important, perhaps more critical in studying art and film from a cognitive perspective is the question of how we psychologically respond to color. Our preferences for and biases toward particular colors have the potential to influence how we respond cognitively and emotionally to art.

Color Preferences. Artists across visual domains recognize how the use of color affects viewers’ perception of their work. Deliberate and comprehensive choices regarding the use of color permeate all types of visual art, including intentional choices to omit color from
artwork. Unsurprisingly, people tend to have strong predelictions for particular colors. While it might intuitively seem like individuals each have their own color preferences that are unique, the psychological research on color preferences reveals a surprising amount of concordance across people in terms of color preferences.

In terms of specific colors, research has consistently demonstrated a cross-gender and cross-cultural preference for blue hues above other hues (Eysenck, 1941; Granger, 1952; McManus, Jones, & Cottrell, 1981; Komar & Melamid, 1997). People also tend to consistently rate yellow and brown hues as being least pleasant, especially in their darker forms (Palmer & Schloss, 2010). Biases across populations are not limited to hue; people consistently tend to favor colors in more saturated forms as opposed to more washed-out or pastel counterparts of the same hue (Granger, 1952).

Naturally, the consistency in color preference drove psychologists to posit theories on how color preference develops. Some have proposed that color preference is an innate artifact of human evolutionary history, which developed to facilitate our early survival in hunter-gatherer societies (Hulbert & Ling, 2007). While some biological evidence supports this idea, if color preferences are present at birth, infants and adults should show similar color preferences, when in fact they do not. Data collected from infants and young children suggest that color preferences change over time, and that while children eventually match adults on their color preferences later, they are not born with those preferences. Infants tend to prefer colors that adults classify as unpleasant, namely dark yellows, yellow-greens and reds (Adams, 1987). Children also have a preference for very high saturation that gradually diminishes to match the adult preference level for saturation (Child, Hansen, & Hornbeck, 1968).

Since preferences for color dimensions seem to be dynamic over the lifespan, it is unlikely that color preferences are built-in. This is not to say that color preference is purely non-functional; in fact, the ecological valence theory of color preference suggests that the early associations humans build with colored objects facilitate their color preferences (Palmer & Schloss, 2010). For example, our early preference for dark yellows in infancy may come from consistent positive exposure to caregiver skin tones and hair color; it is only later that we learn the association between dark yellows and rotten food or excrement, at which point this preference changes direction. Conversely, as we increase our exposure to stimuli like clean water and fresh food, our preferences for blues and slightly-saturated hues begins to dominate color preferences.

Yet another theory, which is particularly relevant for the use of color in an art space, is that we learn strong associations between emotion and color, and color can consequently be used to evoke particular states of emotion. Specific colors have been shown to correlate with arousal (Valdez & Mehrabian, 1994) and scales of emotional valence (Kaya & Epps, 2004; for a detailed review on color-emotion literature, see also Steinvall, 2007). This theory is not necessarily at odds with other theories on color preference; in fact, it may simply supplement the idea that gaining positive associations with a color increases our preference for that color, which is an assumption that guides most current theories on color preference.
The question that remains from our understanding of color preference is whether or not art mimics life; in other words, how do animated filmmakers instill color in an artificial world, and do filmmakers exploit our color preferences in order to make their films more engaging?

HOW IS COLOR USED IN ANIMATION?

Color is arguably one of the most salient features of even the earliest animated films. This is not to imply, however, that the techniques involved in creating an animated space with dynamic color is a simple process. In fact, some of the biggest obstacles in moving animation forward as an art form arose from the complications of colorization.

Cel Animation. Often referred to as ‘traditional animation,’ the cel animation approach dominated the animated film landscape from very early in film’s history to the relatively recent advent of computer animation. Cel animated films composite a meticulously painted background layer with transparent celluloid (or ‘cel’) layer containing foreground information. Each layer carries with it important implications for how color is ultimately represented and rendered in the final film.

The background layer, while usually created first, must work reciprocally with the cel layers in order for the colors to appear natural together and for the layers to appear integrated. The overuse of color, in particular colors that are heavily saturated, tends to overwhelm cel forms placed overtop the background; instead, the background ideally consists of more muted colors to complement the component cel forms. This led to the Disney animated film signature ‘watercolor effect’ of its background layers (Thomas & Johnson, 1995).

The cel layer presents significantly more challenges where color is involved, and these challenges were originally addressed by Disney’s larger-budget animation studios. The physical properties of celluloid itself have implications for color; the thicker the cel, the darker the resulting colors layered onto the cel layer (Thomas & Johnson, 1995). Thus, paint color had to be balanced in such a way that the resulting cel painting did not clash with the watercolor appearance of the background layer. Colors high in saturation were often difficult to achieve because they also ultimately darkened when photographed from the cel. Disney’s animators found that muted colors in the cel layer often were the best complement for a variety of background layers. When designing a character or a cel-layer object, animators were often limited by the expense of cel paint colors, and thus character design was in a sense limited by color. Adding to this complication, cel artists and color keys also had to adjust the color palettes of characters depending on the implied lighting of a background, to avoid a character looking overly-red or overly-saturated in a nighttime scene, for example (Thomas & Johnson, 1995). Color in the cel layer also contained some complications for maintaining realism in the animated scene. For example, outlining characters in black often made their appearance visually heavier and detracted from their integration with the background layer. Disney first introduced colored inking to replace universal blank inking, and colored inking was also integrated with cel Xeroxing technology as that emerged (Thomas & Johnson, 1995). Another color problem dealt with creating depth in the cel layer: textures in hair and fur could be created via airbrushing and drybrushing, but this created a flicker effect when the individual cels were captured in sequence.
Animators ultimately decided this depth was worth a certain small-scale amount of flicker tradeoff (Thomas & Johnson, 1995).

**Computer Animation.** The cel approach dominated animated films for decades, and the interest in streamlining the cel animation process led to the initial involvement of computers in animation. The first film to be digitally composited was Disney’s 1990 film *The Rescuers Down Under* (Prince, 2012). Computer involvement in animation was also prioritized as a means of film restoration and improving film resolution; that same year, digital paint techniques allowed Disney to fix flaws in the original print of *Fantasia* for reissue, and in 1993, *Snow White and the Seven Dwarves* was completely ‘restored’ to create a higher-resolution version of the film (Bordwell, 2012). Computer-based coloring was particularly valuable because it generated more freedom to alter independent components of an image. Prior to computer involvement, color correction had to be done on a whole-frame basis; the process of digitally compositing and altering films meant that color-correction could be done on an individual object or character without the need to alter the entire frame image (Prince, 2012).

The involvement of computers in animation continued to grow as the technology became more inexpensive and accessible, and animators experimented with new computer-based techniques for animating (such as crowd-generation in *Mulan* (1998))\(^7\). By the mid-90’s, the vast majority of cel animated films employed computers to streamline the once-arduous tasks involved in hand-animating films, including colorization. Because animators no longer had to rely on physical paint or hand-calibrate background and cel layers, the colorization and texturization processes became much easier, and artists in turn were able to work with more degrees of freedom in their animating.

The revolution in computer animation began with the first fully computer-based animated film, *Toy Story* (1995). Moving from a two-dimensional animation space into a three-dimensional, digitally-constructed environment had a huge initial investment cost (both in labor and finance), but ultimately gave the animated filmmaker a great deal of flexibility in constructing visual narratives (for a review, see Lasseter, 1987). Constructing and coloring a 3D environment and set of characters involves a great deal of initial time and planning, but the ultimate outcome is a greater degree of control in colorization, in which every individual element in the digital landscape can be fine-tuned in color space.

**Film Stock.** One important caveat worth noting when discussing animation is that the color of the final product is always affected by the film stock. Even in contemporary computer animation, where color design can be done on a very fine-grained scale, the final film is ultimately rendered onto film stock. The choice of film stock, as evidenced especially by the changes in stock availability and popularity over time, as well as advances in stock quality, renders color variably (Bordwell & Thompson, 2004). Technicolor film stock was popular with early Disney animated films, which exacerbated complications with cel painting by rendering colors heavy in midtones. This forced animators and color keys\(^8\) into a particular spectrum of colors when painting in order to achieve the desired final look on the Technicolor film stock (Thomas & Johnson, 1995). Even in modern animated films, the change between the cel or computer and the film stock accounts for some variability in coloring of the final product. Indeed, this is not even the last step in color variance: the original camera negative is almost
always different from the colors displayed in theaters, on home televisions, or on computer screens (Prince, 2012). Some of this variance can potentially be put to rest with the increasing number of films being distributed as Digital Cinema Packages (rather than in 35mm form), but it persists as a problem for those interested in studying pinpointing color in film scientifically (Bordwell, 2012).

It is clear that artists have more freedom with color in animated films. Before digital technology, live action films were confined by the natural color of objects in a scene as well as by the limited amount of post-production work available to alter color (Prince, 2012). However, from animation’s inception, animators have been able to select a wide range of colors to best suit their needs, despite some of the early cost and technical constraints. The introduction of computer animation allows for the greatest amount of freedom in color control, putting the entire digital color environment under the direction of the artistic team.

The precise control of color in this setting not only has artistic consequences, but also important implications for how films can evoke particular psychological responses from its viewers. The rest of this chapter will examine work revolving around the use of color for a particular audience of animated viewers: specifically, how filmmakers use color in animated films intended for children.

CHILDREN’S ANIMATED FILMS: ARE THERE DIFFERENCES IN COLOR USE?

In the introduction to her book *A Reader in Animation Studies*, Jayne Pilling (1997) discusses how Disney, as the first company to invest heavily in animated features, eventually became the model for animated films and subsequently marginalized animation into an art form “somehow intrinsically only appropriate for entertaining children” (xi). Indeed, it appears that the Disney model caused an aggressive bifurcation in the animated feature world, with heavy emphasis being placed on the creation of child-oriented animated films, and a smaller contingent of artists attempting to legitimate animation as an art form appealing to adults. While Pilling is correct in that the latter set of films is certainly underrepresented in the film studies literature, child-oriented animated features have a particular appeal for being studied from a cognitive perspective. Filmmakers in this animation subset face a specific challenge in trying to engage children in their visual narrative; there is ample evidence that the cognitive and attentional capacities of children differ from those of adults considerably, so what changes must the director of a children’s animated film make in order to captivate this unique audience? One potential shift to accommodate this audience appears to take place in colorization of these films.

In order to study the physical properties (including color) of children’s films, we assembled a sample of G-rated children’s films made between 1985 and 2008 (Brunick, DeLong, & Cutting, 2012; Brunick & Cutting, in prep). Films in the sample were the highest-grossing G-rated theatrical films from each year in the range and also included some direct-to-video films. The sample included live-action, cel animated and computer animated films geared to a variety of ages. We considered our entire sample of children’s films for our original analyses; for the purposes of this chapter, only the animated films (both cel and computer) will be discussed. This sample is contrasted with a subsample of adult-oriented, non-animated films.
from the same time period (see the 1985 through 2005 films from Cutting, DeLong, & Nothelfer, 2010). The following sections will (1) discuss how the color parameter in question was mathematically quantified and (2) discuss the trends in the color parameter for the child- and adult-directed samples.

**Saturation.** As discussed earlier, saturation refers to the ‘brightness’ or ‘boldness’ of a color. Saturation radiates outward from the center of the color circle: the center of the circle is white, with no saturation, while the edges of the circle represent fully-saturated forms of a particular hue. However, when analyzing color digitally, saturation is typically not discussed in terms of a color wheel, but instead in terms of a digital color space known as the HSV cone. This space is named for its dimensions: hue, saturation, and value. Value is roughly equivalent to luminance, and this space is essentially constructed by adding this variable to the color wheel (see Figure 2). The base of the HSV cone is a color wheel, and the height of the cone represents value. As value decreases (as the colors become darker), colors are limited in their saturation. Saturation is generally quantified on a scale from 0 (white, no saturation) to 1 (fully saturated).

Saturation levels for each pixel in a frame were digitally computed. The median saturation level for all the pixels in each frame was computed, and an average of the frames was obtained for the entire film. Within the children’s film sample, we found that cel animated films use significantly more saturated colors than computer-generated animated films, independent of the year that the films were made. Both live-action children’s films and the matched sample of adult-aged films have been increasing in saturation over time; in other words, newer films are more prone to be more saturated than older films. However, even with this trend, the live-action children’s films and adult-directed films are dramatically less saturated than their animated counterparts. This finding is both interesting and unsurprising for the same reason: the saturation levels in children’s films likely reflect young children’s preference for bright colors. However, it is unlikely that filmmakers are consciously making these choices based on the psychological literature; filmmakers instead are likely intuiting this preference, perhaps based on their own conceptions of how children respond to film or other parts of their visual environment. Regardless of the basis of this intuition, it is important to note that the saturation trends in the films appear to match the scientifically-established preferences of the target audience.

**Luminance.** Though it can be measured independently of color, luminance plays an important part in color space and ultimately how a color is perceived on-screen. To assess luminance, color was digitally removed from the film using a standard digital grayscale conversion. Each pixel’s luminance value is computed, with values ranging from 0 (pure black) to 255 (pure white). The mean of the pixels in a frame were averaged to create the mean luminance for that frame, and the frames were subsequently averages to create whole-film luminance.

The trend in Hollywood films for adult audiences is a decrease in luminance; in other words, films have steadily been getting darker throughout the studied period, which has implications for directing eye-gaze and attention of the viewer during the film (Cutting, Brunick, DeLong, Iricinschi, & Candan, 2011; Smith, 2012). Animated films for children, conversely, maintain a steady level of brightness independent of year, the target age of the film, or what type of animation (cel or computer) was used. While one could argue that consistent brightness is a
possible artifact of representing particular colors in animation, children’s live action films are actually increasing in brightness over this period; this evidence instead supports an interpretation that the intended audience is driving the brightness level, not simply that animated films are generally brighter.

Another question posed by these findings is the potential interaction between saturation and luminance. As demonstrated by the HSV cone, colors with lower values are limited in their saturation. Is it then possible that children’s films are more saturated only because they are brighter? Or, perhaps, does the inclination of filmmakers to use saturated colors in children’s films necessitate a certain luminance level? While this is certainly possible, it is unlikely that the luminance findings are purely an artifact of the saturation levels, or vice versa. If this were the case, one would expect the trends in both the children’s films and adult-directed films to be complementary; in other words, both luminance and saturation should be increasing or decreasing together in the samples. This is not what we find. In the children’s sample, saturation levels hold steadily across time, while these films have increased in brightness over the same period. Even more importantly, adult-geared films have gotten considerably darker, but have also become steadily more saturated, not less. This evidence suggests that while luminance and saturation have a reciprocal relationship, and while some of the variance in one accounts for variance in the other, the findings reported here on the two metrics are largely independent.

Hue. As discussed earlier, hue generally refers to named colors. In both the color wheel and in the HSV cone, hue is represented around the radial edge. One major problem with this representation of hue is that it is based in circular geometry, which makes mathematically quantifying and comparing hues difficult and unintuitive. Fully isolating luminance from hue in the HSV color space is also problematic; an ideal space for considering hue would allow for a full spectrum of colors to be represented (1) in a more convenient mathematical space and (2) independent of luminance.

Accordingly, we considered hue using the YCbCr color space, which meets these important criteria. This color space takes the form of a rectangular prism on a diagonal axis (see Figure 3). This color space is also named for its axes in the space: Y (on the vertical axis) refers to luminance, while Cb and Cr refer respectively to chrominance-red and chrominance-blue. The chrominance axes plot complementary colors from the color wheel (red-green and blue-yellow, respectively) on opposite rectangular planes of the prism. The distinct advantage of YCbCr is having luminance on its own axis; in this way, one could take a square slice through the prism to get a square containing all colors at an isoluminant level.

Rather than examining whole-film hue, which is nearly impossible without reducing hue on arbitrary dimensions, our research has examined the hue of particular characters in children’s films. We asked independent coders to view children’s animated films in grayscale, and to identify unambiguous protagonists and antagonists in the film. Frames containing these characters were selected, and the characters themselves were extracted from their background. The dominant hue of the protagonists and antagonists were plotted on an isoluminant slice of YCbCr color space. The analyses showed that protagonists, defined as unquestionably positive and morally-right characters, contained more blue and green hues. Antagonists, conversely, contained more red and yellow hues (Brunick, DeLong, & Cutting, 2012). Unlike saturation,
where films mimic the preferences found in children, this analysis shows that the use of hue in children’s films coincides with adult hue preferences. If children’s preferences were being exploited, ‘good’ characters would likely contain more child-preferred hues, such as red and yellow, when in reality precisely the opposite occurs. It is unclear why this trend is present, and certainly merits further analysis. One possible explanation is that the shift in hue preferences supposedly occurs earlier than the shift in saturation preferences; adults may not be as aware of the hue preference in children because it shifts earlier, and thus adults and filmmakers have less exposure to this cognitive facet of child color preference.

The implications for studying children’s animated films, and children’s films in general, are vast. Researchers not only are able to gain insight into children’s cognitive capacities and preferences, but they can also observe the early reciprocal relationship between filmmaker and viewer. While films for adults are mostly classified as art or entertainment, film in a child’s world also serves as an important tool for learning. Facilitating early learning from visual stimuli is a major goal of both psychology and education researchers, and children’s films can serve as an important medium for conveying both artistic and educational information to a young population.

FINAL THOUGHTS

Not only is it important to note that color in film is quantifiable on several dimensions, but we must also recognize that these cinemetric data are accessible and worthy of further study. Animation in particular presents a unique opportunity for quantifying and studying color; animators have always had greater control of the colors used in their filmic world than directors of live action films, and technology has only improved the level of detail and the deliberateness with which the animator can control his color space. This is not to suggest that instantiating color in an animated film is an easy task; whether through meticulous color selection and hand-painting, or through the arduous development of software for digital colorization, the creation of the brilliant colors typical of animated films carries with it a high investment of both time and resources.

The commonalities and differences in perception across people has always been a topic of interest for psychologists, and a cognitive approach to film is yet another way to access and interpret facets of this topic. The preponderance of children’s films among animated films is in a sense very convenient because it allows research to observe the reciprocal relationship between children’s perceptual biases and how filmmakers create art and media for this audience. The developmental perspective affords us insight into the origins of our perceptions and preferences, which will likely prove to be an important pillar in cognitive perspectives to film.
References


**Filmography**


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Figure 1. The color wheel is one of the oldest and most useful representations of color relationships.

Figure 2. The HSV color space adds the value dimension to the traditional color wheel in order to convey the range of colors possible in a digital space.
Figure 3. The YCbCr color space, when sliced into square planes, allows for the display of all hues at an isoluminant level. It also offers the convenience of mathematically representing color on these planes in the form of linear coordinates.
The introduction of computer-generated imagery (CGI) in live-action films has undoubtedly revolutionized what is possible to portray on-screen in live-action films. Recent films, namely *Avatar* (2009), blur the distinction between the once obvious classifications of films as live-action or computer-animated. For the purposes of this chapter, we will focus on more conventional styles of animation: cel animation and computer animation done independent of live-action elements such as motion capture.

Newton’s discussion of color in *Opticks* is arguably the first work to unify the physics of color with how humans perceive it, though it is certainly not the first major work on color perception. Philosophical and artistic discussions date back to Renaissance scholars including Leone Battista Alberti, Cennino Cennini, and Leonardo da Vinci.

Newton defines the colors within the color circle as consecutive arcs, such that the terminal points of any diameter line would correspond to opponent colors. Despite that mathematically, these terminal points should combine at the center of the circle (which Newton defines as white), he also notes his experiments with combining opponent colors of light do not produce “perfect white,” but instead a “faint anonymous colour” (Newton, 1704, p.157).

Luminance is not represented in most color wheels, but is often represented in three-dimensional color spaces. In these representations, luminance is related to (but not identical to) the variable ‘value.’ This is discussed more extensively later in this chapter.

The color parameters as described by Munsell were named chroma (equivalent to saturation), hue, and value (equivalent to luminance).

In modern film, the choice to make a fully black-and-white film or to use limited color has served multiple artistic purposes. Recent examples of limited color include *Schindler’s List* (1993), where color is used for highlighting symbolic content, and *Memento* (2000), where the alternation between color and black-and-white clarifies the unusual narrative structure. *The Artist* (2011) was rendered fully in black-and-white (despite being shot on color film stock) to evoke the historical context of the film. Other modern black-and-white films, such as *Much Ado About Nothing* (2012), avoid color as a means of emphasizing the narrative and the characters over the visual aspects of the film; this use of black-and-white, as well as it’s consequences for the ‘realism’ of the visual space, is hotly contested (Bordwell, 2004).

Two scenes in *Mulan* (the Hun attack and the final celebration scene) required the depiction of large crowds of people. Creating, painting, and animating hundreds to thousands of individual characters in these scenes would have been nearly impossible; computer animators for the film were able to more efficiently and effectively portray the very large crowds of individuals in these scenes using crowd-generating algorithms and software, including Attila (developed for *Mulan* specifically) and an early version of Pixar’s RenderMan.

The term ‘color key’ refers to a subset of animation artists responsible for selecting and coordinating colors on cels and in background layers.

For the complete list of films included in the sample, see the supplemental material for Brunick and Cutting (2013).

The direct-to-video films were selected by identifying the Internet Movie Database (IMDB; http://us.imdb.com) highest-rated direct-to-video films for binned five year periods within the range; thus, five direct-to-video films were included in the sample. As it is almost exclusively a child-gear phenomenon, we felt that this niche of films merited inclusion alongside theatrical films.

The target age range of each film in the sample was obtained from age recommendation ratings from the non-profit organization Common Sense Media (http://commonsensemedia.org).