LOW-LEVEL PERCEPTUAL FEATURES OF CHILDREN'S FILMS AND THEIR COGNITIVE IMPLICATIONS

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LOW-LEVEL PERCEPTUAL FEATURES OF CHILDREN'S FILMS AND THEIR COGNITIVE IMPLICATIONS

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Discussions of children's media have previously focused on curriculum, content, or subjective formal features like pacing and style. The current work examines a series of low-level, objectively-quantifiable, and psychologically-relevant formal features in a sample of children's films and a matched sample of adult-geared Hollywood films from the same period.

This dissertation will examine average shot duration (ASD), shot structure (specifically, adherence of shot patterns to $1/f$), visual activity (a combined metric of on-screen motion and movement), luminance, and two parameters of color (saturation and hue). These metrics are objectively quantified computationally and analyzed across films.

Patterns in children's formal film features are predicted reliably by two variables: the intended age of the film's audience and the release year. More recent children's films have shorter ASDs, less visual activity, and greater luminance than older children's films. Luminance also reliably predicts character motivation (protagonist or antagonist) within films. Films for older children are reliably darker than films for younger children. When comparing the Hollywood sample to the children's sample, children's films are reliably more

saturated and have higher ASDs than their Hollywood counterparts; however, these effects are largely driven by expected differences between animated and live action films rather than the intended audience of the film.

The type of children's film (cel animation, computer-generated animation, or live action) also reliably predicts many of the trends in the data. Newer cel animated films have shorter ASDs and less visual activity; cel animated films for younger children have longer ASDs and more $1/f$-like shot structure than cel films for older children. Age and year interact in predicting saturation in cel films: saturation has increased over time in films for young children and decreased over time in films for older children. Live action films reliably have increased in $1/f$-like shot structure and luminance over time.

Ultimately, many of the trends present between adult-geared and child-geared films are the result of an abundance of animated films for child audiences. Implications of child-geared art and media are discussed.

BIOGRAPHICAL SKETCH

Kaitlin Brunick was born in Fairfax, Virginia and raised in Virginia Beach, Virginia. She attended Princess Anne High School in Virginia Beach, where she completed study in the International Baccalaureate program. Kaitlin then attended the College of William & Mary, where she studied Psychology (under Peter Vishton) and Linguistics (under Anya Lunden and Ann Reed). She graduated summa cum laude and Phi Beta Kappa in 2009 with Bachelors of Arts degrees in these fields. She entered graduate study at Cornell University in the fall of 2009, where she worked under James Cutting to study the low-level perceptual features of films for adults and children. She also examined the implications of these features on learning in child audiences. Following graduation, she will enter a postdoctoral position with Sandra Calvert and the Children's Digital Media Center at Georgetown University to study parasocial interactions and attachment in children's media.

For my parents, Linda and Brian. Thank you for instilling in me early a love of learning.

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I would foremost like to express my deepest gratitude to my advisor, James Cutting, for his invaluable mentorship throughout this process. His seemingly boundless breadth of knowledge, along with his guidance and patience, were the foundations for my success as a graduate student and the beginnings of my academic career past Cornell. I truly would not be where or who I am today without him.

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INTRODUCTION

Children's media and the development of media for children has become a hot-button issue for developmental psychology, communications, and visual studies alike. With media evolving faster than scientific inquiry can proceed, we have limited knowledge about how media affects child media consumers in a cognitive sense. Arguably, children have to learn to consume visual media in the same way they must learn any complex, multi-modal cognitive skill. We also know that children process the world in a way that is broadly different from the tactics used by adults. For this reason, it is particularly important to investigate how to access these learning strategies as they are relevant to emerging media.

One such emerging body of media that has been given relatively little study among psychologists is children's films. Much of the current work on media and children's media focuses on television, though more recently studies of computers and tablet interfaces are becoming more the norm. Television for children is typically designed with curricula in mind, whereas film straddles the line between learning tool and artistic media. The potential to teach children with this media is two-fold: not only can prosocial messages be emphasized in the plot (which they often are), but the creation of children's films also scaffolds child film viewers into adult film viewers, teaching them the regularities and aesthetic components of a distinct type of visual media. In terms of the study of adult-geared films, the cognitive approach to film theory is relatively new to the film studies landscape. Additionally, the recent introduction of *cinemetrics*, or the computational quantifying of film components, carries with it implications for vision scientists and psychologists concerned with how we process dynamic scenes. Previous work has shown, among other things, that the low-level cinemetric features of film (things like shot durations, camera movement, and so forth) have an impact on how we attend to film and dynamic stimuli. Investigating this relationship has proved worthwhile in discovering how we attend to the moving world around us, but also how we function as viewers of a dynamic art form.

Cinemetrics are, by definition, low-level in form. Low-level is what remains when content material is removed, and low-level features are easily quantifiable in an objective, computational way. Low-level features have a reciprocal relationship with content, in that they reinforce one another for deeper processing of the narrative and effortful attention to the media.

Studying the low-level features of children's films raises several important questions. First and foremost, children obviously do not design their own media. While we have a vast knowledge of how to cater curricula and narrative content to children, it is less clear that adult filmmakers know how to cater low-level features to children. Doing so is essential to capitalize on the reciprocal relationship of low-level processing with content. Even if filmmakers could flawlessly implement low-level features that properly engaged child audiences, are we fully aware of what 'works' for children in this domain? Furthermore, have we as filmmakers, media designers, and educators been correctly implementing these features in children's media so far?

This dissertation will examine several low-level features in an array of children's films. From this, I hope to be able to discern the current state of children's films and their formal properties, such that we can assess whether media are in concordance with what we know about children from the developmental literature. The aimed result is a more informed perspective on creating media for children, as well as an account of how media for children so far has evolved.

For these projects described, I will regularly change between singular and plural pronoun usage, as for most of these projects I have worked with collaborators.

CHAPTER ONE
Perceptual Cues in Children's Media: Cuts, Motion, and Luminance

Overview

This chapter will introduce first introduce the films used for the analyses performed in this dissertation. I introduce a sample of children's films, which were selected based on several relevant properties of the films themselves as well as some historical shift in the landscape of commercial film. A comparative sample of Hollywood films will also be introduced. Both the children's film sample and the comparative Hollywood sample are first quantified in terms of *release variables,* or properties of the film pertaining to the films release. These variables are later used as predictors in models of predicting patterns of low-level features.

After an introduction to the samples and their properties, this chapter will outline trends and present in four low-level features: average shot duration, shot structure, visual activity, and luminance. The trends in both the children's sample and the comparative Hollywood sample will be discussed, with particular attention paid to how certain release variables may or may not affect the expression of these features. The children's sample and the Hollywood sample will be compared, as a means of assessing whether filmmakers construct films differently for child audiences and adult audiences. Finally, the implications of these trends are discussed: how they conform to or violate what we already know about low-level features of film in other work, what assumptions filmmakers and film viewers possess about the human visual system, and whether the current state of children's film as a media has implications for the design of future films and other screen media for children.

Film Sampling and Release Variables

This sample of children's films consists of a total of 76 films released between 1985 and 2008. The sample includes the top 3 highest-grossing G-rated films of each year according to Box Office Mojo (http://www.boxofficemojo.com/yearly). The sample also includes the highest-rated direct-to-video children's release for each five-year period (1985-1989, 1990-1994 … 2005-2008) according to ratings and release dates on the Internet Movie Database (IMDB, http://us.imdb.com). Theatrical re-releases of movies were excluded from the sample. The sample includes films from a variety of production companies (see Appendix A). The sample also spans several filmmaking styles (subsequently referred to as the film *type* and discussed in detail below), including live action films and animated films of varying styles.

Two sets of variables were used for analysis: release variables and computed variables. *Release variables* refer to externally-verifiable data about each film, including the year of the film's release, the type of film (animated, live action), and the intended age range of the film's audience. *Computed variables* refer to the results of computational analyses on digitized versions of the films, including the average amounts of luminance, saturation, and motion in the films. Computed variables, including their psychological ramifications and the methods by which they were captured, will be discussed later. The release variables, however, played an important role in the selection and construction of the sample.

Year

It could be argued that children's films were a fundamental part of film's inception as an art form. Children were a prominent element of the early film audience, and films that appealed to both children and adults alike composed much of the early film landscape. Film shorts (reels) as well as feature-length sound films (talkies) were often adaptations of fairy tales, fables, or children's stories. The earliest animated features included memorable characters such as Little Nemo (1911), Gertie the Dinosaur (1914), Felix the Cat (1919), and Mickey Mouse (1928); these characters attracted young audiences with their style and situational comedy, but also attracted older audiences due to the novelty of animated films as a medium. As feature-length Hollywood-narrative-style began to emerge as the norm for Hollywood films, filmmakers continued to embrace dual appeal to both child and adult audiences, though films geared solely toward adult audiences steadily became more common.

Throughout the classic era of Hollywood, filmmakers continued this emphasis on appealing films to 'dual audiences,' – that is, to both children and adults alike. The Walt Disney Company was responsible for the majority of this content, producing both animated features and non-animated features designed for families. Other family-geared content appeared mostly in the form of adapted musicals, such as *Bye, Bye Birdie* (1963) and *The Sound of Music* (1965). The niche of films that appealed only to children (to the exclusion of adults) had arguably not yet developed. The number of family films steadily increased between 1950 and 1980, but was still both dual audience-focused as well as sparse in number.

The mid-eighties marked a pivotal role in the inception of children's films as an independent niche from family films. While family films focused on enjoyable content for both children and adult audiences, children's films sought to entertain children exclusively. These films differ from family films for several reasons, including utilizing more simplified, child-directed themes, having child or child-like protagonists, and sometimes having educational merit. Their simplicity often alienates adult audiences, who find them uninteresting, simple, or vapid. I would argue the niche of children's films began during the mid 1980s, as a result of three main forces: home video prevalence, merchandising, and the 1984 MPAA rating shift.

Home Video. The late 1970s marked the triumph of VHS over Betamax, and within several years, home video technology was inexpensive and omnipresent in homes and schools. Film distributors increasingly focused beyond theatrical distribution to home video distribution as sales of VHS tapes became an increasingly profitable part of the film industry. Film rental chains, including Erol's and Blockbuster, emerged during this period, also contributing to the demand for home entertainment. As home video viewing became more popular, catering to child audiences became a unique demand. The direct-to-video market before this period was small, but direct-to-video became a more popular means of distribution, especially for low-budget films ("Direct-to-Video," 2014). Several of the major distributors began a focus on direct-to-video titles for children during this period, especially low-budget direct-to-video sequels to high-grossing theatrical releases. Mattel backed one of the earlier direct-to-video children's films, choosing to release *G.I. Joe: The Movie* (1987) to television and home video instead of theatrically as it had with its previous films ("*G.I. Joe: The Movie*," 2014). Compilations of shorts like *Mickey's Magical World* (1988) also led the way in popularizing direct-to-video media for children. Despite considerable critical acclaim, *The Brave Little Toaster* (1987) was also released direct-to-television and direct-to-video after failing to find a theatrical distributor ("The Brave Little Toaster (film)," 2014).

The increased prevalence of home video technology nurtured the development of the children's media niche, first by creating a profitable post-theatrical market for films, and second through nurturing the developing direct-to-video industry. Child viewers of film usually begin watching via home video, creating a sudden pressure on this particular market during this period.

Merchandising. The mid-1980s also saw a unique shift in terms of merchandising being connected to film release. Despite that children's toys and films have always co-existed, this period marked the entrance of many toy companies into the film industry. Hasbro introduced several films to complement the more popular toys of the era, including *G.I. Joe: The Movie* (1987) and *My Little Pony: The Movie* (1986) ("Hasbro Studios," 2014). Kenner and American Greetings licensed the rights to the Care Bear franchise, producing a trilogy of films featuring the characters (1985, 1986, 1987). The toys on which these films were based had a definitive target age, which the films attempted to replicate. As such, the films were geared almost entirely to the toy audience of young children (See Appendix B).

This trend proved bidirectional, as filmmakers also sought to profit from merchandising to children. Disney incorporated its merchandising division in 1986 and opened its chain of stores in 1987. The stores allowed for widespread release of toys and merchandise related to Disney films, which prior to this had only been largely available through the Disney park chain ("Disney Consumer Products," 2014).

The advent of pairing merchandise with films as part of the franchising process certainly continued to nurture the development of the children's film niche. As toys were a particularly successful and profitable part of this process, young children tended to be particularly meaningful in guiding this process.

MPAA Ratings Shift. Following the dissolution of the Hays Code, the Motion Picture Association of America adopted a rating system as a guide for movie viewership. This rating system is still in place today but has shifted and changed considerably since its inception in 1968 (Dick, 2006; "Motion Picture Association of America film rating system," 2014; Bordwell, 2004). Prior to 1984, four ratings were used: G (general audiences), PG (parental guidance suggested), R (requires adult supervision for viewers under 17) and X (no admittance under 18). In 1984, the PG-13 rating was introduced. In addition to providing a more variegated system for rating films, it changed the nature of the PG rating considerably. Prior to this, PG films could contain a greater amount of violence or objectionable behavior; following the introduction of the PG-13 rating, where this material was now placed, the PG rating instead applied to films with only mild objectionable content. This had a trickle-down effect on the G rating; as PG films encapsulated more of the films with mild objectionable content, the G rating became a vessel for children's films with almost no objectionable content. Today, the G rating can only be attained under strict guidelines, including no violence or blood on-screen, no crude humor, and no instances of any foul language (Dick, 2006). These guidelines facilitated a more concrete haven for children's films; films for very young audiences, often with little humor or thematic content to offer adult audiences, usually receive a G rating. The dual-audience family films, which still compose a healthy proportion of theatrical releases, mostly receive PG ratings for their inclusion of adult-geared innuendo, humor, or thematic content. This point in time served as a critical shift for the films contained within the G rating,

As a result of these three concurrent developments in the film industry, the current sample of children's films spans 1985 to 2008. All the films in the sample are G-rated, excepting the unrated direct-to-video selections.

Type

In this thesis, "type" will refer to the technique by which the film is constructed, which results in consistent visual differences in the final film product. Live-action and animated films are the most common types of films, though it is often helpful to differentiate among the subtypes of these films[1].

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[1] Live-action films are most often a direct photographic capture of a live image or a photo capture of an image then rendered with computer-generated imaging (as in *Avatar*, 2009). The latter category of films is rendered to appear photorealistic and as though they were constructed without the help of computer graphics. Many rotoscoped films (like *A Scanner Darkly*, 2006) are rendered to look like animated films, though they are

Cel Animation. The time period covered by this sample is important in that it captures a dramatic transition in the frequency of animation styles within children's films (and, more generally, films as a whole). Cel animation, often referred to as 'traditional animation,' has existed almost as long as film has existed as a media. Cel animation dominated the animation landscape until the fairly recent advent of computer animation, which will be discussed later. Animators create cel animated films by capturing a sequence of painted celluloid layers ('cels' for short) on camera against a static painted background. Subtle differences in the images on the cel layers shot in rapid sequence give the appearance of motion when screened at a particular rate (see the later discussion of Motion, Movement and Visual Activity). Cel animated films, particularly those produced by Disney, were arguably the most predominant early style of family film, and over time increasingly marginalized the animated genre toward the child audience (Pilling, 1997).

Computer-Generated Animation. The introduction of computer technology into film began as an effort to enhance live-action films, but was quickly also developed in ways that streamlined the cel animation process. *The Rescuers Down Under* (1990) was the first animated film to employ the use of computer technology to aid in compositing (Prince, 2012). Classic animated films were digitally restored from their damaged or worn original camera negatives (OCNs) and rereleased in higher-definition formats (Bordwell, 2012). However, the

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rendered from direct photographic capture. Many types of animation exist, including cel animation, stop-motion animation, cutout animation, and computer-generated animation. This thesis will define live-action as one type, but differentiate the subtypes of animation to include cel animation, claymation, and computer-generated animation.

tide of animation shifted considerably when animators began using computers to create entirely-digital films rather than just enhancing previous animation methods[2]. Notably, the release of *Toy Story* (1995) considerably shifted norms for animation as well as the visual style of animated films (for a review, see Lasseter, 1987). Most notably, the difference in these two animated types is on-screen depth; cel animated films are often referred to as '2D animation' because of the limited visual depth afforded by the static background against which cels are shot, while computer-generated animated films are able to create realistic depth in the visual scene. Following the release of *Toy Story*, many major animation studios were pressured to follow its style and success, with Disney eventually acquiring Pixar.

This sample encapsulates this major historical shift in animation styles, beginning in an age of classic cel animation, transitioning to digitally-assisted cel-animated features, and seeing the gradual emergence and eventual domination of computer-generated animation (hereafter, CGA) as the norm.

Live Action and Claymation. The other types of films included within this sample are live action films and claymation films. Live action films are the most common type of film in the industry and are classically the style (and the namesake) of 'motion pictures.' The live action cinematographic process does not differ substantially from the process employed in

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[2] For the purpose of this thesis, films are categorized into types based on their visual aesthetic in film form rather than their means of construction. As computer usage became the standard for animation following the release of *Toy Story* (1995), many animated films that followed were designed to artistically resemble traditional animation despite using considerable computer-based technology for the animation process. Examples include *Mulan* (1996) and *Hercules* (1997). Similarly, live-action films employed greater computer usage to create photo-realistic but impossible on-camera feats, such as the speech, expressions, and actions of animals in *101 Dalmatians* (1996) and *Charlotte's Web* (2006). Despite that these films employ considerable usage of computers, they are artistically designed to resemble other types, and are categorized as such here.

traditional photography; both methods use cameras to chemically imprint patterns of light onto film stock, which is then developed. Because this technique of filmmaking is the most common form, it is unsurprising that this children's film sample also contains a number of live action films.

Claymation inhabits a gray area between live action and animated styles of film because it contains properties of both types. Several other less common styles of film also occupy this space, including pixillation, stop-motion film, and cutout animation[3]. Despite that they are shot non-continuously on camera, usually one frame at a time in the style of cel animated films, the shots are composed of non-drawn (i.e. 'real-life') targets, including clay, plastic, paper, or live figures. These types of film, particularly claymation, existed in short forms since very early in filmmaking, particularly in experimental film (Bordwell, 2004). However, popularity of claymation television shows grew in the 1970s, resulting in greater prevalence of claymation in film (Bordwell, 2004). Claymation sequences in films (a notable example is *Clash of the Titans,* 1981) and feature-length claymation films emerged quickly thereafter. Studios like Aardman and Laika quickly became known for their respective claymation style in feature films.

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[3] Although these styles are commonly confused, there are distinct differences between them. Claymation uses subtle changes in malleable clay or plasticine between frames. Stop-motion or pixillation refers the use of live subjects (animals or people). Cutout animation is created from subtle changes in paper-constructed scenes that are adjusted between shot frames; this technique was made popular by *South Park* (1997), despite that the show uses computer software to approximate this style rather than shooting from actual paper scenes (Bordwell, 2004).

This sample contains four types of films as described above: live action (n = 23), cel animated (n = 39), CGA (n = 13), and claymation (n = 1)[4].

Intended Age

The shift in the MPAA rating system (see above section on MPAA Ratings under Film Sampling and Release Variables) resulted in the G rating for American films being marginalized to include almost entirely films geared toward children. However, even within this niche of films, considerable variation exists in the age for which a film might be geared.

In order to avoid classifying these children's films as a homogenous sample in terms of target age, we employed data from Common Sense Media (http://www.commonsensemedia.org) to variegate more specific intended ages for films within the sample. Common Sense Media provides age rating scales for films of all MPAA ratings in order to assist parents in determining the appropriateness of films for children of particular ages. Though this metric is arguably not purely objective[5], it does provide a consistent metric for intended age throughout both the children's film and Hollywood film samples.

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[4] The children's film sample contains a singular claymation film: *Chicken Run* (2000). Because this film is the only kind of its type in the sample, it will be included in limited analyses, and conclusions about claymation films as a type are limited (see 'Exclusions').

[5] Ratings are generated by the Common Sense Media staff, described as "concerned parents and individuals with experience in child advocacy, public policy, education, media and entertainment" with "a broad range of views and backgrounds." The organization identifies as non-partisan and not-for-profit. (http://www.commonsensemedia.org/about-us/who-we-are)

Common Sense Media rates films for ages with a three-color scale: 'off' (red: inappropriate), 'pause' (yellow: potentially appropriate and best left to parent judgment), and 'on' (green: appropriate). They also circle a target age on the scale. Intended age for the sample was calculated by computing the median of the lowest full age on the 'pause' scale with the circled target age. This computation was done to account for the variance in size of the 'pause' scale for each film, the likelihood that actual viewership within the 'pause' range differed, and the fact that some target ages were within the 'on' range while others were in the 'pause' range.

Figure 1. An example of a Common Sense Media entry. The entry above is for the film *The Care Bears Movie* (1985; http://www.commonsensemedia.org/movie-reviews/the-care-bears-movie). Each media entry contains a scale (usually containing ages 2 – 18) colored to reflect the Common Sense rating system. For the samples, the metric of intended age was generated by taking the median of the lowest whole 'pause' (yellow) age and the circled ('target') age. In the above entry, the intended age would be the median of 2 and 4 (3).

Within the sample, our computed intended age ranged from age 3 (including movies such as *Sesame Street Presents: Follow That Bird* (1985) and *The Land Before Time II: The*

Great Valley Adventure, 1994) to age 7.5 (*The Secret Garden*, 1993). Five films did not have age information available, and they were excluded from subsequent age analyses[6].

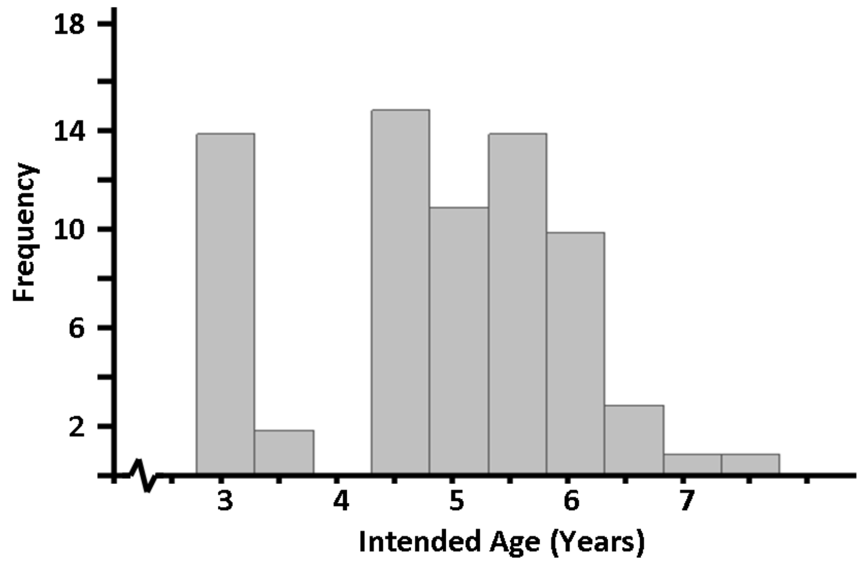

Figure 2. The distribution of the children's films by intended age, computed from data from Common Sense Media. (n = 71).

The age variable was of interest because of its potential to indicate how filmmakers address audiences of differing developmental states; for example, do variables like shot structure and luminance (discussed in detail later) vary based on the intended age of the film?

The release variables, including year, type, and intended age helped to define the sample of children's films that will be examined throughout the thesis. They will also be examined in relation to the computed variables.

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[6] The films lacking Common Sense Media data are *One Magic Christmas* (1985), *Prancer* (1989), *DuckTales the Movie: Treasure of the Lost Lamp* (1990), *All I Want for Christmas* (1991), and *We're Back! A Dinosaur's Story* (1993). Sequels to the *Land Before Time* franchise films were extrapolated from the age range of the first release. Ratings were obtained in October of 2010, and some films may have changed in rating since the initial sampling.

The Comparative Hollywood Film Sample

While an examination of children's films will in itself provide insight into the state of children's media, it will also be helpful to have a comparison group of adult-geared films from a similar period in time. In this way, we will be able to examine both the trends in children's films as well how they relate to and potentially differ from media intended for adults.

For the sample of Hollywood films, we drew from the sample collected by Cutting, DeLong, & Nothelfer (2010) and revisited by Cutting, et al. (2011). For every year ending in 0 or 5 between 1935 and 2010, researchers sampled 10 films from that year based on box office gross figures or IMDB rating. Thus, their sample includes 160 films from 16 years across a span of 75 years.

Year*.* As this children's film sample selects from films released between 1985 and 2008, we hoped to match the selection of Hollywood films in a way that approximated this time period. As a result, we included all 10 films from 1985, all 10 films from 1990, 8 films from 1995[7], 10 films from 2000, and 9 films from 2005[8]. All the films carried an MPAA rating of PG (n = 16), PG-13 (n = 21), or R (n = 10), making them distinct from the children's sample on the basis of rating.

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[7] *Toy Story* (1995) and *Pocahontas* (1995) were originally part of the Hollywood sample in the work by Cutting, et al. (2010). They are excluded from the Hollywood sample as they are part of the children's film sample.
[8] *Chicken Little* (2005) was originally part of the Hollywood sample in the work by Cutting, et al. (2010). It was excluded from the Hollywood sample as it is part of the children's film sample.

Type. The sample contains only two types of films (discussed in Film Sampling and Release Variables), live action (n = 45) and CGA (n = 2). Whereas the children's sample is diverse but biased toward animated types, the Hollywood sample is heavily biased toward live action films, making type an important variable in later comparative analyses.

Intended Age. In addition, we computed the same metric on intended age for the Hollywood film sample. The median scale value for the children's films likely provides a reliable metric for intended age; however, because the scale is truncated at age 18, this metric for the Hollywood films likely produces something closer to lowest appropriate age. For example, many of the rated R films, including *The Usual Suspects* (1995) and *Goodfellas* (1990) have no 'go' ages listed on their scale; the former has a 'pause' for ages 17 (the circled age) and 18, and the latter has no information (simply listed as 'Not for Kids'). In the case of *The Usual Suspects*, it is unlikely that 17 is truly the target age, as its content is much more likely geared for older adults. Additionally, some of the films in the Hollywood sample that carried a PG rating overlap in the Common Sense age rating with the children's film sample. Both *Dinosaur* (2000) and *Casper* (1995) carry a PG rating but have a median scale rating of 6, falling close to the mean intended age for the children's sample. For comparative purposes, we nonetheless included the metric for the Hollywood sample. When comparing the children's film sample and Hollywood film sample, we will address both this metric and the more viable metric of rating (though the Common Sense rating is helpful for within-rating comparisons).

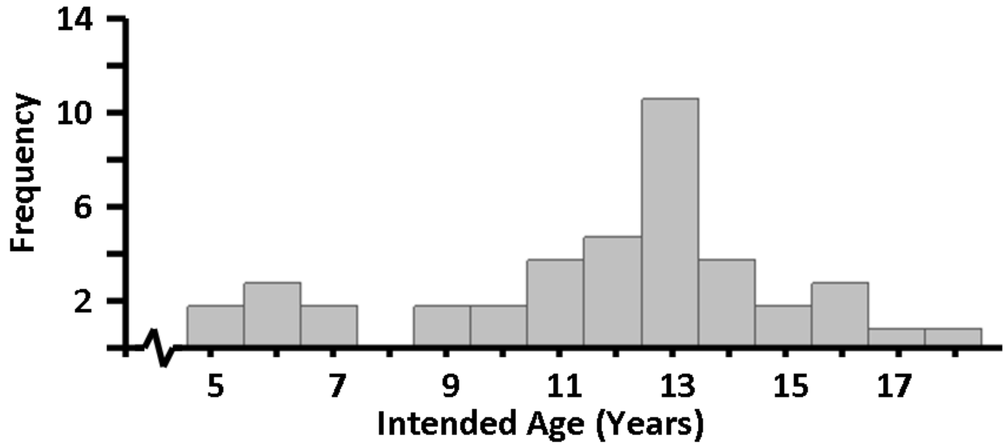

Figure 3. The distribution of Hollywood films by age, computed from data from Common Sense Media (n = 42).

Exclusions

Several films, for reasons detailed below, had to be partially excluded from certain subsequent analyses.

Intended Age. Five children's films, as of 2012, did not have entries in the Common Sense Media database, and thus did not have age data from which intended age could be calculated. Two of these films were cel animated films: *We're Back: A Dinosaur's Story* (1993) and *DuckTales: Treasure of the Lost Lamp* (1990). The remaining three were live action films: *One Magic Christmas* (1985), *Prancer* (1989), and *All I Want for Christmas* (1991). Additionally, five Hollywood films also lacked Common Sense Media entries and were excluded: *Police Academy II: Their First Assignment* (1985), *Rocky IV* (1985), *Spies Like Us* (1985), *The Hunt for Red October* (1990), and *Ace Ventura 2: When Nature Calls* (1995). Collectively, these 10 films were excluded from analyses involving intended age as a metric, or where intended age was a variable in the regression model.

Type. The only claymation film in the children's sample or the Hollywood sample is *Chicken Run* (2000). Discerning trends for claymation as part of the categorical 'type' variable would be impossible given a singular data point in the category. As a result, we excluded the film (and claymation as a category) from analyses where type was a metric or included in the model. In the Hollywood film sample, *Dinosaur* (2000) and *Madagascar* (2005) were similarly excluded, as they were the only two CGA films in an otherwise entirely-live action sample[9].

Appendix A contains a complete list of films in the children's film sample and the comparative Hollywood sample, along with their release variables.

Analyses to be Performed

With the release variables serving as predictors in the regression models, we will examine a series of four computed variables, and the patterns exhibited by children's films (and the matched set of Hollywood films) in those domains. First, we will examine *average shot duration* (ASD), a common filmic metric, but also an important quantifiable variable given the contentious but largely qualitative assertions about pacing in children's media. Second, we will examine shot structure and its fit to power spectra, a metric pioneered in the

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[9] In addition to being the only CGA films in the Hollywood sample, these two films are arguably 'adult-geared' in name only. Both *Dinosaur* and *Madagascar* are thematically designed as children's films, but did not meet the criteria for G ratings for 'intense images' and 'mild language, crude humor, and some thematic elements,' respectively (Classification and Rating Administration, http://filmratings.com). This alone is not enough to exclude these two films from the Hollywood sample, but their existence as the vast minority in the Type variable merits exclusion. Several other films in the adult sample that could be considered children's films, such as *Casper* (1990) and *Teenage Mutant Ninja Turtles* (1990) remain in place in the Hollywood (adult) sample.

domain of human cognition by David Gilden and colleagues (Gilden, Thornton, & Mallon, 1995; Gilden, 2001; Gilden & Hancock, 2007), and subsequently applied to film shot structure by Cutting and colleagues (Cutting, DeLong, & Nothelfer, 2010). Third, we examine a motion metric called visual activity that quantifies the amount of on-screen motion. Finally, we assess a measure of on-screen luminance.

Average Shot Duration

Overview

Films are composed of continuous visual sequences known as *shots*. Filmmakers link these visual sequences with transitions of various types. The most common transition is called a *cut*, and occurs when two pieces of film are juxtaposed in projection with no other visual interlude. Cuts create the appearance of jumping between visual scenes (see Figure 1 below). Cuts are by far the most common transition in modern Hollywood film, composing over 99% of transitions (Cutting, DeLong, & Nothelfer, 2010). Other transitions, including dissolves, wipes, and fade-ins and –outs are much rarer, but often chosen stylistically as they carry particular psychological ramifications for viewers (Cutting, Brunick, & DeLong, 2011). By comparison, cuts are often 'missed' by viewers, who often fail to recognize whether a cut occurred or how many cuts occurred in a given clip of film (Smith & Henderson, 2008).

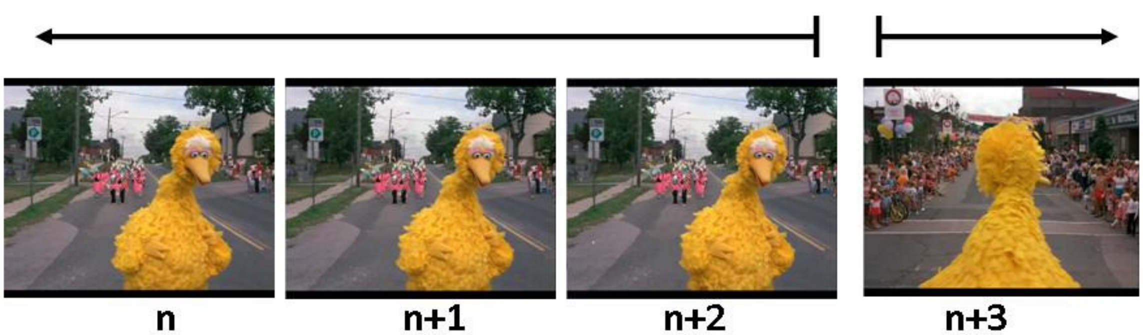

Figure 4. Four sequential frames from *Sesame Street Presents: Follow That Bird* (1985). Frames n, n+1, and n+2 are visually continuous, and they are part of the same shot. A cut (sudden visual discontinuity) occurs between frames n+2 and n+3; frame n+3 begins a new shot.

Because the length of shots can be measured by recording when cuts occur, *average shot duration*[10] (ASD) has emerged as a metric. Two of the most prominent sources for shot duration data are film scholar Barry Salt (2006) and the Cinemetrics database curated by film scholar Yuri Tsivian (http://www.cinemetrics.lv). In compiling ASD data on thousands of films, considerable evidence exists that ASD has steadily decreased since the inception of feature-length films in the early 20th century (Salt, 1974; Salt, 2006; Bordwell, 2002).

Questions recently arose regarding whether the mean shot duration was the most representative metric for film, based on the notion that means are a poor representative statistic for these lognormal-like distributions (Salt, 1974; Redfern, 2009; DeLong, Brunick, & Cutting, 2012; Redfern, 2012a; Redfern, 2012b; DeLong, 2013). Considerable debate eventually yielded an advantage for median shot duration as the preferable statistic, given that the lognormal distribution is a robust estimator of shot length distributions (DeLong, 2013). While median shot duration would have been the ideal descriptor for the shot distributions in the sample, it would marginalize the current data set from other films for comparison, as historically average shot duration is the computed metric[11]. Average shot duration and median shot duration are tightly correlated, suggesting that while MSD would be ideal in describing the within-film distribution, ASD and MSD are nearly interchangeable when comparing between films, as most of the described analyses will do (see Figure 5).

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[10] This paper will refer to this metric, sometimes called *average shot length*, as *average shot duration* (ASD). Because the term *length* is also often used in the film literature to refer to elements of shot scale (de Seife, 2011), this paper will use the *duration* to refer to the temporality of shots.

[11] Ideally, future analysis would account for the superiority of median shot duration in reflecting within film trends.

Furthermore, the decreasing trend in shot lengths is still viable independently of whether mean or median is used for analysis.

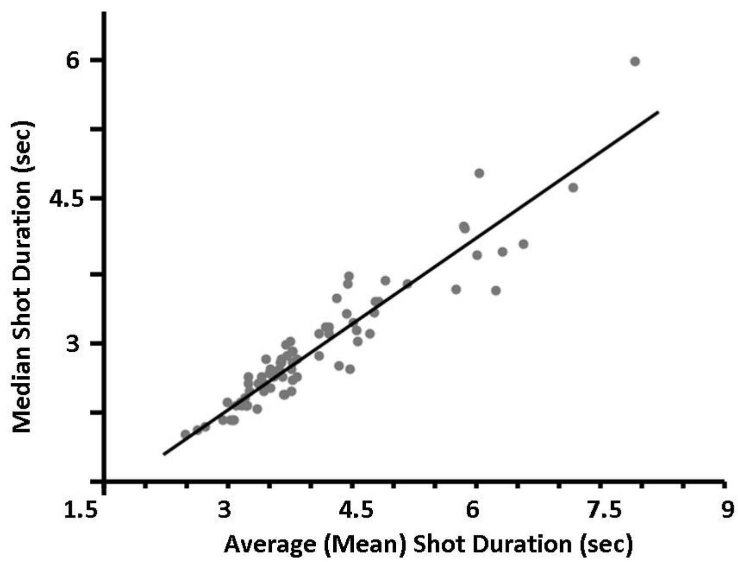

Figure 5. Plot of MSD by ASD. Though MSD reliably produces smaller numbers due to the log-normal shape of within-film distributions, the two variables are tightly correlated ($r = .942$, $p < .0001$). ASD is used in further analyses to allow for comparisons on this metric outside the film sample.

Psychological Implications

ASD is arguably the most pervasive quantifiable metric used in the film literature; however, it is also a contentious topic in psychological discussions of the value of children's media. Cross-disciplinary dialogues have emerged in the psychological, educational, and pediatrics literature about the *pacing* of children's media, particularly television. Pacing, as defined by much of the existing research, refers to some combination of ASD, shot structure, and within-shot motion; typically, categorical levels of pacing are determined by human coders. Definitions of pace will also occasionally include content-related measures, such as scene change and character change (Wright, Huston, Ross, Calvert, Rolandelli, Weeks, Raeissi, & Potts, 1984). In this way, researchers have quantified with high-ICR what 'pacing' as a variable might look like and how to distinguish it, but have not yet mathematically analyzed it. The most relevant pacing index (which produces a relative continuous numerical metric) was devised by McCollum & Bryant (2003). In their system, cut frequency, scene change, auditory changes (dialogue, music), and on-screen motion were included in a weighted analyses of children's media to produce a pacing metric. The metric showed robust differences between network and cable programming, as well as between shows labeled curriculum-based or entertainment-based[12].

Many have argued the outcome of children viewing fast-paced programming (as opposed to slow-paced programming) produces negative attentional outcomes, but conclusive findings have been scarce. For instance, evidence exists both for (Geist & Gibson, 2000) and against (Anderson, Levin, & Lorch, 1977) the notion that attending to fast-paced television produces later difficulties in impulse control and attentional focus. Prominent pediatrics researcher Dmitri Christakis (2009) has claimed that fast-pacing in television is responsible for the emergence of attention-deficit hyperactivity disorder (ADHD) in children with particular levels of early viewing (Zimmerman & Christakis, 2007; Christakis, Zimmerman, DiGiuseppe, & McCarty, 2004; Zimmerman, Christakis, & Meltzoff, 2007).

[12] McCollum and Bryant provide an insightful review into the critiques of pacing in children's media, along with a temporally-arranged literature review of the attempts to quantify and analyze pace.

However, these findings contained some methodological problems and could not effectively be replicated (Stevens & Muslow, 2006; Ferguson & Donnellan, 2014).

Many of these studies and critiques have focused on (1) primarily television and (2) deferred or longitudinal outcomes of media exposure. Some, however, have taken a more learning-relevant approach in examining pacing as it is relevant to video-dependent learning. For instance, it is clear that relatively slow pacing is more effective in recalling video content (Wright et al., 1984). Heightening pace can lead to increased visual attention to a visually-discontinuous media, such as magazine-style children's programs (Wright et al., 1984). Additionally, when the media itself is more child-focused in narrative structure, better learning of complex material is more likely to occur (Campbell, Wright, & Huston, 1987). Sound effects are helpful for keeping children visually attended to fast-paced media, which underscores the psychological underpinnings of some of the intensified continuity rules in Hollywood films (Calvert & Scott, 1989; Smith, 2012; Bordwell, 2002).

While the pacing literature has examined immediate effects of learning and long-term behavioral effects, the pacing metric nonetheless confounds ASD with other metrics like shot structure, motion, and content. The study of pacing is relevant, as it is the closest related low-level metric examined from a psychological perspective. Nonetheless, it will be useful to (1) titrate out ASD from other variables in pacing and (2) compute ASD as a point of comparison to Hollywood films.

Methods

Average shot duration can be computed in one of two ways. The first method, employed by Salt (1974, 2006), involves counting the number of cuts in a film and dividing the total length of the film by this number. This provides a convincing whole-film statistic, but does not generate information about the distribution of shot durations within a film. This thesis employs the second method for computing shot duration: recording the frame number at which each individual cut occurs, compute the duration of the shots between these cuts, and average the length of each individual shot over the entire film. With this approach, we not only get a whole-film metric of ASD, but also the potential to invoke information about a film's distribution, as seen below in Figures 6, 7 and 8. Note that while the distributions are similar in shape, the range of both parameters (number of shots and ASD) differ radically.

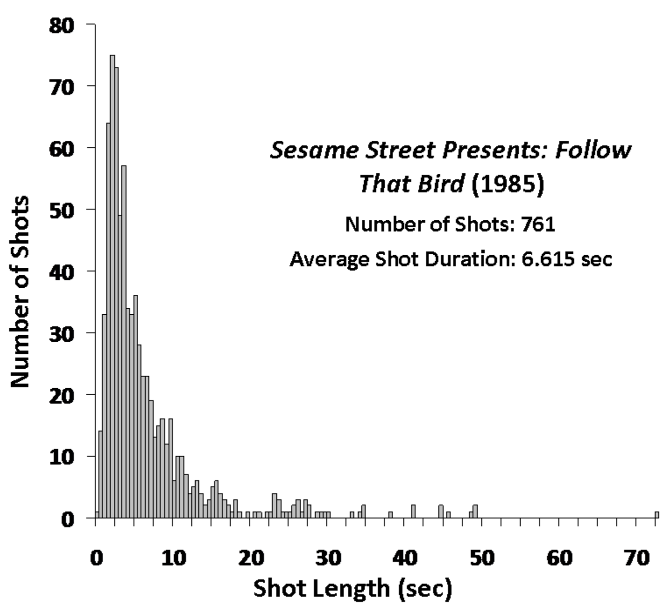

Figure 6. Shot duration distribution of *Sesame Street Presents: Follow That Bird* (1985). This live action film has fairly few shots (761) and contains a relatively large proportion of long-duration shots; about 17 percent of the films shots are longer than 10 seconds, with one shot lasting just over 3 minutes. (Figure modeled from DeLong, Brunick, and Cutting, 2010).

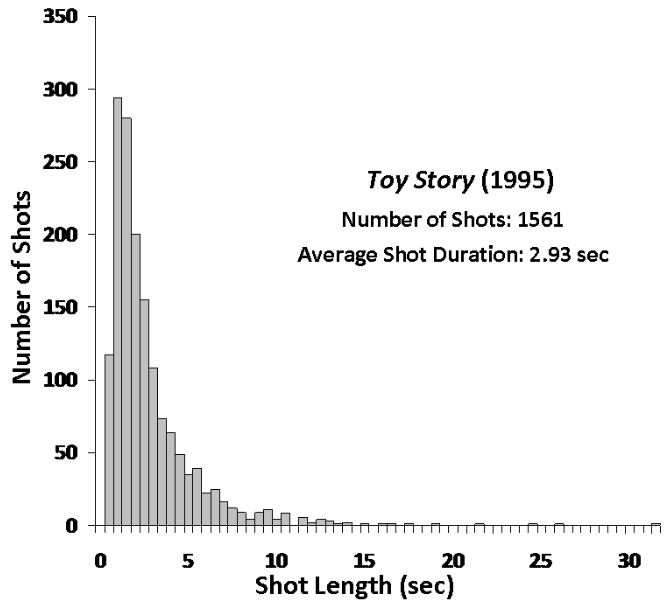

Figure 7. Shot duration distribution for *Toy Story* (1995). This CGA film has a large number of shots (1561) and one of the lowest ASDs in the children's film sample.

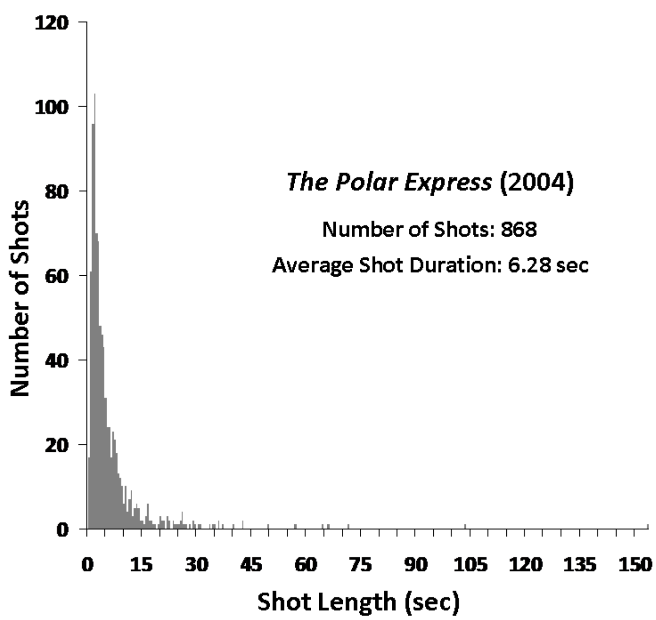

Figure 8. Shot duration distribution for *The Polar Express* (2004). This CGA film has a much longer ASD than other films released in the surrounding years.

Given that little variance exists in the total length of the films, one can easily infer that films with higher numbers of shots will have a lower ASD. Figure 3 depicts the shot duration distribution of *Toy Story* (1995), which has a relatively high number of shots and a much shorter ASD (86 percent of the shots in the film are shorter than 5 seconds). Conversely, films like *Follow That Bird* (1985; Figure 2) and *The Polar Express* (2004; Figure 4) have much longer ASDs, but far fewer shots. These films, however, differ in their tails, with *The Polar Express* having several extremely long-duration shots which skew the distribution plot tremendously. *The Polar Express* is an outlier in the ASD domain, having a dramatically longer ASD than any other film released within 10 years[13].

To compute ASD as well as the shot duration distributions, we need to compute the location of shot boundaries. For the Hollywood sample, a three-step MatLab-based system for cut coding was employed. Significant changes in luminance were flagged by a computer program as potential cuts, which were then accepted (and labeled with the transition type) or rejected by a human coder (see Cutting, et al., 2010 for a review). Because the luminance change algorithm performed poorly on identifying potential transition information in animated films, films in the children's sample were hand-coded by human coders. Films were stripped of their soundtrack and given to coders, who clicked through the films frame-by-frame; upon discovering a transition, coders recorded the frame number of the transition. This provided a much higher coder hit rate for transitions than watching the film at normal

[13] The exception to this is *The March of the Penguins* (2005), which has been excluded from some analyses for being a considerable ASD outlier and because it is the only documentary film in either sample.

speed with its soundtrack; filmmakers intend for most transitions to go unnoticed and not interrupt the visual continuity, so often viewers miss the appearance of cuts when films are viewed at normal speed with a soundtrack (Smith & Henderson, 2008). The duration of each intervening shot was computed from the locations of the transitions. The shot lengths were then averaged to attain the whole-film ASD metric.

Results

Both children's films and the component sample of Hollywood films have average shot durations that decrease across historical time. The Hollywood sample was examined with MPAA rating, intended age, and year as possible covariates in the regression model; the children's sample included type, intended age, and year. For this and all further analyses, unless otherwise noted, backward elimination regressions were employed, and eliminated parameters are noted.

Year. Films in the Hollywood sample decreased in ASD over time, though the trend was not statistically significant, $F(1,38) = 3.1173$ ($p = .09$). Cutting and colleagues (with an expanded version of this sample; 2011) were able to show a decrease across a wider range of time, the truncation of the sample to only include films from 1985 – 2005 shows that the ASD decrease over time is not reliable for this subset of time. Intended age and MPAA rating were unhelpful contributors to the model.

In the children's sample as a whole, once age is removed as an unhelpful contributor, there is a trend for ASD to decrease over time ($R^2 = .09$, F (1, 68) = 6.41, $p < .05$), matching the general pattern present in the adult-geared sample.

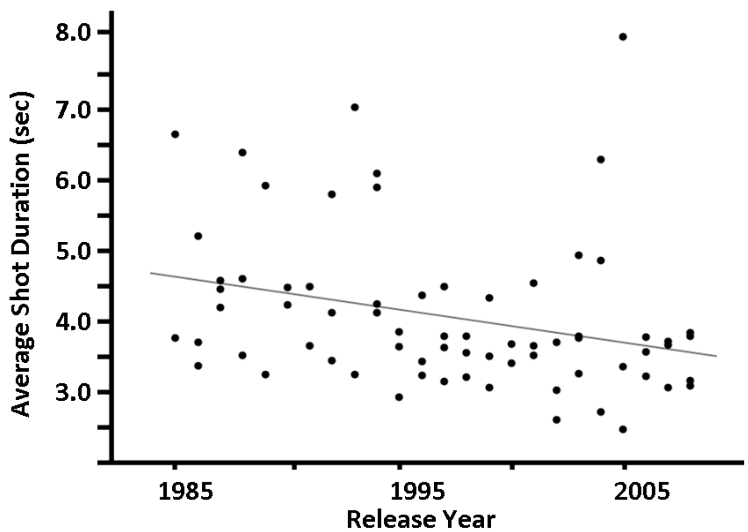

Figure 9. ASD of children's films across time. The decrease in average shot duration is moderate but statistically significant.

It is important to note, however, that this change over time is heavily driven by type, in particular, cel animated films. While neither live action films nor CGA decrease significantly over the examined year range, as shown in Figure 10, cel animated films exhibit a decrease in ASD, $F(1,33) = 7.78$ ($p < .01$). No differences exist between the types in the sample of children's films.

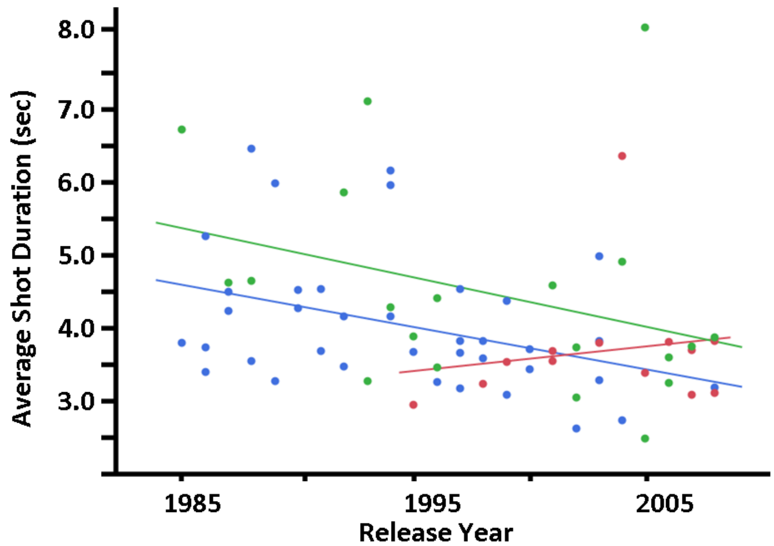

Figure 10. ASDs of children's films over time by type of film. Cel animated films (blue) exhibit the only significant decrease in ASD over time. Live action films (green) exhibit a trend that is non-significant, even with the exclusion of the outlier *March of the Penguins* (2005). The trend in CGA (red) appears to increase, though this is likely the artifact of the small sub-sample size.

For a sample including both the Hollywood and children's films, year was the strongest predictor for decreasing ASD, $F(1,107) = 9.96$ ($p < .01$). In comparing the two samples to one another, the Hollywood films have longer ASDs than the children's films, $t(108) = 2.23$ ($p < .05$) until year is introduced as part of the regression model, at which point the difference is non-significant. Additionally, we found no meaningful difference between the children's live action films and the Hollywood films (all of which are live action; $t\,(58) = .47$, $p = .64$), underscoring that the cel animated films seem to drive this difference in ASD between the two samples.

Age. The intended age of the film as its own metric carried fairly little weight in the model and was not predictive of ASD in children's films. However, this metric was important within sub-types of films, particularly cel animation (see Figure 11). In cel animated films, as the intended age of the film increased, the ASD decreased, $F(1,34) = 8.26$ ($p < .01$). This effect was not present in live action or CGA films. Age and year were reasonably equal in their ability to predict change in cel ASD ($\beta_{age} = -.39$, $\beta_{year} = -.41$).

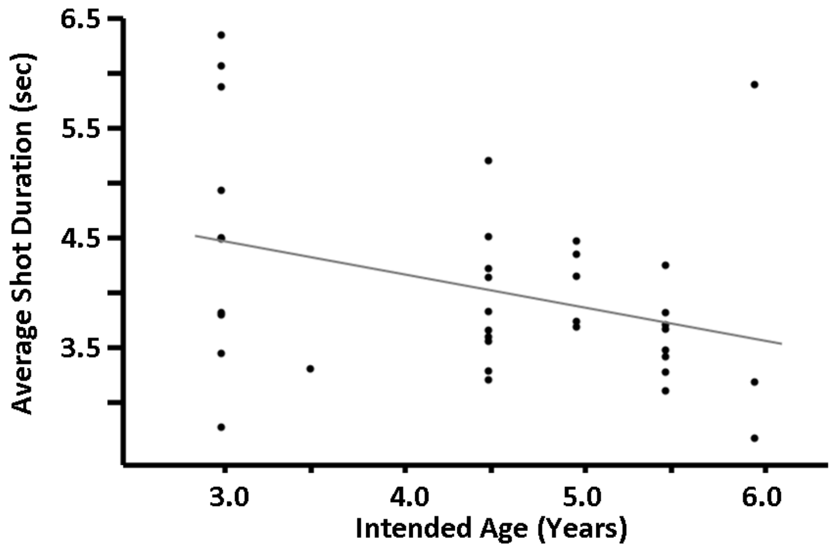

Figure 11. ASD of cel animated films by intended age. As the intended age of cel animated films increases, the ASD for the films decreases.

Discussion

The average shot duration of this sample decreases over time, consistent with findings of a great deal of previous literature. Taken as a single sample, both the Hollywood films and children's films together follow the patterns previously described by Salt (1992, 2006), Cutting (2011) and many others. Despite not being statistically significant, the Hollywood sample trends toward a decrease in ASD over time. This could be a potential artifact of two things: (1) the truncated year range may be too small to express this change meaningfully or

(2) the decrease in ASD in films is beginning to reach floor (in other words, shot durations can only become so small while still containing meaningful content).

Children's films also show a meaningful decrease in ASD over time, though the effect is largely driven by cel animated films. Children's live action films, like the Hollywood film set, may also be approaching floor, as they do not exhibit a meaningful decrease in this time range. The novelty of computer animation means that relatively few films exist in this category, nor has enough time passed since their inception for a year-based trend to be meaningful.

The decrease in ASD over time for cel animated films could be the result of several things. First, cel films represent the highest proportion of the children's film sample, so the decline in ASL over time could simply be a reflection of the overarching decline of ASD in all films. Second, the introduction of computer technology into animation fundamentally changed the way cel animated films were composed. Colorization, background construction, and motion rendering were all processes that changed with the introduction of computers. With animators now able to rely less and less on expensive hand-drawn and hand-colored background layers, filmmakers had fewer restrictions on containing action to a single shot. However, long sequences of action were not always preferred by animators, as longer shots required higher numbers of unique cells. This is evidenced by the very short ASDs in early cel animated films, such as *Cinderella* (1950) and *Pinocchio* (1940), which have ASDs of 3.99 and 5.43, respectively. *Cinderella* and *Pinocchio* differ markedly from their contemporaries in ASD[14]. Additionally, cel animated films would have likely differed meaningfully from the other groups in ASD if something in particular about this form of animation affected shot lengths. It is likely that cel animated films have comparatively exhibited shorter ASDs throughout time, and as such the trend present in this data reflects the general shortening of ASD in films rather than something peculiar in the cel animated form.

While the difference between the children's film sample and the Hollywood film sample is not significant, the trend is worth examining and discussing critically. In simply glancing at the data, one might surmise that children's films exhibit much lower ASDs on average than Hollywood films of the same year. This could invoke alarm in those who credit faster pacing with negative outcomes and poor comprehension, as it would appear that children's films are faster paced than Hollywood films. This superficial analysis is unrealistic for a number of reasons. First, the decrease in ASD of all the films over time contributes to the model of this data; the difference between children's films and Hollywood films dramatically reduces in significance when change over time is added as a covariate. Second, there is an inherent sampling problem in terms of genre. While the Cutting et al. (2010) sample was selected from a wide range of genre, almost all children's films fall into two main genre: adventure and comedy. Genres predictably differ in motion indexes (see *Motion, Movement, and Visual Activity* later in Chapter 1) as well as ASD (Cutting, Brunick, & DeLong, 2011). Dramas tend to exhibit the longest ASDs; for example, the ASD of *Cast Away*

[14] Drawing from the Cutting et al. 2010 sample, the remaining 9 films from 1940 have a mean ASD of 10.06 (compared to *Pinocchio*'s 5.43), and the remaining 9 films from 1950 have a mean ASD of 12.73 (compared to *Cinderella*'s 3.99).

(2000) is 9.48. By contrast, action and adventure films exhibit relatively low ASDs. In other words, the ASD/fast-pacing of children's films may merely be an artifact of the fast-paced genres selected for children's films. Finally, it is worth taking type into consideration, and comparing only the live action films from each sample shows no difference in ASD.

Intended age was a meaningful predictor of ASD, but only for cel animated films. Longer ASDs are associated with younger intended age groups, and ASD decreases as the intended age of a film increases. This is an unsurprising finding; because cel animation is almost always identified as a child-specific medium[15], filmmakers intending to cater to a young audience may in fact keep metrics of pacing in mind when creating films. Understanding that young children in particular learn best from slow pacing, these filmmakers may have deliberately used longer shot lengths to anticipate young audiences' learning capabilities. Alternatively, longer shots in films for younger audiences could have emerged as an artifact of some other perceived need of this age group: slower speech rates of characters, longer establishing shots, lower rate of scene changes, and so forth.

In sum, ASD for children's films in this sample is decreasing over time. This effect is driven considerably by the decline in ASDs for cel animated films in particular, more so than the trends of live action and CGA films, though no meaningful differences exist between the means of the film types. At first glance, it would appear that ASDs are shorter for children's

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[15] Disney's early investments into cel animated features quickly marginalized this form of filmmaking as "somehow intrinsically only appropriate for entertaining children," much to the dismay of filmmakers seeking to make adult-geared cel animated films (Pilling, 1997; as referenced in Brunick & Cutting, 2014). This notion permeates a great deal of children's media research as well, with cel animation (and more recently, CGA animated) being considered an intrinsically appealing style for child audiences (for example, see Campbell, Wright, & Huston, 1987).

films than for Hollywood films, but further analyses debunk that children's films exhibit faster pacing in this way. The ASD of children's films over time reflects and supports current knowledge that ASD has been decreasing over historical time. ASD also decreases as the intended age of the film's audience increases, supporting the notion that filmmakers are sensitive to younger audiences' needs for slower pacing to aid comprehension.

Shot Structure

Overview

In examining media, particularly media for children, there are often questions about how media captures, affects, and interfaces with attention. Attention is a notoriously nebulous concept in psychology; indeed, attending to something visually and 'paying attention' in the canonical sense need not (and often do not) overlap. While there is considerable evidence for this in adults, children also exhibit this discrepancy between attention and attending visually. Children that were given distractor toys while watching educational television clips visually attended to the television half as much as children without toys, and yet no difference in recall or comprehension of the educational material existed between the groups (Lorch & Anderson, 1979). This is true of typically developing children, but it is also true of children diagnosed with attentional problems, including ADHD (Landau, Lorch, & Milich, 1992).

Attention is often studied in terms of vigilance. Vigilance is difficult, and our ability to maintain attention decreases over time, as does our ability to perform detection or discrimination tasks relevant to being vigilant (for examples, see Parasuraman, 1979; Haider, Spong, & Lindsley, 1964; Paus, Zattorre, Hofle, Caramanos, Gotman, Petrides, & Evans, 1997; Oken, Salinsky, & Elsas, 2006). Vigilance in young infants, especially how low-vigilance and high-vigilance infants differ in looking behaviors, is important to understanding the development of top-down attentional processing (de Barbaro, Chiba, & Deák, 2011; Aston-Jones, Rajkowski, & Cohen, 1999). Psychologists often discuss attention with regard to attentional shifts, or what motivates us to change attention (visually or otherwise) between two or more stimuli. Shifts in attention are most often characterized as a bottom-up process, with low-level information guiding visual and attentional reorientation (for examples, see Treisman, 1980; Rorden & Driver, 1999; Ditterich, Eggert, & Straube, 2000; Lawrence, Myerson, & Abrams, 2004). Recently, mind-wandering has been a topic of research, and studies have perhaps unsurprisingly found that mind-wandering impedes memory for information presented during mind-wandering (Smallwood, McSpadden, & Schooler, 2008). What has been historically left unexamined until recently is what kinds of attentional fluctuations are present naturally in humans; that is, in the absence of effortful vigilance, and with no deliberate shifts being imposed, how does attention to a given task fluctuate? Astrophysicist-turned-psychologist David Gilden and his colleagues were the among the first to attempt to model natural fluctuations in human attention; by examining varying latencies in reaction time tasks, these researchers discovered an underlying pattern in human attentional shifts (Gilden, Thornton, & Mallon, 1995; Gilden, 2001). This pattern is known as $1/f$ noise.

$1/f$ noise is a distinct type of mathematical noise originating mainly in the signal analysis literature. It is also known as "pink noise," and is characterized as a type of power law[16]. In this particular power law, power (which is related to amplitude) and frequency have an inverse, decreasing relationship. This is in contrast to other common noises plotted on

[16] The two are sometimes used interchangeably, but it is important to note that pink noise is one subtype of a power law, a category which also includes things like Zipf's law and gamma corrections.

similar log-power/log-frequency axes, including white noise (or $1/f^0$) and brown noise (or $1/f^2$). $1/f$ noise is importantly not a unique phenomenon to human attentional rhythms demonstrated by Gilden and colleagues; it is an underlying pattern found in many natural and man-made complex systems, including citations of scientific papers, moon crater diameters, city populations, wealth, and family name frequencies (Newman, 2005). It is also not necessarily characteristic of all human attentional rhythms; adults with ADHD were more likely to exhibit attentional variations that followed $1/f^2$ (random walk) rather than $1/f$ (Gilden & Hancock, 2007).

Cutting, DeLong, and Nothelfer (2010) applied Gilden's model to Hollywood films, and found similar $1/f$ patterns emerging from the shot structures in these films that also seem to emanate during cognitive tasks. Since about 1960, Hollywood films in their sample shift away from randomness in their shot structure toward shot structures that more closely resemble $1/f$ models. They hypothesize that filmmakers, on some non-conscious level, use shot structure to capture the waxing and waning attention of their audience back to their film. This is certainly not to say that we are unable to attend to films that do not adhere to this type of shot structure; instead, we may simply find that films more adherent to this structure are more intrinsically engaging. Indeed, films that were more commercially successful were also more likely to adhere to this pattern. We have known both cognitively (Bordwell, 2002) and scientifically (Smith, 2012) that filmmakers seek to engage viewers and focus audience attention toward the screen. There are many deliberate ways in which filmmakers attempt to do this, but the adherence of the film to a $1/f$ structure is an emerging artifact of engaging storytelling, not an intentional effort (Cutting, et al., 2010).

This poses an interesting set of questions about film in relation to children's media. First, adults are obviously responsible for the construction of children's films and media; in other words, children are not designing their own media. If adult filmmakers are imposing their notions of what is engaging on their films' shot structures, are they also imposing these biases on children's films as well? It is likely that children's filmmakers are either (1) using adult attentional information on children's films, which would make them identical to Hollywood films in their shot structure or (2) non-consciously attempting to discern what shot structures 'look good' for children's films, as filmmakers already seem to do with ASD in cel animated films (see *Average Shot Duration*). The problem with the latter as a possibility is that is requires a more conscious, effortful participation on behalf of the filmmaker; it is more likely, as Cutting et al. argue, that the process of imposing an attention-grabbing shot structure on a film is fairly intuitive on the filmmaker's part. We also don't know how child audiences will receive media in this fashion; while we know from Gilden's work that adults emit particular patterns of cognitive noise, we also know that the attentional processes of children are very different from adults. For example, children have trouble attending to multiple features of objects or voluntarily shirting their own attention (Trick & Enns, 1998). However, the overwhelming majority of research on children's attentional patterns is on atypically developing children, specifically children with ADHD and autism. As such, we don't necessarily know what to expect when it comes to typically-developing children's emissions of attentional rhythms. It is possible that we develop the $1/f$–like attentional fluctuations very early in life based on lots of complex input, or it is possible this develops slowly over the lifespan and that early attentional rhythms are random or follow some other pattern. The current research aims to answer the first question: what kinds of patterns are present in the shot structures of children's films, and do they differ from what has been found among Hollywood films?

Methods

Following Cutting et al. (2010), we examined the global relationships between shots across films in comparison to the Hollywood films. After identifying shot boundaries either manually or with a MatLab-based algorithm, we computed shot durations and normalized them for each film. As in the original analyses, we followed Thornton & Gilden's (2005) recommendation for computing power spectra using (1) composite spectra-based estimation and (2) 2^n- sized windows[17].

To compute the largest windows for these analyses, typically we would determine the closest value of 2^n that matched the number of shots within a film without exceeding that number. Most films in both samples (children's and Hollywood) contain between 800 and

[17] Thornton and Gilden (2005) discuss why the composite spectrum calculations (which are composed of multiple window-averaged spectra) are superior to simple window-averaged spectra. First, while simple window-averaged spectra reduce variance in the output and provide smoother output spectra, neighboring frequencies are correlated, which is non-ideal. Second, and perhaps more importantly, estimating low-frequency power spectra rely on large window sizes; the larger the window size (m), the fewer their number, and this diminishes statistical power. The composite spectrum allows for much more reliable estimates of power at all frequencies because m is no longer fixed, and can approximate spectra in low- and high-frequency domains.

2,000 shots, though there are exceptions[18]. For a film with 2000 shots, the closest value of 2^n that is smaller than 2000 is 2^{10} (1024). For a film containing 1023 shots, the closest value of 2^n is also 2^{10}, but because 2^{10} is greater than 1023, the appropriate corresponding window would be 2^9 (512). However, because of the high variance introduced by very large windows with low frequency, we used a more conservative estimate of 2^{n-1}; in this case, a film with 2000 shots would use a maximum window size of 2^9 instead of 2^{10}. Power was computed for all windows between 2^0 and 2^{n-1}.

We fit the same hybrid model of $1/f^\alpha$ and white noise used by Cutting and colleagues (2010) to the resulting composite spectra of each film. The resulting slope (α) provides an estimate of how much colored noise is contained within each spectrum. In other words, the closer the slope is to 1, the more the shot structure of the film resembles $1/f$, and potentially contains relevant attentional cues. The closer the slope is to 0, the more the shot structure of the film resembles white noise ($1/f^0 = 1$, flat spectrum), and the shot structure in this case is close to random.

Results

Year, intended age, type (children's films), MPAA rating (Hollywood films) and ASD were examined as relevant contributors to the model. ASD is correlated with slope ($r = .1876$, $p < .05$, $n = 123$); this is not necessarily surprising given that the two metrics are tightly

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[18] For example, *Sesame Street Presents: Follow That Bird* (1985) contains only 761 shots, while *Herbie Fully Loaded* (2005) contains 2228 shots.

interlinked. The windows of spectra computation are determined by how many shots are in the films and how long those shots tend to be (given a fairly steady total length of films). As a result, it is impossible, and not necessarily interesting to try to decouple ASD and slope in these analyses. As a result, ASD was removed from the model.

For the Hollywood films, there was no change in slope as a factor of year, MPAA rating, or intended age. Previous research has shown the steady decline in slope through historical time, and this discrepancy with the current analyses will be addressed further in the Discussion. No meaningful difference was found between the Hollywood sample and the children's sample as a whole in terms of slope.

No trends emerge from analyses of slope for the children's film sample as a whole. However, type is once again a strong predictor in the model, so examining slope within types will be a more relevant framework.

CGA Films. A raw correlation shows a significant relationship between release year and slope, $r = .5825$, ($p < .05$, n = 13). It appears that even within the short time period in which CGA films have emerged, they are already mirroring the trends of Hollywood films in their approach of $1/f$–like shot structure. However, when intended age is added to the model, neither year ($F(1,9) = 1.28$, $p = .29$) nor age ($F(1,9) = 0.31$, $p = .59$) remain as significant predictors of slope. The very small sub-sample of CGA films means that the statistical power of these analyses is low.

Live Action Films. When using intended age and year as predictors in the model, live action films also increase in slope over historical time, $F(1,17) = 4.82$ ($p < .05$). In other words, more recent live action films are more likely to exhibit slopes closer to 1, or shot structures that more closely approximate $1/f$ noise (see Figure 12). Intended age was not a robust predictor of slope for live action children's films.

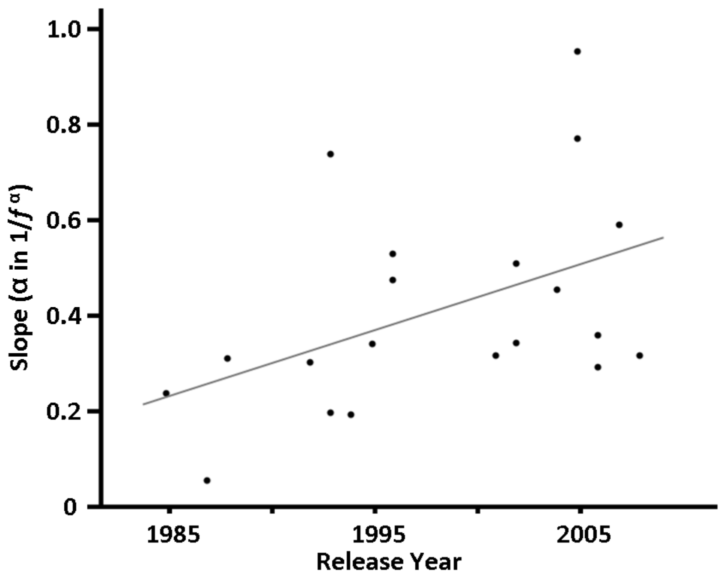

Figure 12. The slope of the colored noise in live action children's films by release year. More recent films are more likely to exhibit colored noise closer to $1/f^1$ (pink noise), while older live action children's films tend to have more random shot structures.

Cel Animated Films. Unlike CGA and live action films, the slope of cel animated films has remained fairly steady over time (see Figure 13).

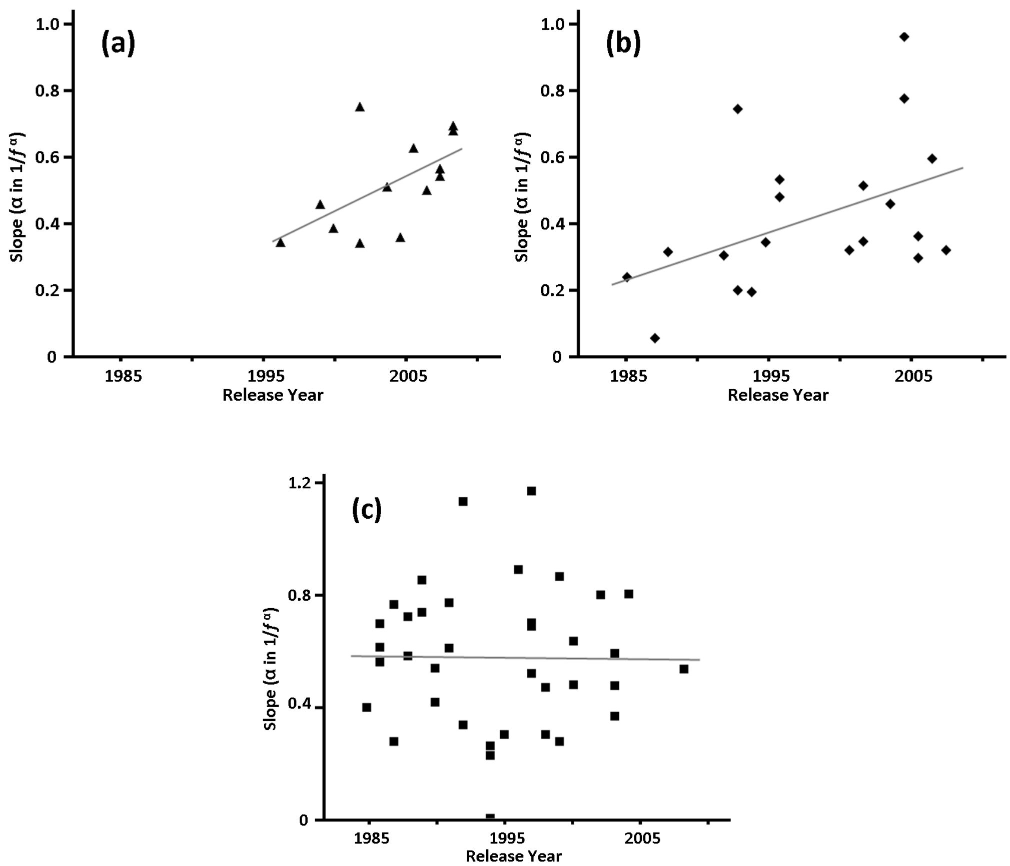

Figure 13. The slope (α in 1/f^{α}) of (a) CGA children's films, (b) live action children's films, and (c) cel animated children's films. In contrast to CGA and live action films, the cel animated films have remained fairly constant in their slopes over historical time. (NB: the ordinate of (c) is larger to reflect the greater variance in slopes of cel animated films.)

By contrast, the cel animated films change in slope based on the intended age of the film. As the intended age of cel animated children's films increases, the slope of the film's colored noise also increases, $F(1,34) = 4.85$ ($p < .05$). This effect is robust when controlling for release year (see Figure 14).

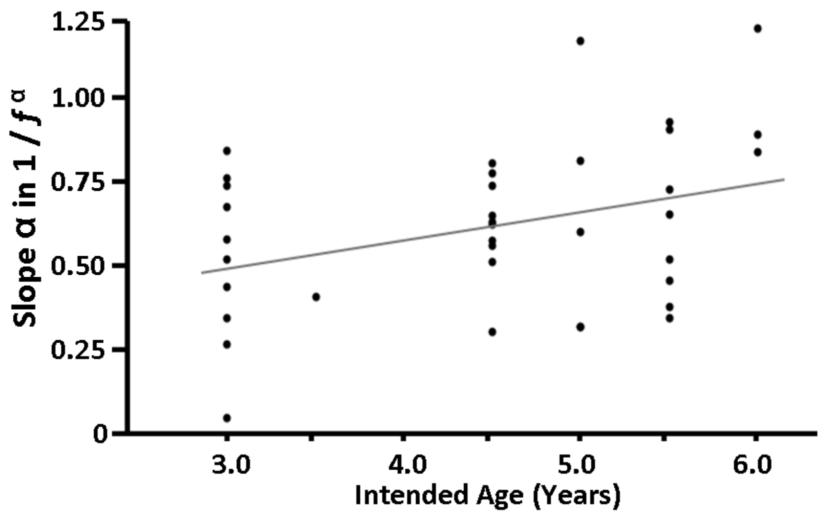

Figure 14. Slope (α in $1/f^{\alpha}$) for cel animated films by intended age. As the intended age for a film increases, the value of the slope also increases.

Discussion

The slopes of the power spectra for children's films exhibit some interesting trends, again marked with some distinctions based on type. CGA films and live action films follow the progressive increase in the value of their slopes through historical time; more recent films of these types are more likely to have a higher value for α and more closely approximate the $1/f$ shot structure that could be a useful modulator of human attention. This trend for CGA films, while statistically robust, relies on a very small sample size over a truncated year range. As such, it seems unwise to imbue this finding with a great deal of importance without further study across a larger span of time.

This finding for live action films, however, is both robust and interesting. Similar to computations for ASD, the slopes between children's live action films and Hollywood films (which are all live action) do not differ significantly, and both increasingly approach 1.0 in slope over time. This would suggest that live action children's films were not immune to the steady change in shot structure exhibited by Cutting, DeLong, and Nothelfer. However, the change over time was not robust for cel animated features, suggesting that perhaps the live action type is unique in driving this effect.

Though the live action and cel animated groups are not statistically different from each other (either independently or using year as a covariate), it is worth addressing why live action films appear to undergo a decrease in slope over time while the trend over time for cel animated films appears flat. One possible reason for the difference is that editors approach live action films and cel animated films fundamentally differently in the editing process; in particular, there is generally a wealth of excess filmed material present for live action films. This has not always been the case, but the decreasing cost of film stock and the subsequent advent of digital filmmaking meant the live action filmmaker could shoot a seemingly limitless amount of material. Fewer restrictions on the number of shots to sample from increases the likelihood that the shot structuring process was a more organic, explicitly-controlled skill of the filmmaker. By contrast, cel animated films rely on individually painted and shot cels, which come at a high cost. Cel animated films are heavily storyboarded in order to decrease the amount of excess material and labor required of animators. Thus, the editor in this situation is much more limited in terms of potential shot placement. Even after the advent of computer-assisted cel animation, the labor and cost of rendering, digital compositing, and the remaining non-computer-assisted tasks still placed heavy limits on editors of animated films. However, the nuances of the editing process are an unlikely candidate in accounting for this difference; if this were the case, it would be unlikely that we would observe any trends for any variable regarding shot duration or structure. In fact, we see both that cel animated films decrease over time in ASD, and a trend emerges between shot structure and intended age for these films, which will be addressed shortly.

The most likely culprit here is the inextricable covariate of ASD as a contributor to shot structure. Cel animated films have historically had shorter ASDs than their contemporaries (see *Average Shot Duration*), and because ASD and slope are negatively correlated, it is reasonable to infer that slightly shorter ASDs correspond to slightly higher slopes which have remained fairly consistent over time. The correlation between ASD and slope is strong but certainly not entirely predictive, which is why we observe a flat trend in slope over time rather than an increase that would match the decreasing ASD.

Intended age was not a meaningful predictor of slope for live action or CGA films, but analyses showed that younger intended ages predicted lower slopes for cel films. In other words, cel films with younger audiences were more likely to have shot structures that were closer to random, while cel films designed for older child audiences were more likely to have shot structures that more closely approximated $1/f$. This trend is interesting, if perhaps not surprising, in that filmmakers seem to structure cel films for older children and films for adults similarly, and there is some implicit assumption that older children are equivalent to adults in their attentional fluctuations and preferences. What is surprising, however, is that our expectation was for the films to be fairly uniform across intended ages, even if the films differed as a group from the Hollywood films in slope. Instead, we see what could be a trajectory indicative of developmental understanding in cel films. The filmmaking strategies that yield $1/f$–like structures in films for older children and adults seem to differ from how filmmakers choose to assemble children's films. The trajectory here could be an artifact of two filmmaking realities: either (1) there is a distinct filmmaking style for children's cel animated films (where shot structure is closer to random) that slowly decomposes as intended age increases, which is then gradually replaced with more typical $1/f$ shot structure, or (2) there is a distinct style only for Hollywood films that is increasingly introduced as the intended audience gets older, and prior to that, a 'lack' of a visual style simply results in a more random shot structure. Deciding between these two options is impossible given only the current data, but further study of the shot structure of cel animated films for very young children could shed light on this problem. Also, behavioral studies that titrate out the developmental trajectory of the $1/f$ pattern in attentional rhythms could also provide insight into this problem, and would generally provide insight into how to design further media for children.

Finally, it is worth noting that this subset of Hollywood films sampled from Cutting and colleagues do not exhibit the change over time in shot structure that the larger sample presents in the 2010 paper. This is almost certainly due to the truncated year range, as the authors note that the trend importantly began around 1960.

While the children's sample once again failed to exhibit holistic trends, examining the particular subtypes of children's films again gave meaningful insight into how shot structure in these forms have changed over time and evolved with their audience. Harnessing children's attention using low-level information could be a crucial facilitator for early learning in media, and these findings are certainly worthy of further examination.

Motion, Movement, and Visual Activity

Overview

Arguably, motion is the most important visual cue that drives human attention and perception (Smith & Mital, 2013; Mital, Smith, Hill, & Henderson, 2010). Myriad work in low-level visual perception and statistics has examined our abilities to perceive motion, with the general conclusion that 'motion' is not a homogenous perceptual phenomena, but is instead a diverse set of perceptual processes largely governed by our visual system. Beginning at the retinal level, different types of motion are processed and routed differentially through the visual system. Ganglion cells (particularly to M-cells with large receptive fields) communicate directional movement of light across the retina (Harlow & Hill, 1963). While ganglion cells project to many different terminations throughout the brain, including SCN, AOS, and SC, they importantly project to LGN and V1, which eventually route to areas considered specialized for motion, namely MT/V5, MST, and STS (Livingstone & Hubel, 1988; Yabuta, Sawatari, & Callaway, 2001; Grossman, Battelli, & Pascual-Leone, 2005). The interaction of multiple projection pathways, which integrate not only perception of motion, but also 2D information about trajectory and disparity, contribute to our eventual perceptions of motion (DeYoe & Van Essen, 1988).

Not all motion is created equal. Particular types of motion tend to differ in how our visual system processes them. For example, the whole-retinal motion generated from optic flow is processed in MST (Duffy & Wurtz, 1991) while local motion tends to rely more on V4 and MT (Kleinschmidt, Thilo, Büchel, Gresty, Bronstein, & Frackowiak, 2002)[19] Biological motion perception is impaired when TMS is applied to STS (Grossman, Battelli, & Pascual-Leone, 2005). Motion need not be present for humans to perceive motion: implied motion in static images will activate MT and MST (Kourtzi & Kanwisher, 2000). Apparent motion will also register perceptually as motion, and apparent biological motion will also activate relevant areas for biological motion (Stevens, Fonlupt, Shiffrar, & Decety, 2000).

Motion and Film Physics. On-screen motion is a prominent factor in why we find films compelling; no other art form can effectively approximate real-world motion in the way that films do. This is not to imply that rendering this motion on-screen is an easy task; in fact, having films look realistic in terms of movement has historically been a challenge for filmmakers.

An important discrepancy to note in the literature on motion and film is why we perceive motion in on-screen settings in the first place. For many years, the notion existed that cinematic motion was the result of the psychological phenomenon *persistence of vision*, in which images that are projected onto the retina 'linger' for a short period of time. The thinking was that persistence of vision allowed film audiences to integrate different images over time such that we perceived a constantly moving image (see Anderson & Anderson, 1993 for a review). The phi and beta phenomena were also introduced as possibilities

[19] It is worth re-stating the point made by DeYoe and Van Essen (1988) when discussing the apparent specialization within the visual system to particular types of motion (or other visual input): suggesting that only one area is responsible for holistic processing of a particular type of motion is unrealistic and likely incorrect. Visual processing rarely has a one-to-one relationship, and instead draws from input from multiple projection pathways. In other words, we are looking at a more distributed view of visual processing rather than an entirely modular one.

explaining our visual experiences of motion in film. However, in light of the vast, more contemporary research in visual processing (notably Livingstone & Hubel, 1988), these three explanations appeared increasingly antiquated. Joseph and Barbara Anderson, in two papers (1978, 1993), attempt to replace the notion of persistence of vision (as well as phi and beta phenomena) with the more accurate *short-range apparent motion* as the reason for our on-screen perceptions of motion (see also Cutting, 2005). Short-range apparent motion more accurately describes our on-screen perceptions of motion because (1) the spacing of two frames is very small (usually in the order of 42ms) and (2) the correlation between the sequential frames is usually very high. Our data supports the latter assertion in a robust way (see Figure 16 in Methods).

While motion in particular types of film, such as animated films, will be discussed later, one motion problem affecting films universally is projection rate. In order to give the impression of smooth motion across individually-projected frames, and ideal rate needed to be established for both filming and projection. In early cinema, frame rates varied widely and tended to be much slower (between 16 and 20 frames per second (fps)) than modern films (Bordwell & Thompson, 2004). Some films varied projection rate within films, and some were projected at lower frame rates, which resulted in jerky motion and flicker. (Bordwell & Thompson, 2004; Landis, 1954). The introduction of sound meant that a standard frame rate would need to be adopted to prevent possible perversions of the soundtrack, which is when the industry standard was established at 24fps. Today, the standard frame rate is still 24fps, though multiples of this number with the use of an episcotister is common as a means of further counteracting flicker in stroboscopic motion (Cutting, 1986). Cel animated films are projected at 24fps but are often filmed at 12fps, a process called 'two-ing' that will be explained further later. Digital media is often 'filmed' (though no film is actually involved) and screened at 30fps. Finally, a more recent trend in cinema is higher-frame-rate filming and projection. Peter Jackson's *The Hobbit: An Unexpected Journey* (2012) was filmed and screened at 48fps, with some audiences praising its hyper-realism and other condemning its unusual made-for-TV-like visual style (Marks, 2012). Though high-frame-rate filming has existed for decades (Showscan[20], for example), it did not gain commercial traction until very recently.

Creating Motion in Animated Films. Rather than photographic real-world objects and people that move naturally, animators in the cel and computer animation worlds are charged with creating motion from a blank canvas. Constructing motion in this way requires considerably more effort, namely because the fine-tuning of our visual systems to biological and non-biological motion occurs very early in development (Cohen & Cashion, 2003; Berenthal, Proffitt, & Cutting, 1984; Fox & McDaniel, 1982). Even very slight perturbations to how we expect things to move, particularly biological motion, result in motion-based uncanny valley problems for viewers[21].

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[20] Showscan, developed by Douglas Trumbull, pioneered the technology of filming at 60fps on 70mm film (U.S. Patent No. 4,645,318, 1987).

[21] The viewer response to the early Pixar short *Tin Toy* (1988) was negative, in part because the motion rendering of the human baby was so unnatural. The unnatural movements violated the principle of avoiding jerk in biological action trajectories (Viviani & Flash, 1995; Viviani & Schneider, 1991).

To avoid jerk and unnatural motion in cel animated films, three main techniques were implemented. First, animation traditionally is filmed 'on twos' (also called 'two-ing') in which only 12 unique cels are generated for each second of film, and each cel is shot twice in sequence to produce 24fps. While this produces naturalistic motion in relatively-slow motion sequences, high motion sequences become jerky when shot on twos. To compensate, high-action sequences are usually shot on ones (24 unique cels captured once) to give the effect of smoother motion. However, even shooting on ones is occasionally not enough to convey very high levels of motion. Instead of trying to vary the frame rate of the film to compensate for this, animators use a second technique called limited animation. In limited animation, the moving element in the frame is either smeared or reduplicated in a single frame to give the appearance of very fast motion (see Figure 15a). Finally, motion appears realistic in high-motion live-action films because the camera captures *motion blur* on sequential frames. While the rendering of motion blur is important for computer-animated films, it is difficult to implement in cel animated films. Cel animators approximate motion blur using a third technique called object trailing, where paint is smeared directionally within the frame (see Figure 15b). The later introduction of computers to assist in cel animation reduced the need for these techniques as motion blur could be digitally inserted.

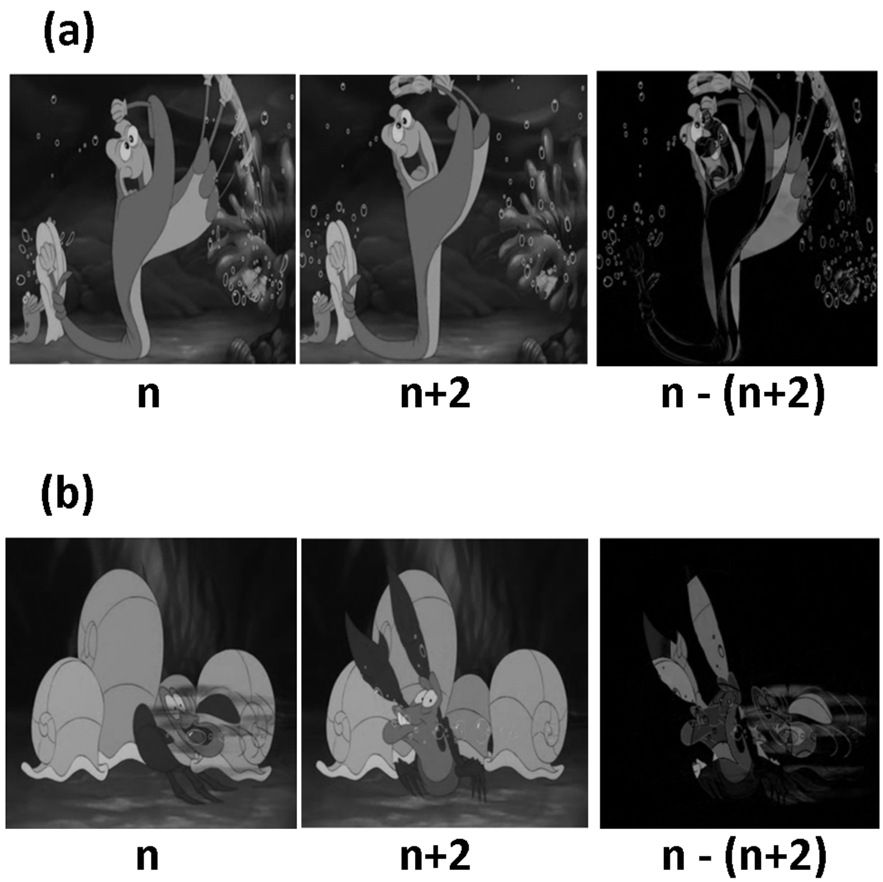

Figure 15. Limited animation techniques in *The Little Mermaid* (1989). Both (a) and (b) show two frames that are one frame apart in the film (frames n and n+2, respectively). They also show a difference image (n – (n+2)) of these two frames, with black space conveying no motion, and light space suggesting change/motion. In (a), the animators use reduplication in the first frame of the ray's arms and drumstick to convey the fast motion of his drum playing. In (b), the technique of object trailing is demonstrated, with the paint smears on Sebastian's body in the first frame suggesting that he is quickly sliding into the frame from the right side of the screen.

Finally, computer generated animation faced the unusual problem of navigating three-dimensional space while still conveying naturalistic movement. *Motion capture* was a particularly helpful tool in early creations of digital skeletons that moved with realistic trajectories (Moeslund & Granum, 2001). As technology has evolved, the motion capture process has become dramatically more sophisticated; for example, markers are no longer required since motion capture systems are not able to estimate invariant surface properties of the human form (Moeslund, Hilton, & Krüger, 2006; de Aguiar, Theobalt, Stoll, & Seidel, 2007). Animators combine these hyper-realistic movements with traditional animation techniques to create an optimal (not uncanny) representation of motion in digital characters (Lasseter, 1987; Johnston & Thomas, 1995; Thompson, 1980). Combining the two traditions allows for stylistic choices to seem more realistic: for example, the human-like motion but cartoon-like form of human characters in *The Incredibles* (2004) and the ability of non-biological character Wall•E to move like an animate and biological character in his namesake film (2008). Additionally, the creation of photo-realistic motion blur (sometimes called anti-aliasing) was important for computer animators. Several techniques exists for rendering motion blur after the fact in a photographic or cinematic image: some involve averaging across a subsample of frames, while others subsample random frames as needed to create the most authentic-looking motion blur with the least amount of rendering time (Brinkman, 2008). Arguably, the most state-of-the-art motion blur algorithms are part of Renderman, the software used and developed by Pixar. The rendering process of this software often created images that were too crisp, resulting in pixillation; Pixar had to recalibrate how Renderman processed motion, and used the 2006 movie *Cars* to showcase the advances in motion blur technology. By this point, the Renderman software was able to not only capture realistic motion blur, but also instill it in the image selectively so things like cars' 'faces' were not blurred (Telotte, 2010). The blur of objects is only half of the effective motion blur equation. In order for 'camera' movements to appear realistic in a situation where there is no literal space or camera, motion blur resembling optic flow should also be effectively generated. The simulation of optic flow through the use of tracking cameras is especially important in computer-generated animation or effectively establishing notions of definite space (Telotte, 2010). Motion blur designed to simulate optic flow or large-scale movement in the optic field is often best done (or revisited) in post-production; in this way, the animator or director can selectively control for variables that distract from naturalistic optic flow (Brinkman, 2008).

Quantifying Motion and Terms. Up to this point, this paper has used the terms "motion" and "movement" fairly interchangeably. In fact, they are distinct concepts when discussed in relation to both perception and film. In film, *motion* tends to refer to visual change in objects or people in the frame, while *movement* refers to visual change as a result of moving or manipulating the camera in some way. These terms map onto similar distinctions made by psychologists, particularly James Gibson, who called motion a change within the visual field and movement the resulting change in an observer's endogenous perspective shift (1954; Brunick, Cutting, & DeLong, 2013). The critical difference according to Gibson is whether the change in the visual field was objective or subjective. It is not always possible to titrate these two apart; computer algorithms do not perform well at this task, and humans often fail to correctly identify which they experience (Brandt, Dichgans, & Koenig, 1973). As a result, for these analyses, we use the overarching term *visual activity* to represent a combined metric of both motion and movement.

We should expect, based on how animation and live action films handle on-screen activity differently, to see differences in this sample between the types. Because visual activity is often part of the pacing equation faulted for poor learning from media in children (see the discussion in *Average Shot Duration*), it will also be worth examining whether a difference exists between children's and Hollywood films, and whether children's films also follow the increasing visual activity trend found by Cutting, DeLong, and Brunick (2011).

Methods

We computed the visual activity index for each film following methods used by Cutting, DeLong, and Brunick (2011). From the compressed *.avi files, we correlated pairs of images extracted from the films. The image pairs were not directly adjacent, but instead were separated by one intervening frame. This was done for two primary reasons: first, digital conversion of some older films occasionally results in hybrid frames, and second, cel animated films are traditionally shot 'on twos.' Correlating adjacent frames in these circumstances, particularly the latter, would decrease the estimated motion in the film because every other frame pair would be identical. As such, we instead correlate frames spaced two apart (frames 1 and 3, 2 and 4, 3 and 5, and so on)[22].

Each image pair correlation produces a measure of similarity between the two frames (for a visual, see the difference images in Figure 15). A high correlation statistic (r) would mean the frames are very similar, while a relatively low correlation statistic would reflect large differences between the frames. This statistic was computed for each pair of lag-2

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[22] It is important to note that technically this process measures flicker as a proxy for measuring visual activity. Low-level motion statistics for specific motion subtypes can also be computed for films, but is done in a dramatically different fashion (Nitzany & Victor, 2014).

frames in the film. The whole-film activity statistic was computed by taking the median value of these frame pair correlations; the median is an appropriate statistic because the vast majority of frame pairs exhibit very little change, and the distribution of inter-frame correlations within a film tends to follow an exponential distribution (see Figure 16).

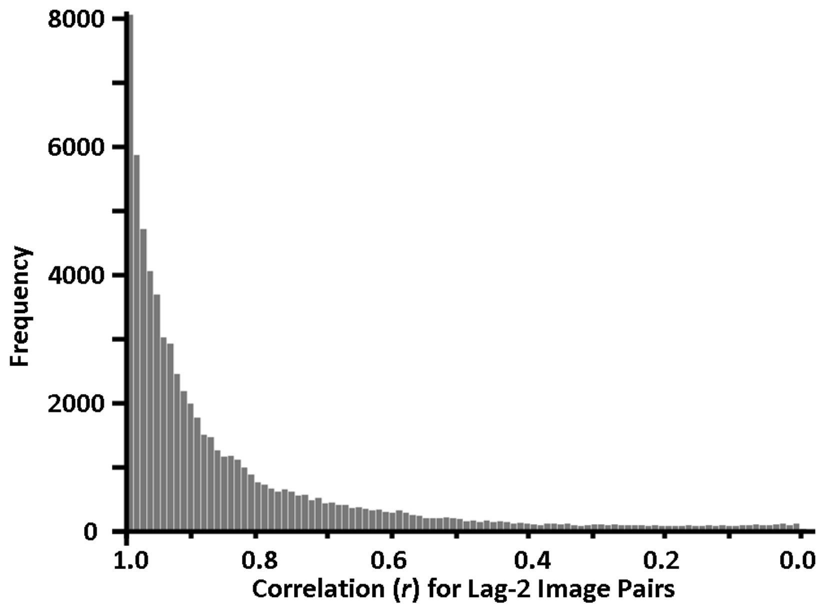

Figure 16. The frequency of binned inter-frame correlations for the film *We're Back! A Dinosaur's Story* (1993). It is worth noting the very high frequency of highly-correlated frame pairs (in other words, frames with very little motion).

Results

Release year, intended age, and average shot duration[23] were included as covariates in the model. MPAA rating was removed from this model and all further analyses as it has limited relevance as a predictor.

[23] Cutting, DeLong, & Brunick (2011) note an interesting relationship between ASD and visual activity. Films (and specific film sequences) tend to have higher motion and shorter ASD or longer ASD and lower levels of

The Hollywood films for the truncated year range to not exhibit the effect of year initially demonstrated by Cutting, DeLong, and Brunick (2011). No significant effect of intended age or year was present for the Hollywood films. ASD was a meaningful predictor in the model, $F(1,34) = 6.6376$ ($p < .05$); as ASD increases, VAI decreases, as shown in Figure 17.

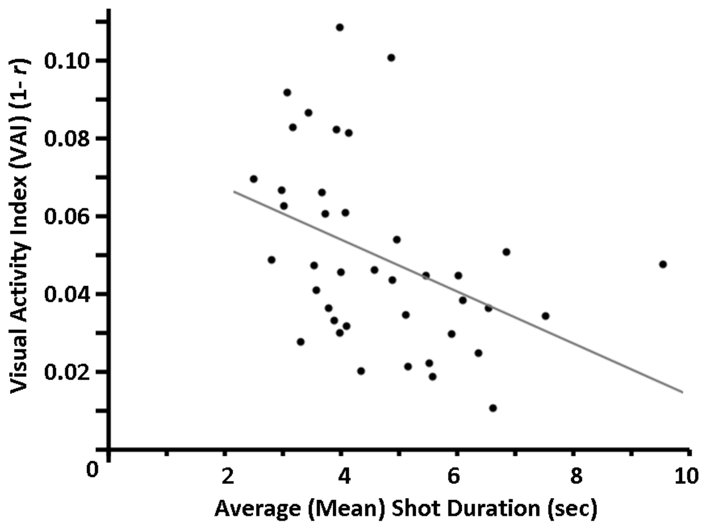

Figure 17. Visual activity by ASD for the sample of Hollywood films. As the ASD for a film increases, the visual activity across the film decreases.

For the children's films as a group, significant effects existed for both type ($F(2, 58) = 5.11$, $p < .01$) and year ($F(1,58) = 7.94$, $p < .05$) as predictors. Live action children's films had lower VAIs than CGA films ($t(31) = 2.44$, $p < .05$), but neither group differed from cel films. Newer films in the children's sample were also more likely to exhibit lower VAI.

motion. When long ASDs combine with high motion, viewers tend to find this unpleasant (these films have been termed *queasycam films*).

We examined the differences in VAI present between the film types. VAI was not meaningfully predicted by year, intended age, or ASD for live action or CGA films. On the other hand, all three predictors were statistically meaningful for cel animated films. More recent cel animated films were more likely to have lower visual activity, $F(1,33) = 21.73$ ($p < .0001$). As with the Hollywood films, as ASD increases, VAI decreases, $F(1,33) = 22.36$ ($p < .0001$). These trends are shown in Figures 18 and 19, respectively. Finally, films with lower intended ages were more likely to have higher VAIs, but only when controlling for the effects of year and ASD, $F(1,33) = 5.84$ ($p < .05$). Age ($\beta = -.34$) was indeed a less robust predictor of VAI in cel films than either year ($\beta = -.66$) or ASD ($\beta = -.70$).

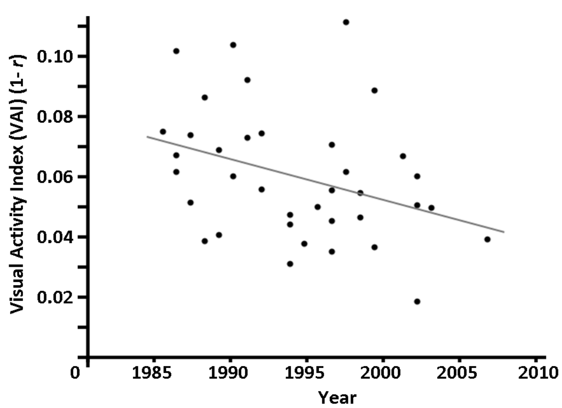

Figure 18. Visual activity over time for cel animated films. In more recent years, cel animated films exhibit less motion.

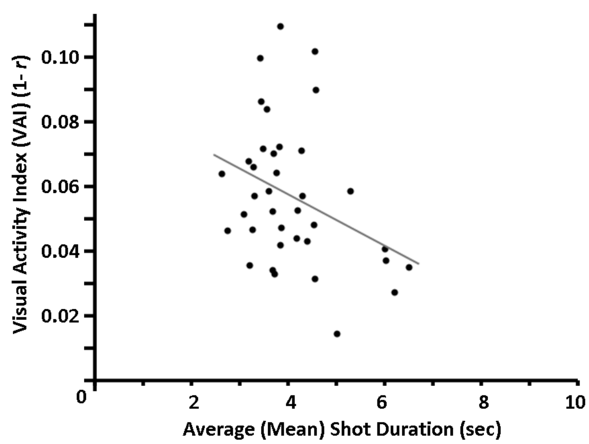

Figure 19. Visual activity by ASD for cel animated films. Films with longer ASDs exhibit less visual activity.

Finally, we examined the differences in visual activity between the children's films and Hollywood films. We found no differences between the two samples in visual activity.

Discussion

Visual activity exhibited interesting and somewhat predictable trends in these samples of films. Hollywood films did not show the increase in VAI over historical time described previously in the literature (Cutting, DeLong, & Brunick, 2011). Once again, we can safely assume this to be an artifact of the truncated age range in the sample compared to the initial sample Cutting and colleagues used. Films in their original sample went back as early as 1935, where films typically exhibited half as much visual activity as they did in the later films included in the current sub-sample. Increased variance in visual activity between films made before and after 1970 likely means that the current sub-sample does not have the robust effect for year that the sample spanning 75 years exhibits. What we do see in the Hollywood films (and again later in the cel animated films) is a relationship between VAI and ASD. The interaction between these two was discussed thoroughly in the previous paper on visual activity; the authors cite a necessary tradeoff between the average length per shot and the amount of motion they contain. Shots can either be short and contain high levels of motion, or be longer and contain relatively low levels of motion. Films that have long shots containing fairly high levels of motion tend to generate an unpopular 'queasy-cam' effect, and a if films contain high-motion sequences, a recovery period of slower sequences should generally follow to avoid overwhelming the viewer (Cutting, DeLong, & Brunick, 2011). While variance in visual activity certainly takes place throughout the course of a film, there is generally an upper-limit in terms of what viewers will accept in terms of continuous, high-motion sequences. This is not unique to adults, as coordination of head and eye movements to form gaze stability is fully developed by 3 months of age (Goodkin, 1980). Perhaps not coincidentally, we also see this pattern in the cel animated films, presumably for similar reasons. The trend for this relationship also exists for live action films, but not at a significant level, and the sample size for CGA films was once again prohibitive small for observing a relationship.

For the children's films as a whole, we see meaningful effects of year and type on VAI. Surprisingly, newer children's films tend to have less visual activity, which is in contrast to previous findings. Because the cel animated sub-sample has been so influential in the broader children's sample, it is likely the cel animated films are once again driving this effect. Indeed, the within-type effect of year is strong for cel animated films, with reasons discussed in detail later. There are differences between the types, namely that CGA differs significantly from live action, but that neither of those groups differs from cel animation. CGA has the highest level of visual activity among the types, presumably because of the increased amount of control animators have over the entire scene in these films. Additionally, camera position is not limited by a physical camera as it is in both cel and live action films; the computer animator has complete control in putting the 'camera' wherever he/she wishes, and is not limited in any way physically in the movements of this 'camera' through space. For example, the opening shots of *Wall•E* (2008) depict a quick, flying camera motion through the planets in the solar system, finally landing in Earth's atmosphere, where it skims across continents and wastelands, finally landing on the protagonist at work in the landfill. Obviously this would be an impossible feat for live action films, and would require a tremendous amount of work to approximate such an effect in a cel animated film. In other words, more degrees of freedom exist in camera positioning in CGA films, and as such, we would expect more movement if almost no restraints exist on camera placement and movement.

As in previous analyses, we also examined within-type trends for visual activity. No meaningful predictors emerged for visual activity in either live action or CGA films. Live action films exhibited a trending relationship between ASD and VAI (which is unsurprising given the reasons discussed above), but it failed to reach statistical significance. By contrast, ASD, year, and intended age were all meaningful predictors of visual activity in cel animated films. Once again, given the nature of the limits of our visual system, it is not surprising that these films exhibit a tradeoff between shot length and visual activity. What is surprising, however, is the seemingly contradictory relationship present between VAI and year. Previous research shows a steady increase in visual activity through historical time, and yet cel animated films seem to instead decrease in their visual activity over time. Though this seems counterintuitive, there is a fitting explanation. Near the beginning of the children's film sample, computer technology was introduced to assist in the cel animation process, which traditionally is labor intensive, expensive, and time-consuming. The computer assistance streamlined processes like digital compositing, colorization, and critically for these analyses, motion. Animators no longer had to simply rely on short-range apparent motion to convey motion to film viewers; technologies gradually evolved that allowed cel animators to insert motion artifacts like blur into filmed sequences. As a result, relationships between adjacent frames were closer, smoother, and increasingly anti-aliased (Johnston & Thomas, 1995). As a result, earlier films exhibited high levels of motion because of the lack of anti-aliasing technology. The introduction of computers to aid cel animators in their process allowed for better and smoother rendering of motion, reducing the differences between adjacent images, and thereby reducing visual activity as our statistic computes it.

Finally, there was a meaningful predictive relationship between intended age and visual activity. Though we would have expected films for younger ages to contain less motion, we instead find the opposite, where higher levels of visual activity are present in films for younger ages and a decrease in visual activity ensues as the target audience gets older. There are several possible explanations for this. First, it could be that filmmakers are (possibly erroneously) assuming that younger audiences require more visual stimulation to captivate their attention. This possibility lends credence to critics of fast pacing in children's media. Secondly, this trend could have emerged as an artifact of content-focus in films for older children. A better understanding of narrative and character motivation in older audiences might lead to more low-motion sequences of exposition and character development in cel films for older children (Huston & Wright, 1983; Valkenburg & Vroone, 2004[24]). Content analyses of the films would be required to account for this as a possibility. However, it is worth noting that this trend, though significant, is only marginally present.

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[24] These authors' work with television shows an attentional shift between low-level features and content as the primary focus to occur between 18 and 30 months, well below the age range targeted in this sample. However, there remains the possibilities that this attentional shift is gradual throughout childhood depending on the medium, and also that longer media (like film) would require more reorienting from low-level cues in children who require less reorienting from much shorter media like television.

The correlation is weak, and intended age only emerges as a significant predictor when year and ASD are also listed as predictors within the model.

The children's sample yielded both expected (ASD) and surprising (year) findings with regard to filmmakers' usage of visual activity. Expanding this sample to include more recent films and a higher percentage of CGA films would benefit future analyses and inform interest in what types of films suit children and their motion preferences.

Luminance

Overview

Light is the entire basis for human vision, so it is unsurprising that the study of light's intensity (luminance) and how the visual system responds to luminance is a topic of tremendous study. Though humans have a visual range for luminance of about 10^{10} photons/s/m^2/sr, this span reaches the absolute extremes of human vision. On a daily basis, we encounter a much more truncated range of light (Land & Nilsson, 2012). When viewing a film, this range of light truncates further. Though it depends on how light- or dark-adapted our eyes are, humans are generally incredibly sensitive to luminance changes.

Luminance is a potent variable in guiding attention. Even very slight changes in luminance are enough to override top-down control of visual attention (Theeuwes, 1995). Changes in luminance for visual on-screen search tasks can radically change eye-movement patterns and visual search strategy (Krupinski, Roehrig, & Furukawa, 1999). It has also been implicated as a means of detecting event boundaries or aiding in the detection of content change (Hochberg & Brooks, 1990; Zacks & Magliano, 2011; Cutting, Brunick & Candan, 2012).

Though film stock has dramatically improved in quality over the last few decades, the ability of the viewer to discriminate on-screen elements in low-luminance scenes is heavily dependent on the dynamic range of the stock. This varies further based on the illuminance of the viewing environment and the device on which the film is viewed; for example, the experience of luminance will be different for viewers watching analog film in a dark theater compared to the experience of viewing on a television in a moderately-lit room. For theatrical viewing, the dynamic range of film stock has considerably improved to communicate more subtle visual differences in luminance. This may be a moot point, however, as increasing digital projection fundamentally changes the light space for theatrical viewing (for an insightful overview, see Bordwell, 2012). This may also carry different implications for adult viewers and child viewers, as the latter group is more likely to view both in-home and on a smaller screen (Rideout, Vandewater, & Wartella, 2003; Atkin, Greenberg, & Baldwin, 1991).

The intended audience of a film (which also has implications for film type) is likely to play a role in luminance in screen-media for children. Any informal survey of children's clothing stores or toy aisles reveal that adults have a bias toward constructing bright things for children, and we would expect the same to be true for children's media[25]. Animation in particular is generally conceived of as a child-specific medium, though many filmmakers and artists take issue with this generalization, and there is certainly nothing intrinsically child-specific about the medium. Because the Disney corporation made early, high-volume efforts into producing animated features, and because nearly all these features were family-friendly, animation became increasingly pigeon-holed as a child-specific form.

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[25] This effect is complicated by the simultaneous presence of highly saturated items for children. Because increasing saturation necessarily decreases luminance (see the Chapter 2 discussion of Color Spaces), the preference for high-luminance items faces a necessary complication. Whether a preference tradeoff in children exists with regard to the inverse relationship of these two variables has not been thoroughly studied.

Cel animation in particular presents challenges for luminance. Previous research and anecdotal evidence suggest that, historically, cel animated films are generally brighter than live action films (Cutting, Brunick, DeLong, Iricinschi, & Candan, 2011). The reason for this could be intentional or technical. Filmmakers could be intentionally making animated films bright because they intend for their animations to be child-geared, and they have some conceptions about what children might prefer visually. It could also be the case that cel animated films traditionally had to calibrate luminance equilibrium carefully because of the chemistry of their materials interacting with the animation aesthetic. For example, the signature watercolor effect of cel background paintings emerged from the fact that darker backgrounds overwhelmed cels placed on top of the background. Additionally, the thickness of the paint on celluloid often determined its brightness and saturation, so careful attention was paid to how cels were painted to avoid the cel figure being too dark for the background. As a result, both background painters and cel animators necessarily worked in a 'brighter' space to keep luminance steady between foreground and background (Johnston & Thomas, 1995; Brunick & Cutting, 2014). As a result, cel films may have higher luminance simply because they tend to deliberately avoid dark, heavy colors as a means of maintaining visual balance.

It is worth noting that discussions of luminance in vision science and film are laden with mentions of color. Color and luminance are intertwined and vary predictably, but here, color will be discussed separately as part of the next chapter. For this analysis, we will address luminance independently through the use of grayscale conversion as a means of isolating luminance from color.

Methods

The same set of compressed 256 x 256 pixel films was used for these analyses. The computation of luminance was modeled after Cutting and colleagues (2010); however, the procedure was modified such that the computation could be conducted on raw *.avi files rather than component *.jpeg files. Each frame was converted from RGB to grayscale, first by converting from RGB to HSL, and then retaining only the luminance (intensity) value for each pixel. Our digitization of the films forced the films into an sRGB space, meaning that the original luminance values of the film[26] may have been inadvertently shifted; to account for this, a reverse gamma correction of 2.2 was applied to these values. The result is a value for each pixel ranging from 0 (black) to 255 (white). The median luminance value for each frame was determined, and the mean of these values served as the whole-film luminance statistic. Examples of computed luminance are shown in Figure 20 below.

[26] This correction is performed to account for changes in luminance that might occur between viewing the film on DVD (the source of these films) and on a computer screen. The gamma correction here does not correct for changes in luminance between the OCN and the digitization process, nor does it attempt to imply what the "original" luminance of the film was intended to be. Indeed, the notion of "original" luminance is difficult to access, given that it varies widely depending on how and where the film is viewed.

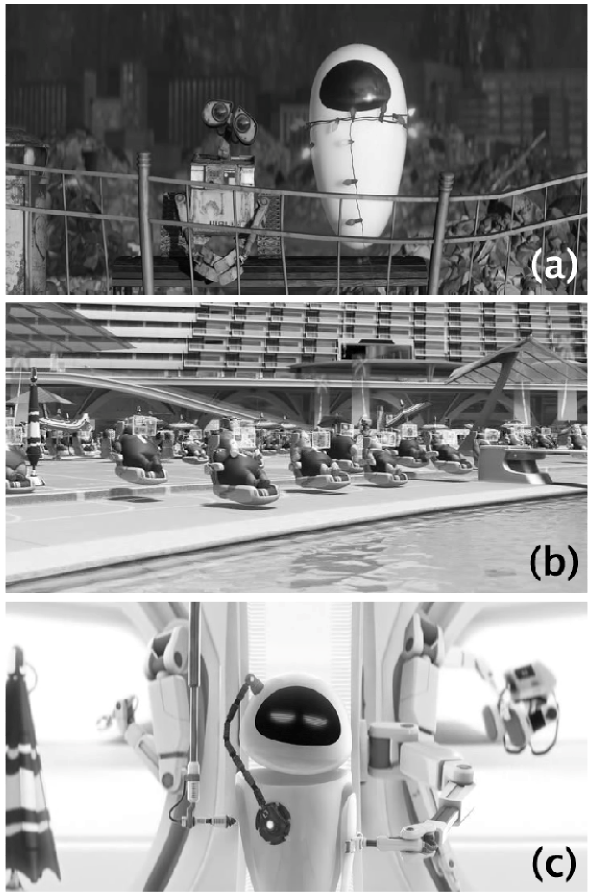

Figure 20. Still frames from *Wall·E* (2008) that exhibit varying luminance. The mean luminance value for the whole film is about 135; (b) illustrates a frame with this mean amount of luminance. Luminance varies throughout the film; (a) shows a relatively dark frame while (c) shows a relatively bright frame. The values of (a) and (c) are 80 and 137, respectively, corresponding roughly to a standard deviation above and below the mean.

Results

Luminance was analyzed with year, intended age, and type as predictors in the model. For the Hollywood film sample, none of these variables were meaningful predictors of luminance. Hollywood films had generally lower luminance than children's films, but this finding was not statistically significant.

For the children's film sample, there were effects of type, year, and age as predictors of luminance. Cel films were significantly brighter than live action films, $t(55) = 2.80$ ($p < .01$), but neither group differed from CGA films. More recent children's films were more likely to be brighter, $F(1,65) = 7.69$ ($p < .01$, see Figure 21). Finally, as the intended age of a film increases, it is more likely to be darker, $F(1,65) = 4.13$, ($p < .05$, see Figure 22). Year ($\beta = .35$) was a more robust predictor than intended age ($\beta = -.25$) for luminance.

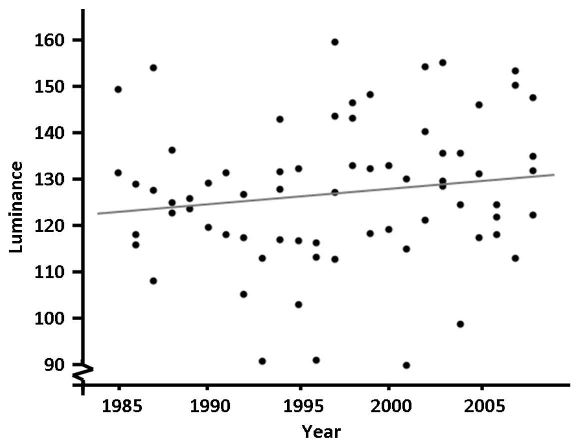

Figure 21. Luminance over time for children's films. Newer children's films tend to exhibit higher luminance.

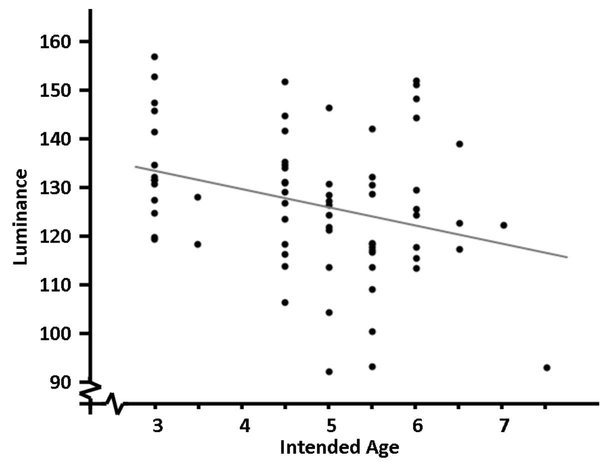

Figure 22. Luminance by intended age for children's films. Films for children tend to get darker as the intended audience ages.

In looking within type, no patterns emerged for either cel animated films or CGA films, though they follow the general trends present in the whole children's film sample. For live action films, more recent films were more likely to be brighter, just as with the children's sample as a whole, $F(1,16) = 7.65$ ($p < .05$, see Figure 23).

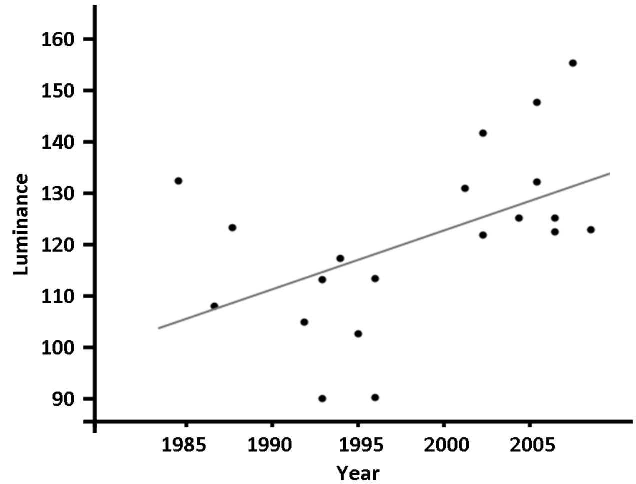

Figure 23. Luminance over time for live action children's films. Newer films for children are brighter.

Discussion

Analyses of luminance revealed interesting and robust trends for children's films, though no trends were present for the adult films. The current analyses did not imitate the findings of Cutting, Brunick, DeLong, Iricinschi, and Candan (2011), who showed a decrease over time in the luminance of their film sample. The authors posit the downward trend in luminance over 75 years to be the result of film stocks with richer darks, less need for bright lighting in filmmaking, or some combination of the two. The truncated year range seen for this sub-sample of Hollywood films may not be relevant for either possibility; film stock reached an ideal dynamic range by this time period (not to mention advents in digital film making), and studio-era filmmaking was long over by the start of this sub-sample. Thus, it is not entirely surprising that the Hollywood film sub-sample once again shows no meaningful trend.

Children's films, however, vary in their luminance based on type, year, and intended age. Cel animated films, as expected, are significantly brighter than their live action counterparts, though neither of these groups differed from CGA films. Cel films have not changed over time, but rather maintained a consistent, higher-level of brightness throughout time. Live action films are the one type to exhibit a within-type trend: more recent live action children's films are more likely to be brighter.

This trend for more recent films to be brighter is not limited to live action films only; year was a meaningful predictor of increasing luminance across the whole children's film sample. This change is in stark contrast with the findings of Cutting and colleagues, who found luminance to be decreasing over time. It seems not to be an effect of animation or technology, as the only type for which this relationship is also meaningful is live action films. Making adult-geared films darker has the effect of giving the director tighter control of visual attention in viewers (Lin & Yan, 2011; Smith, 2012; Cutting, Brunick, DeLong, Iricinschi, & Candan, 2011). This tight control of vision may not be necessary for younger viewers, as they are more likely to rely on low-level features in the first place, while adults rely more on content and have much greater screen-center focus (Huston & Wright, 1983; Le Meur, Le Callet, & Barba, 2007; Mital, Smith, Hill, & Henderson, 2010). However, adults have relatively high concordance in visual focus when viewing dynamic scenes while children exhibit less concordance (Kirkorian, Anderson, & Keen, 2012), and it may instead be in filmmakers' best interest to have lower luminance to better facilitate visual controls in child audiences. It may simply be that filmmakers who create children's films are attempting to produce a brighter product, thinking this will be a cognitively engaging component of their visual aesthetic.

In addition to year, intended age was a meaningful predictor of luminance. As the intended age of children's films increases, the luminance decreases. This underscores the previous theory that filmmakers have notions about film brightness that differ between younger and older audiences. Films for older children are made to have more of a resemblance to adult-geared films in their luminance, while the notion that films for children should be bright holds for the younger-age films.

Luminance, however, is intrinsically entangled with color. This relationship, as well as other color parameters, will be discussed further in Chapter 2.

General Discussion

Examining ASD, shot structure, visual activity, and luminance in children's films produced several noteworthy trends, especially in comparison to samples of Hollywood films. Appendix C shows the computed variables for the Hollywood and children's film samples.

The Differences between Children's Films and Hollywood Films

In the analyses and discussion of each of these variables, we discuss the patterns in the children's films with reference to both (a) a sample of 75 films released between 1935 and 2010, documented by members of my lab, and (b) a sub-sample of this same set of films using a truncated age range that matches the sample of children's films selected for analysis. In many cases, the lack of change in the truncated range led us to comparisons established in previous work on the larger sample. The only significant effect found for the truncated sample existed between visual activity and ASD, wherein visual activity decreased as shot lengths of films increased. This effect is expected given the principles of motion tolerance and 'queasicam' filming discussed earlier in the chapter.

What is potentially most interesting to note across the examinations of computed variables is that the truncated Hollywood sample never statistically differed from the children's film sample. This could be an artifact of the relative novelty of children's film as a genre; child-specific films have only been a niche for the last 30 years, a relatively short time given the history of film as a whole. Arguably, even within the current sample, we have not accessed films *exclusively* for children, as many of the G-rated films in the sample have similar appeal for adults. To observe many of the trends in Hollywood samples, previous work used samples spanning more than 70 years, and it may require a more extensive spread of time to properly examine trends in the evolution of this film type.

However, it may also be possible that children's films and films for adults simply don't differ in a meaningful perceptual way. While myriad literature exists on how children's television and children's media differ from television and media for adults, children's film may exist in an overlapping class between art and entertainment. While we can identify predictable differences in media designed for entertainment or education (in the case of children's media, usually both), we are more likely to view film as an artistic endeavor with perceptual components unique to it being an art form. We do not often distinguish art by its audience; in fact, art is generally intended for a more general audience. To examine film as simply children's entertainment in long-form, we would likely need to explore deeper niches of children's films, particularly in the direct-to-video market. These films need not appeal to general audiences because they need not be commercially successful; they are instead designed purely for education or entertainment. In other words, it may be inappropriate to compare studies of children's television to studies of children's tablet media or to the present study of children's film; all share the commonality of being screen media, but they all also function differently in the commercial and artistic market.

The Evolving Children's Film Sample

While we do not (yet) see much of a difference between Hollywood and children's films, we do see trends within the children's films that match or conflict with previous research on adult-geared media. Like myriad previous work with Hollywood films has shown, ASD in children's films is decreasing over time. This suggests that children's films are not immune to the evolving change in shot duration characteristic of very large samples of films. By contrast, however, trends over time for children's films are different from those found for Hollywood films in particular domains: visual activity in luminance. Hollywood films exhibit more on-screen motion as time passes, but children's films seem to exhibit lower levels of motion through time. Hollywood films are getting darker, and children's films appear to be getting brighter. While the former finding may simply be an artifact of better motion technology in animation, it is certainly still possible that both of these trends reflect an increasing awareness in filmmakers of what child audiences want or need in their films. It may also be due to an increased availability of home viewing, particularly television, where children view films on small screens with a likely brighter surrounding environment; under these conditions, contrast and motion is more perceptually-salient on-screen if the screen content is brighter. Whether these notions of what is best (in terms of motion and luminance) for child audiences is accurate based on psychological literature remains to be seen; however, it appears that filmmakers over time have attempted to cater their visual aesthetic to younger viewers based on some conception of children's visual preferences.

The Importance of Type

For nearly all of the analyses conducted, the effect of the type of film was meaningful. In addition, within-type analyses revealed patterns not always present in the larger sample. Some of these patterns emerged as artifacts of the medium, including changing technology, changing production costs, and availability of resources. Some of these changes or relationships instead simply seem unique or intrinsic to the type of film. For example, the decrease in visual activity for cel animated films through time can be explained by the emergence of computer-assisted technology helping to create better anti-aliasing techniques in cel animated films. Conversely, the fact that live action films for children have gotten brighter over time is likely not attributable to any technological change, other than the potential increase in the availability of televisions and tablets as film viewing environments.

Cel animated films compose the largest subset of the children's sample, and these films are often hailed by both filmmakers and psychologists as somehow intrinsically pleasing to child audiences. Cel animated films decrease in visual activity and average shot duration over time. They also appear to increase in $1/f$-like shot structure and decrease in average shot duration and visual activity as the target age of these films increase.

CGA films are relatively novel in the film world, but their novelty also means a small sample size and low power. However, CGA films contain higher levels of visual activity than live action children's films. Over the short span of time that they have been part of the film landscape, their shot structure has also seemed to increasingly approximate pink noise.

Finally, live action films, like their adult-geared counterparts, increase in pink-noise-like shot structure through historical time. However, unlike Hollywood films, they increase in luminance through historical time; this increase has not been sufficient to catch them up to the luminance levels of cel animated features, which live action films are still significantly darker than.

Ultimately, there is clearly motive for examining the types of films and their production nuances independently of other types. In addition to the findings described above, it is worth noting that the types in the children's sample differed meaningfully in every release and computed variable, as illustrated below in Table 1.

Table 1

Means and Standard Deviations for Release and Computed Variables by Type

	Cel (n = 37)	Live Action (n = 20)	CGA (n = 13)	ANOVA Student's *t* post-hoc
Age Mean	4.47	5.60	4.58	$F(2,67) = 7.80^{***}$
Age Std Dev	1.05	1.01	1.15	Live > Cel ($t(67) = 3.85$)*** Live > CGA ($t(67) = 2.72$)***
Year Mean	1994.46	1998.25	2003.23	$F(2,67) = 10.19^{***}$ Live > Cel ($t(67) = 2.22$)*
Year Std Dev	6.10	7.22	4.17	CGI > Live ($t(67) = 2.27$)* CGI > Cel ($t(67) = 4.42$)***
VAI Mean	0.06	0.05	0.07	$F(2,67) = 3.45^{*}$
VAI Std Dev	0.02	0.02	0.03	CGA > Live ($t(67) = 2.62$)*
Lum Mean	132.04	120.62	125.05	$F(2,67) = 3.69^{*}$
Lum Std Dev	13.32	17.02	19.03	Cel > Live ($t(67) = 2.64$)*
ASD Mean	4.05	4.47	3.71	n.s.
ASD Std Dev	0.90	1.39	0.82	

*$p < .05$, **$p < .01$, ***$p < .001$

Moving forward in examining formal features of children's media, it will be of interest and important to acknowledge type. If these types differ in their low-level perceptual features from one another, it is not a far cry to assume that how child viewers attend to and process them will also vary.

CHAPTER TWO

Children's Films and Color: Accessibility and Affect

Overview

Color is often spoken about in a monolithic sense, when in reality, our notion of color is derived from a wide variety of sub-components. While it is relatively easy to quantify the lowest levels of motion and luminance (as seen in the previous chapter), what does it mean to examine color in a low-level sense? Necessarily, color must be first broken down into its sub-components and then reassessed with each of those sub-components in mind to present a holistic vision of color in film. This chapter will examine color as a higher low-level feature, and will address the low-level sub-components of color in detail with regard to their use in film.

I would consider color a higher low-level feature not only because it can be broken down into component elements, but also because color carries a particular and conscious psychological weight that is unique among low-level features. As discussed in Chapter 1, ASD, shot structure, motion, and luminance are all important for maintaining and guiding visual attention, but viewers remain largely unaware of these effects. They also help us segment narratives in a medium that is both spatially and temporally discontinuous, but again, viewers tend not to attribute any of this ability to these features (Cutting, Brunick, & Candan, 2012). Other largely non-conscious effects are guided by these features. Shorter shots in rapid sequence affect heart rate (Carruthers & Taggart, 1973). Evidence exists to suggest motion in film can increase (Reeves, Thorson, Rothschild, McDonald, Hirsch, &

Goldstein, 1985) or decrease (Detenber & Reeves, 1996) autonomic arousal. By contrast, more cognitive effects are present for color and parameters of color. Luminance is one such sub-component of color, and luminance reliably differs across genre with different affect (DeLong & Helzer, 2010). Hue, another component of color, has been linked to emotional valence, arousal, and judgments of morality. The color preference literature and associated color affect studies will be discussed further for the individual color parameters.

Discussion of color in this chapter will focus on two color parameters: saturation and hue. In order to understand the analyses performed in the chapter, we will need to first examine several color spaces. Additionally, a brief overview of film colorization will be helpful in understanding the mechanics of film color.

Color Spaces. Attempts to organize color mathematically are known as *color spaces*, where certain properties of color are mapped in three-dimensional space as a means of quantifying the parameters of color. The first attempt to organize color quantifiably was Newton's *Opticks* (1704). Newton expressed colors on a circle, with the ordering of the colors matching the order in which colors refract out from the prism. Colors that are diametric opposites on the color wheel are referred to as opponent colors, and Newton notes that the combination of these colors in light space produces a faint off-white like color (1704). Color circles (or wheels) are still common representations in both art and science today, and have been expanded on to include luminance (see HSV). Albert Munsell (1912, 1919) devised another color system also based in the physiology of color perception. Munsell's color parameters—*hue, chroma*, and *value*—are still the most common means of quantifying color (especially digitally). The Munsell color chip system is still in wide use today as a means of psychological testing, but its relevance to quantifying color is limited because it is a discrete color system that occupies an irregular space. The continuous spaces relevant for these analyses are the CIE, HSV, and yCbCr.

CIE Color Space. Following Albert Munsell's work, the scientific community assembled to produce a standard color space that would (1) have a quantifiable component and (2) reflect the full gamut of normal human color vision. The result was CIE color space, in which the entire range of colors visible to the human eye was plotted in a two-dimensional, three-axis space[27]. The axes roughly correspond (but are not directly equivalent to) the peak responsiveness of S, M, and L cones in the retina (Hurvich, 1981). A good deal of mathematical effort is required to isolate the parameters of color in this space, and defining particular colors in relation to other colors is difficult in this way. CIE is also inappropriate for screen media; the range of color visible on-screen is a vastly truncated subset of the colors our visual system is capable of processing (see Figure 24). To accommodate the smaller set of colors available in digital settings, the RGB, HSV and yCbCr spaces (among others) were devised.

HSV Color Space. HSV color space is unique in its ability to isolate the three Munsell-developed characteristics of color into continuous mathematical space. HSV color space is conical, with height representing value, saturation (equivalent to chroma) represented on the

[27] The axes in CIE space correspond to cross products of Standard Observer tristimulus values with target objects' relative reflectance and illumination. For a review of the construction of CIE space, see Hurvich (1981).

radial axis, and hue represented around the perimeter. HSV space is shown in Figure 25. Hue, saturation, and value (luminance) are the most prevalent subdivisions of color, and these variables will be the low-level color variables discusses in this thesis. Hue refers generally to named colors, but corresponds to the wavelengths of color in the visible spectrum, and is represented in HSV space the same way Newton represented hue in *Opticks* (1704). Saturation refers to the 'boldness' of a color; pastel colors are unsaturated, while the bold colors toward the edge of the conical base are fully saturated. Value is roughly equivalent to luminance[28]. Hue is scaled from 0 to 360 (representing degrees on the color wheel), and saturation and value both range from 0 (purely unsaturated; black) to 1 (full saturation; white). As luminance was examined in chapter 1, this thesis will use HSV space to examine certain properties of hue and saturation in analyses.

RGB Color Space. By far, the most popular digital color space is RGB. The majority of computer monitors, digital televisions, and handheld devices display color using RGB or an RGB variant. RGB functions based on the additive property of light wherein red, green, and blue can be presented in weighted tandem to create the visual effect of a wider array of colors. Each pixel is represented with an R, G, and B value that ranges from 0 – 255, where high values represent higher amounts of the channel color. Despite being the most popular,

[28] Luminance is roughly equivalent to value, brightness, or intensity. Because luminance is technically a measure of how much light is reflected from a surface, the term may be inappropriate for application to surfaces that produce their own light (including television screens and monitors). However, because the concept of luminance/lightness is termed so differently between color spaces, the term luminance will be used here.

isolating the RGB channels provides no meaningful color information, and easy conversions between RGB and HSV allow for more adept examination of color properties.

yCbCr Color Space. One disadvantage of HSV color space is that while the color parameters of hue, saturation, and value are presented in separate axes, they are not independent in color space. For example, there is no way to 'slice' the HSV cone to produce a plane with equiluminant colors or equally saturated colors. yCbCr space was introduced in part to account for this problem. yCbCr space exists as a rectangular prism with luminance (y) on the diagonal axis. The other two axes are opponent color axes: red-green (chrominance red; Cr) and blue-yellow (chrominance blue; Cb). Taking a slice of the rectangular prism produces an equiluminant square with all colors represented. yCbCr space is illustrated in Figure 26. yCbCr space is critical for equiluminant analyses, and the linear slices of the space are mathematically very simplistic to draw from.

Color in Film. Film has the potential to exist in digital space and/or analog space depending on how the film is shot, rendered, and printed. How, then, do we talk about film with regard to color and color space? The answer is not a direct one, but relies on some knowledge of the production process; again, particular types of films carry different implications for color expression.

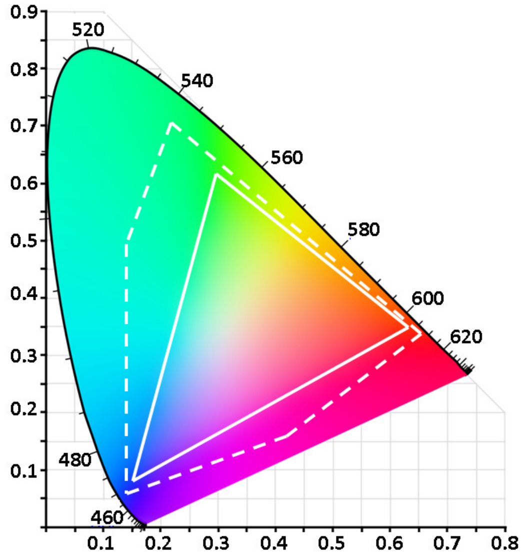

Figure 24. CIE color space. The solid white triangle represents the subset of colors in CIE space that can be replicated in digital (RGB) space. The dashed white line represents the gamut for modern film stock (adapted from Oran & Roth, 2012). NB: This representation of CIE is only accurate if viewed in pigment; digital viewing of this image necessarily represents the colors incorrectly because it is confined to digital color space representation.

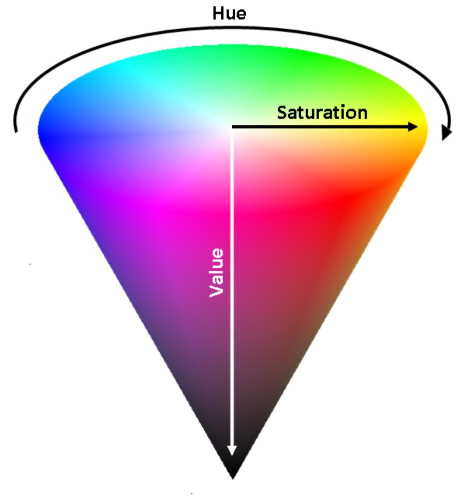

Figure 25. HSV color space. Value runs the height of the cone, while saturation runs the radial axis. The base of the cone is the color wheel with hue around the base perimeter.

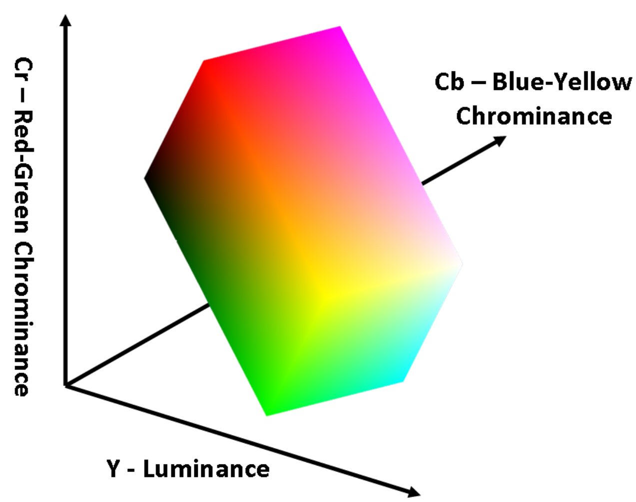

Figure 26. yCbCr color space. Luminance (y) runs the diagonal axis, while the other axes represent chrominance. Square slices of the rectangular prism produce equiluminant patches of all hues in the space.

The earliest films lacked color, and early colorization techniques were limited to painting directly on the film strips. The processes of *tinting* and *toning* films emerged early, where in a part of the film space (negative or positive space, respectively) was chemically replaced with dye to create colorized film (Bordwell & Thompson, 2003). Many iterations of color stock soon followed, with Technicolor's Process IV for stock and development becoming the standard. Though it is no longer used today, the basic principles of the Process IV film stock are still in play. When exposed, the silver halide crystals contained in film stock chemically alter in structure to create the image; three layers (magenta, yellow, and cyan) develop at two paces (creating low- and high- spatial frequency information within the image). The combination of these processes renders the red, green, and blue on-screen in a process of simultaneous additive and subtractive color mixing. Because almost all film is rendered onto film stock, which is then copied for theater distribution, the final color of the film relies greatly on the stock itself. When a film is first transferred onto stock and developed, the resulting product is referred to as the *original camera negative* (OCN); while the OCN will have certain stock and color properties, copies made for distributions to theaters will not share those qualities, and even further differences arise when films are converted for DVD and digital release (Prince, 2012).

Early cel animators not only had to face issues of film stock, but also dealt with difficult artifacts of animating on celluloid. The Technicolor stock rendered colors very high in midtones, so animators had to confine the set of colors they used in painting cels to a specific set that would render correctly on the stock (Thomas & Johnson, 1995). Additionally, the thickness of celluloid determined how dark and how saturated paint would ultimately become when it dried on the cel layer (Thomas & Johnson, 1995), so animators further had to correct their paint sets to ensure that the final product was both aesthetically pleasing and fitting with background layers. An entire position was developed in cel animation studios for the purpose of standardizing and matching color across a wide variety of filmic conditions: the color key. The need for this person demonstrates the high level of attention required in making sure the intended artwork and the final product were similar. (Brunick & Cutting, 2014).

Digital animation also offers its own set of challenges. Digital involvement in animation began with reconstruction of cel films from their OCNs that allowed higher-resolution and color-accurate versions of *Fantastia* (1940) and *Snow White and the Seven Dwarfs* (1937) to be produced for home video (and later, DVD release) (Bordwell, 2012). Parts of the frame could be altered independently of others, a previously-impossible feat that required a shift in the whole frame's coloration (Prince, 2012; Brunick & Cutting, 2014). When films that were fully digitally-animated (like *Toy Story* (1995)) began to emerge, a great deal of up-front labor cost eventually paid off in the animators' ability to edit color in the finest grains possible. Each individual element in the digital scene can be altered by single units in digital color space; however, moving between color spaces is challenging. Cel animators work in paint and shoot directly (in most cases) to film stock, never leaving analog color space. The range of colors possible in an analog space is much larger than the range possible in most digital spaces (see Figure 24 above). Creating a film in a digital space and transferring it to film stock means the OCN will reflect the limited color space of digital composition, and re-transferring it to digital for home media means there might be high levels of variation between the original product and the viewers' experience.

Some live action and CGA filmmakers work solely in a truncated digital space, filming digitally, doing computer-based post-production, and replacing a film stock OCN with a hard drive-based OCN. One of the major complaints some filmmakers have with digital filmmaking is the truncated color space, as well as the visible change in texture of the final product (Bordwell, 2012). Proponents of the form argue there is not a substantial amount of difference between the colors produced in digital space and real-world experience; though technically more colors exist outside digital space, the average amateur viewer would likely be unable to pinpoint them.

Color spaces, particularly the difference between analog and digital color spaces, play a crucial role in the understanding of film color. Ultimately, the correspondence between the artist's color intention and the resulting color of the OCN is never perfect; however, the two are very similar given filmmakers' high level of attention to these production issues. For the analyses in this chapter, we obtained digital versions of the films from digital home video sources; in other words, we worked with the product that viewers are most likely to watch in-home. As a result, we will talk about saturation and hue in terms of digital color spaces, though an analog color space might be more relevant if we were drawing from the theatrical stock version or the OCN.

We perform three analyses in this chapter—one of saturation and two of hue. Saturation is examined like previous low-level features with regard to the entire film. A coarse metric of hue is also calculated on a whole-film scale. In addition, we examine hue with regard to character motivation to assess if the connections between color preference and affective assessment transmit to filmmakers' colorization of characters.

Whole-Film Saturation

Overview

Saturation is a dimension in HSV color space, and a commonly used parameter of color in color descriptions. Saturation generally refers to the 'boldness' of a color. Figure 27 illustrates images with a variety of saturations.

Figure 27. An image from *The Land Before Time* (1988) varying in saturation. The frames (a), (b), and (c) are arranged from least to most saturated. The original frame from the film is (b); the saturation of the frame (0.37) closely matches the saturation of the whole film (0.40). Desaturated frame (a) has a saturation level of 0.20, while hyper-saturated frame (c) has a saturation value of 0.62. *The Land Before Time* is the least saturated of the cel animated films.

Adults and children differ in their preferences for saturation. Adults tend to prefer moderate saturation, while children prefer extremely saturated colors (Child, Hansen, & Hornbeck, 1968; Pitchford & Mullen, 2005; Palmer & Schloss, 2010). There is some evidence that this preference for high saturation is both helpful for early learning of colors names but also part of the reason why children learn names of achromatic colors (brown, grey) later (Pitchford & Mullen, 2005). Children may prefer these high saturations because more highly saturated colors are more easy for children to discriminate between, as there is more distance between them in HSV space (Gaines, 1972). Adults may prefer higher-than-average saturated colors for the same ease of discrimination but also prefer a space of more variegated colors. Saturation is one of the key variables in the ecological valence theory of color preference, as highly-saturated colors are generally positive indicators of safe food and the absence of disease (Palmer & Schloss, 2010). Saturation also predicts affect; positive affective value is more likely to be attributed to colors with higher saturations (Guilford & Smith, 1959).

In examining saturation in film, we would likely expect to see trends within the groups that mirror this distinction: Hollywood films will be saturated, but not as saturated as children's films. Based on the physical properties of cel painting and film stock discussed earlier, we may also expect to see a difference in type.

Methods

Like previous analyses, the calculation of whole-film luminance was computed from the compressed 256 x 256 pixel *.avi films. Films were converted from RGB to HSV color space. The saturation value for each pixel within the frame was recorded on a scale of 0 (completely desaturated; white) to 1 (completely saturated). We computed both the median and mean saturation of the pixels for each frame; ultimately, we chose the median as the most representative statistic as the covariance of luminance with saturation skewed the distributions of saturation values. The whole-film saturation statistic was computed by taking the median value of saturation for each frame across the entire film.

Results

Year, age, type, and luminance were used as covariates in these models. Luminance was included because of its inherent covariance with saturation in HSV color space (see Discussion).

For the current Hollywood sub-sample sample of films, there was no effect of year[29] or age. There was a marginal effect of luminance in predicting saturation, $F(1,35) = 3.99$ ($p = .05$, see Figure 28). Initial comparisons between the children's sample and the Hollywood sample revealed that the Hollywood films are much less saturated than the children's films, $t(108) = 4.54$ ($p < .0001$); however, this effect is almost entirely driven by type. When type, year, and luminance were factored in as predictors, the predictive value of intended audience subsides, and type emerges as the most significant predictor, $F(2,61) = 13.60$ ($p < .0001$). In examining the difference between the Hollywood films (all live action) and only the live action children's films, no difference existed between the two groups.

For the children's sample, age was not an effective part of the model ($p > .90$), so it was removed. There was no effect of year, but effects of luminance and type were present. As luminance increases, saturation in the children's films decreases, $F(1,61) = 6.00$ ($p < .05$; see Figure 28). The cel animated films were significantly more saturated than their live action counterparts, but neither of these groups differed from CGA films, $t(55) = 4.18$ ($p < .0001$).

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[29] Unlike luminance and VAI, saturation analyses had not previously been conducted on the sample of 160 films used by Cutting and colleagues; these analyses are new for this thesis. While there were no significant predictors of saturation for the current sub-sample of Hollywood films, we ran saturation analyses on the entire body of Cutting et al.'s 160 Hollywood films to examine historical trends. For the color films in the sample ($n = 118$), we found a dramatic increase in saturation for these films over time ($r = .40878$, $p < .0001$).

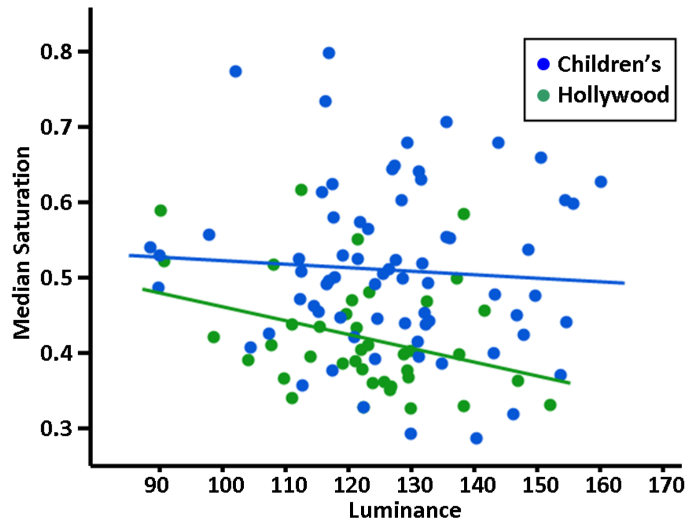

Figure 28. Median saturation of children's and Hollywood films by luminance. Saturation and luminance have a mathematically-necessary inverse relationship, such that saturation decreases as luminance increases.

We also examined the within-type patterns of saturation. For live action films, age was not an effective predictor and was removed from the model. Luminance again predicted saturation with the similar negative trend seen in previous analyses, $F(1,17) = 11.54$ ($p < .01$). None of the predictors were significant for CGA films, even when luminance was removed from the model.

For cel films, luminance was no longer a helpful predictor ($p > .95$), so it was removed from the model. The interaction of age and year, but neither age nor year independently, predicted saturation for cel animated films ($F(1,33) = 4.62$, $p < .05$). For cel films geared toward younger audiences, cel films are likely to increase in saturation over historical time. By contrast, cel films geared toward older children are likely to decrease in saturation over historical time. The interaction is illustrated in Figure 29.

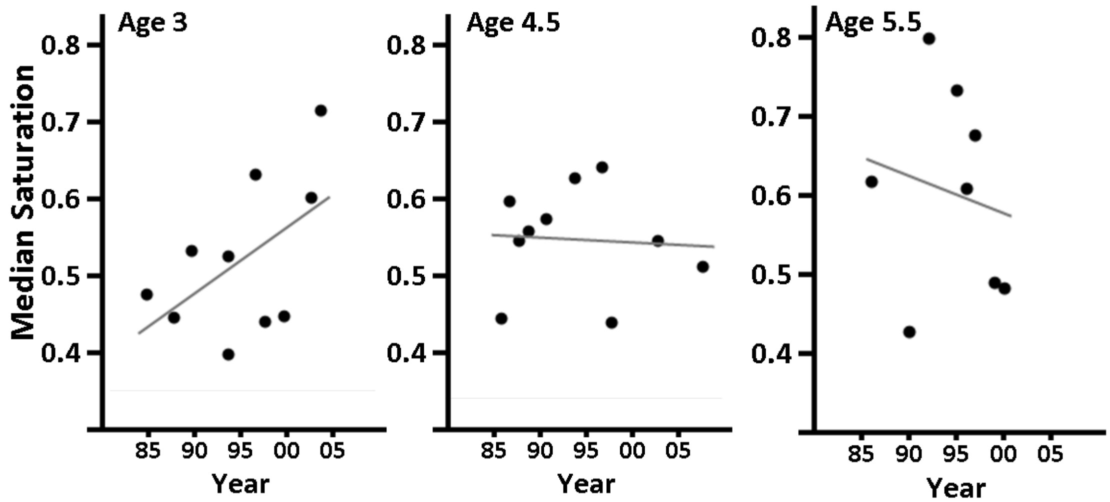

Figure 29. Median saturation for cel animated films by year across three age groups. An interaction between year and age predicts saturation for the cel animated films. Cel films for younger audiences have been increasing in saturation over time (shown in the data for Age 3), while cel films for older audiences have been decreasing in saturation over time (shown in the data for Age 5.5). Not all age groups are shown.

Discussion

Saturation analyses particularly underscore the importance of differentiating between type, especially with regard to how luminance and saturation interact in color space. The difference between the Hollywood and children's film samples is almost entirely driven by the high-saturation cel animated films, and in fact no differences exist between the live action children's films and the Hollywood sample. It is clear that the differences in saturation cannot be attributed directly to the intended audience, but instead should be thought of as an artifact of film type. An indirect relationship between these variables arguably exists: people are more likely to assume cel animated films are for child audiences, and many people think there is something intrinsically appealing about this type of film to children. Whether that is true remains to be seen (and will be discussed further in the General Discussion).

Given that children have preference for higher saturations, we should certainly expect the interaction between age and year for cel animated films. Films for young children are becoming increasingly saturated, potentially to account for this preference in young audiences. Somewhat unexpectedly, however, we also observe a decrease in saturation over time for older audiences as part of this interaction. Given that the Hollywood film sample does not change meaningfully in saturation over time, and that the broader Hollywood sample reflects an increase in saturation over time, we would more likely expect no change over time for cel films for older children (or perhaps even a slight increase to match the pattern of the adult-geared films). This decrease could be an attempt to 'correct' cel films for older children down to the lower level observed in Hollywood films. Again because type is conflated here, this downward trend could also be the result of a change attempting to make cel films for older children more visually similar to live action films; this could be an attempt by filmmakers to bridge older children between the highly-saturated mostly-cel animated world to the lower-satuation, live action world of Hollywood cinema. In any case, it does seem to reflect an interesting degree of developmental knowledge on the part of filmmakers.

Finally, it is worth discussing the relationship between luminance and saturation, and in particular, how this relationship varies over type. For both the Hollywood films and the live action children's films, luminance and saturation had a robust negative relationship, suggesting that these variables naturally interact in live action cinema. Conversely, luminance has a near-meaningless relationship to saturation in cel animated features and CGA features. There are two important factors that explain this relationship. First, in most color spaces, these two features of color exhibit the same covariance that is present in the data. In HSV space, for example, saturation and value (luminance) are separately-quantified variables; however, as value decreases (as colors get darker), saturation is necessarily restricted. Hence, as you move away from the base of the HSV cone down the height axis, the radial axis also decreases, which is why the space takes a conical shape in the first place. The base of the HSV cone is where the brightest colors exist, but as you move outward radially, there is a necessary tradeoff between saturation and luminance (in other words, the base of the HSV cone is not isoluminant). Despite that saturation and value are separately quantified in HSV space, they are not independent; their predictable covariance in color space matches the relationship they exhibit in this data. Second, animated films, especially in digital color space, allow filmmakers to have very precise control of colorization. Almost all animated films after 1991 use digital colorization rather than hand-painting, and this digital process would allow animators to more independently vary saturation and luminance. Relying on hand-painting techniques would produce more naturalistic covariance between luminance and saturation because animators are still relying on analog techniques. However, digital colorization increases the degrees of freedom available to animators to render color in their work, which increasingly decouples the relationship between luminance and saturation.

Hue

Overview

Hue is the earliest-learned and most salient component of color for most people. Though hue is based on the wavelengths of the visible spectrum interacting with the sensitivities of our S, M, and L cones, we often conceive of hue in terms of color names.

Preferences for particular hues are well-established in both children and adults. Adults prefer short-wavelength hues (blues) over all other colors (Eysenck, 1941; Granger, 1952; McManus, Jones, & Cottrell, 1981, Palmer & Schloss, 2010; Memphill, 1995). This reportedly generally transcends both sex and culture, though some sex and cultural variations on this preference have been noted (Choungourian, 1968; Guilford & Smith, 1959; Taylor, Clifford, & Franklin, 2013). Children, by contrast, tend to prefer colors that are rated low in preference by adults. Young infants reportedly have no initial chromatic preferences (Adams, 1987), but some have claimed very early learned preferences for dark yellows and reds that resemble skin tones, evoking positive valence (Palmer & Schloss, 2010). Preschool-aged children have a preference for red that appears to deteriorate over time and is then replaced with the adult-consistent preferences for blues (Child, Hansen, & Hornbeck, 1968; Katz & Breed, 1922; Franklin, Gibbons, Chittenden, Alvarez, & Taylor, 2012).

Additionally, hues carry relatively consistent affective content. Unsurprisingly, more highly preferred hues are often associated with more positive emotions (Osgood, 1973; Hemphill, 1995). Reds tend to evoke notions of dominance, strength, and activeness (Osgood, 1973). While adults are more selective in their positive associations with particular colors, children are much more likely to ascribe positive emotions to a variety of hues than adults (Hemphill, 1995; Boyatzis & Varghese, 1994). Several theories have developed to explain the consistency in preference and affect across populations. Some have attributed sex differences to evolutionary sex-specific changes in trichromacy (Hulburt & Ling, 2007). This theory is tenuous not only because the sex-difference color literature is contentious, but because it also implies that color preferences are innate, which would not be able to successfully account for documented changes in color preference through developmental time. Ou, Luo, Woodcock, and Wright (2004) simultaneously explained away some cultural differences and supported unified preferences across cultures by breaking colors into four indexes that predicted these similarities and differences. Palmer and Schloss (2010) account for color preferences across dimensions of hue, saturation, and brightness with a learned model of how colors are associated with appetitive and aversive reactions from ecological stimuli. Ultimately, it is difficult to determine if there is a definitive explanation for color preferences given both the variability in findings as well as the change in preferences and affective response over the lifespan.

Because children and adults seem to shift dramatically in their preferences for hues, we might expect this shift to be a salient feature of children's film, especially if color is a more cognitively accessible low-level feature as we predicted. To examine hue in these films, we computed a rough statistic for whole-film hue and then analyzed major characters and their color breakdowns in a series of children's films.

Whole-Film Hue

Methods. Using the same 256 x 256 pixel films from previous analysis, we determined color triplet (RGB) values for each pixel in each frame. The triplet with the highest overall frequency in the frame was recorded. The triplet was then converted to HSV, where the value of H was retained for each frame. The median value of H across all the frames of the film provided a coarse[30] metric for whole-film hue[31].

Results. The mode hues of the children's films ranged from 0 to 228. Their linear mean is 60, and their directional mean and median are 56.87 and 60, respectively (standard deviation = 63.1). The films are heavily biased toward 0 (red) and 60 (yellow), and circular tests of multimodality confirm a bimodal ($p < .001$) but non-uniform ($p < .001$) distribution of hues. No linear models were predicted by age or year. Linear analyses by type showed that cel animated films were likely to have bluer hues than live action, but that neither group

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[30] I discuss this whole-film hue metric as a rough metric for one primary reason: it is difficult to get a measure of what individual hue best represents a film. While the most frequent color seems the obvious choice, simply assessing hue while controlling for saturation and luminance reduces a necessary amount of color depth that seems necessary for (1) visual variegation of an image and (2) our ability to perceive film as an art form. Reducing color too far in dimension arguably diminishes its effect in the film. In addition, summary statistics for hue are arguably somewhere between not helpful and meaningless. Linear statistics provide inaccurate information, and circular (directional) statistics require a much greater amount of precision and invariance to have meaning. The linear median was used for this analyses because it is an accurate a representation as any summary statistic could realistically be in this complex and variable hue space.

[31] A preferable way to conduct these analyses, which is currently underway, is to first convert the films from RGB to HSV, and then calculate the frequency for non-unique hues across all saturations and values. This approach is a closer approximation of hue frequency in the frame; however, converting the films from RGB to HSV space requires considerable computational power. The mode would be the ideal statistic to attain the most frequent hue across the entire film, but many of the films did not have a mode. As mean would have been a meaningless statistic, median was used.

differed from CGA, $F(2,59) = 4.91$, ($p < .05$). Hue information and frequency is shown in Figure 30.

Hue	Frequency
0	12
60	12
30	11
180	9
120	5
210	4
20	3
36	2
40	2
45	2
195	2
200	2
90	1
225	1
228	1

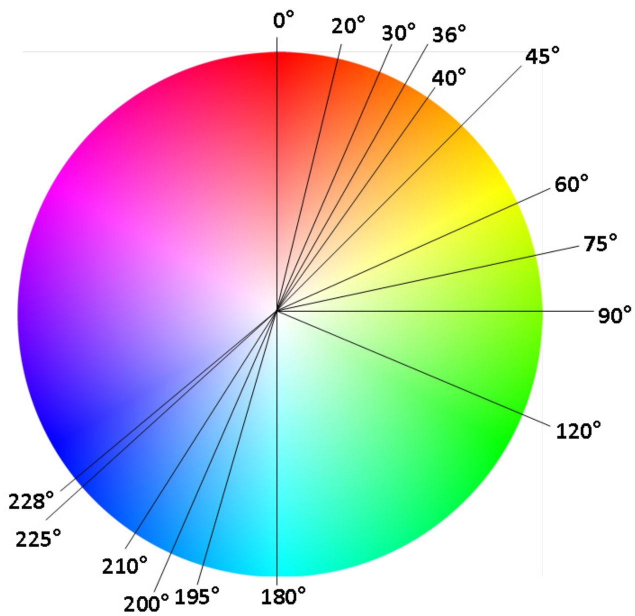

Figure 30. The most frequent hues in the children's films, and their frequencies as the mode hue of a film, for the children's film sample. Data appear bimodally situated around orange and blue hues, though statistical summaries of color data are not necessarily more meaningful than a full representation of the distribution.

Discussion. Limited conclusions can be drawn from this data, though the data are interesting in an observational sense. The effect that live action films tend to be warmer is likely an artifact of the increased presence of human figures (and thus warm skin tones) in the frames. Neither age nor year predicted changes in hue. However, the notion that film hue may be bimodally designed around orange-teal contrasts is a frequent topic in the film literature, and this data certainly may reinforce that notion (Helmer, 2013).

Because hue varies tremendously over the course of films, and because whole-film hue may not be the most interesting or helpful statistic, examining a subset of hue might be a more relevant approach. In particular, given the considerable literature on color and affect, examining character coloration may have consequences for the moral trajectories of characters through story space.

Character Hue

Methods. To better assess character coloration in particular, we chose to isolate character depictions across the film and analyze their hue.

Coding. Two coders were given each film in 256 x 256 pixel *.avi format. Films were rendered in grayscale to remove all color information. Coders were instructed to watch the film and record the major and minor protagonists, antagonists, and ambiguous characters in the film. Major and minor characters differed in how essential they were to the plot; coders were told to code characters as major if the plot was impossible without them. Minor characters were said to be characters that had names and considerable screen time but were not necessary for plot advancement. Characters were also assigned 3 possible 'moral' alignments by coders. Protagonists were characters whose motives were generally good ('good guys') and antagonists had motives that were generally evil ('villains'). Coders were asked to code any character that changed considerably over the course of the plot or characters that had questionable motives as ambiguous. When they had completed their viewing of the film and indexed the relevant characters, they were then asked to record frame numbers within the film of stills corresponding to images of each character. Coders submitted a set of frame numbers (minimum of three) corresponding to stills of major and minor characters. Coders were free to select any frame from the grayscale film, with the one request that the intended character feature prominently in the frame.

Image Extraction. Coding of characters was conducted in grayscale to eliminate any potential color bias from coders. Frame numbers from the coders were used to collect corresponding images from the color versions of the film. Frames were saved as *.jpg files. We then used image extraction algorithms to remove the character from any background information in the frame. This allowed us to analyze the hue of the character in the frame independently of the background of the frame.

Hue Information. Each character image was first converted from RGB to yCbCr using the standard MatLab call. The mean of each yCbCr dimension (luminance, chrominance blue, and chrominance red) was computed for each image and normalized. This allowed us to compare the mean hue for each image independent of luminance.

Exclusions. Initial analyses showed relatively invariant color information across the live action films. This is likely due to the predominance of skin tones as the major visual element of live action characters. The faces in the films were highly stereotyped in their color profiles. As a result, we only included animated films (both cel and CGA) in the analyses. In addition, we excluded sequels of films where the original was also in the sample to avoid doubling-up particular characters[32].

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[32] From the set of both cel (n = 39) and CGA (n = 13) films, 9 sequels were excluded (*Care Bears II: A New Generation, An American Tail 2: Fievel Goes West, The Land Before Time 2, The Land Before Time 5*, *Rugrats in Paris, The Little Mermaid: Ariel's Beginning, Toy Story 2* and *The Land Before Time 10*). This reduced the sampled films to 32 cel films and 12 CGA films.

Coders reported some films as lacking an explicit 'villain.' In some of these cases, potential villains were coded as ambiguous (for example, Sharpay in *High School Musical 3: Senior Year* (2008)). In others, an explicit villain was lacking altogether; for instance, in *Prancer* (1989), the death of Jessica's mother and the subsequent economic strife her family faces are the primary negative forces driving the plot of the film. If the film did not have at least one protagonist and one antagonist according to these criteria, the film was excluded[33].

Results. Images of 52 major antagonistic characters and 118 major protagonists from 39 animated films were analyzed in color space. Protagonists and antagonists as groups did not differ in red or blue chrominance (see Figure 31). Neither year nor age was an effective predictor of a character's chrominance-red or chrominance-blue values. However, protagonists and antanogists differed robustly in luminance, $t(157) = 4.45$ ($p < .0001$). Protagonists were more likely to have higher luminance values than antagonists.

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[33] Films that had no major antagonist included *Pokemon: The First Movie, Brother Bear, Clifford's Really Big Movie, The Polar Express,* and *Chicken Little.* This further reduced the sampled films to 29 cel films and 10 CGA films.

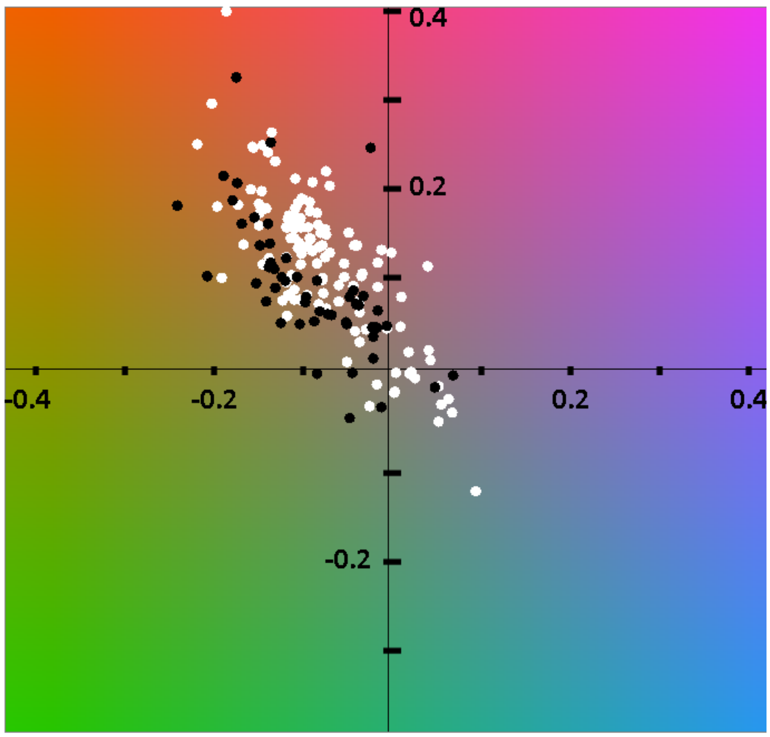

Figure 31. Mean chrominance-red and chrominance-blue values of protagonist (white) and antagonist (black) characters plotted in truncated yCbCr space. No meaningful chrominance differences existed between the groups on either axis.

Discussion. The motivations of characters did not reliably predict the use of hue in characters for children's films; year, age, and type were all also insufficient predictors of hue. While we may require greater visual sampling of characters, or the inclusion of minor protagonist and antagonists, to observe an effect, it seems likely that there are simply no robust differences between coloration of protagonists and antagonists.

We were able to find a relationship between character motivation and luminance, with positively-motivated characters being more likely to have brighter values in yCbCr space. This, in part, could explain the lack of findings with hue; filmmakers may rely solely on luminance to distinguish good from evil characters in their films. This is itself a powerful strategy, as myriad research shows a moral association between dark and light (Meier, Robinson, & Clore, 2004; Sherman & Clore, 2009). It seems luminance is being used strategically, while hue instead is being used stylistically.

General Discussion

Color is arguably the most cognitively accessible of the formal media features. While other film features tend to guide our attention or regulate our viewing without our conscious knowledge, we can readily identify colors, their properties, and associate with them particular mental states and affects. As such, we might have expected to see children's films make use of color in a dramatic way, but what we instead see is a bifurcated function of color based on its parameters. Saturation tends to act more concurrently with the features discussed in Chapter 1: change in saturation is reliably predicted by an interaction of age with year (for cel films), and saturation use has methodically differed between types, which may be an indicator of a differential performance in child-geared versus adult-geared films. Hue, on the other hand, appears to have less psychological relevance than we might expect. Rather than interacting with age or changing over time, hue tends to simply follow the bimodal, opponent pattern that theoretically maximizes the contrast between hues associated with skin tones and their blue-range opponent colors (Helmer, 2013). While this opponent relationship may have other interesting psychological implications, including contrast as a mechanism for guiding visual attention, hue seems to largely be used as an aesthetic medium rather than a psychological one. Perhaps the cognitive availability of color is indeed what causes it to be optimized for art; we often explain other low-level patterns emerging as artifacts of sub-conscious intuitions of the filmmaker. For example, filmmakers do not consciously attempt to make their films abide a $1/f$–like shot structure; they simply have (1) ample exposure to a body of successful and unsuccessful films with particular shot structures and (2) and inferred sense of what kind of shot structure 'works' based on that body of knowledge. The resulting shot structure pattern is unintentional and non-deliberate. With color, filmmakers can readily access and fine-tune its components, so this conscious effort may interfere with process of relying on specialized psychological inferences. As such, it still seems that color (or rather, hue) functions as a 'higher' low-level feature, with its major implications in aesthetics, while the 'lower' low-level features, including saturation, develop at a pace indicative of certain psychological and temporal variables.

CONCLUSIONS

The goal of this dissertation was to assess many of the common low-level features in children's film using quantitative methods. This pursuit was necessary if we are to understand anything about the current state of children's media. Most of the existing research has focused on television, and the metrics of assessing formal features have been largely coder-defined rather than computationally calculated. Ultimately, we need to understand what *works* for children in terms of a viewing situation, but understanding this question also involves understanding of the goal of the media. Film, unlike television, rarely has the pretense of being explicitly educational, though it often is in the social-moral domain. So what are we trying to make work for young viewers? Children's films, like Hollywood films, are artistic works, and we are attempting to allot artistic experiences to children in ways that are perceptually salient. We also are scaffolding children to be adult viewers of film. By exposing them to visual narratives that allow them to construct their own narrative maps, we can foster narrative comprehension in the visual and cognitive domains. Though it was not examined as part of the current work, both audio information and content information also contribute to this scaffolding process (Calvert, Huston, Watkins, & Wright, 1982; Calvert & Scott, 1989); the relative contribution to child comprehension of each of these elements in isolation is worthy of further study. Finally, film aims to entertain, and meaningfully engaging with a film is the first step to allowing it to provide entertainment. Different goals of film may rely on different or similar formal features to guide visual attention to particular elements, and the first step to assessing how to accomplish this is to know the current state of the media and understanding relevant film trends.

The major finding across this work indicates that somehow filmmakers and adult audiences seem to conceive of animation as somehow intrinsically salient to and appropriate for child audiences, and that most differences between adult-geared and child-geared films are the result of differences between animated and non-animated films. The gradual appropriation of this media over time to child audiences has led to an expectation that animation is a children's film type, but there is relatively little to suggest that anything about the type in particular is intrinsically salient to child audiences. This work has found considerable evidence that the most developmentally-appropriate changes in low-level features are happening in animated films, but directionality is still a problem. In other words, are these trends emerging because animation is an intrinsically-appealing media for children, or do filmmakers make these low-level adjustments because they are already of the mindset that animation is a child-space? Some research has examined issues of the inherent comprehensibility of cartoon images, finding that adults tend to comprehend representations of images in cartoon form better than in photo-realistic sketch form or photographic form (Moll, 1986; Readance & Moore, 1981). However, these studies (1) were done with adults and high-school level teenagers, not children, (2) show small effect sizes, (3) use static rather than dynamic images, and (4) encountered different results when using non-literate adult populations, which would have implications for pre-literate children. Further research, both anthropological and psychological, will be necessary to make headway on this question.

Developing media for children with optimally engaging formal features is a gateway to facilitating better learning from media. The learning in this case need not be limited to education; indeed, film may provide the most education about concepts like art form and narrative structure instead of television-typical, curricula-based learning. This allows children to be better consumers of both art and media, and facilitates a level of cognitive development unique to both of those domains. Studying children's films as the union of art and media affords a unique opportunity to differentiate which low-level features best facilitate learning in specific cognitive domains.

Appendix A: Release Variables for Children's Film Sample and Hollywood Film Sample

Children's Film Release Variables

Film Title (Distributor, Release Venue)	Release Year	Length (min)	Number of Shots	Average Shot Duration (s)	Intended Age[1]	Type
The Care Bears Movie (Sam Goldwyn, Theatrical Release)	1985	77	1118	3.81	3	Cel Animated
One Magic Christmas (Disney, Theatrical Release)	1985	89	1062	4.84		Live Action
Sesame Street Presents: Follow That Bird! (Warner Bros., Theatrical Release)	1985	89	761	6.62	3	Live Action
An American Tail (Universal, Theatrical Release)	1986	81	839	5.21	4.5	Cel Animated
The Care Bears Movie II: A New Generation (Columbia, Theatrical Release)	1986	77	1142	3.76	5	Cel Animated
The Great Mouse Detective (Disney, Theatrical Release)	1986	74	1256	3.43	5.5	Cel Animated
Benji the Hunted (Disney, Theatrical Release)	1987	88	1101	4.61	5.5	Live Action
The Brave Little Toaster (Hyperion/Disney, Direct-to-TV Release[2])	1987	90	1154	4.49	5	Cel Animated
The Chipmunk Adventure (Sam Goldwyn, Theatrical Release)	1987	76	1021	4.24	4.5	Cel Animated
The New Adventures of Pippi Longstocking (Columbia, Theatrical Release)	1988	100	1275	4.62	6.5	Live Action
The Land Before Time (Universal, Theatrical Release)	1988	67	585	6.36	3	Cel Animated
Oliver and Company (Disney, Theatrical Release)	1988	74	1160	3.57	4.5	Cel Animated
All Dogs Go to Heaven (United Artists, Theatrical Release)	1989	89	1004	5.91	6	Cel Animated

Film Title (Distributor, Release Venue)	Release Year	Length (min)	Number of Shots	Average Shot Duration (s)	Intended Age[1]	Type
The Little Mermaid (Disney, Theatrical Release)	1989	83	1408	3.31	4.5	Cel Animated
Prancer (Orion, Theatrical Release)	1989	103	1218	4.82		Live Action
DuckTales the Movie: Treasure of the Lost Lamp (Disney, Theatrical Release)	1990	74	1117	3.52		Cel Animated
The Jetsons Movie (Universal, Theatrical Release)	1990	82	990	4.50	3	Cel Animated
The Rescuers Down Under (Disney, Theatrical Release)	1990	77	1025	4.27	5.5	Cel Animated*
All I Want for Christmas (Paramount, Theatrical Release)	1991	92	873	6.05		Live Action
An American Tail: Fievel Goes West (Universal, Theatrical Release)	1991	76	901	4.52	4.5	Cel Animated
Beauty and the Beast (Disney, Theatrical Release)	1991	84	1375	3.71	5	Cel Animated
Aladdin (Disney, Theatrical Release)	1992	90	1456	3.50	5.5	Cel Animated
FernGully: The Last Rainforest (Fox, Theatrical Release)	1992	76	1006	4.16	5	Cel Animated
The Muppet Christmas Carol (Disney, Theatrical Release)	1992	85	866	5.79	4.5	Live Action
Homeward Bound: The Incredible Journey (Disney, Theatrical Release)	1993	84	1456	3.31	5.5	Live Action
The Secret Garden (Warner Bros., Theatrical Release)	1993	102	848	6.99	7.5	Live Action
We're Back! A Dinosaur's Story (Universal, Theatrical Release)	1993	71	794	4.77		Cel Animated
The Land Before Time 2: The Great Valley Adventure (Universal, Direct-to-Video Release)	1994	73	879	6.08	3	Cel Animated

Film Title (Distributor, Release Venue)	Release Year	Length (min)	Number of Shots	Average Shot Duration (s)	Intended Age[1]	Type
The Lion King (Disney, Theatrical Release)	1994	89	1202	4.15	4.5	Cel Animated
The Pagemaster (Fox, Theatrical Release)	1994	80	932	4.27	6.5	Live Action*
Thumbelina (Warner Bros., Theatrical Release)	1994	86	822	5.89	3	Cel Animated
Babe (Universal, Theatrical Release)	1995	92	1336	3.89	5	Live Action
Pocahontas (Disney, Theatrical Release)	1995	81	1293	3.69	5.5	Cel Animated
Toy Story (Disney/Pixar, Theatrical Release)	1995	81	1559	2.99	3	CG Animated
101 Dalmatians (Disney, Theatrical Release)	1996	103	1661	3.49	4.5	Live Action
The Hunchback of Notre Dame (Disney, Theatrical Release)	1996	91	1536	3.29	5.5	Cel Animated
Muppet Treasure Island (Disney, Theatrical Release)	1996	99	1258	4.40	5.5	Live Action
Anastasia (Fox, Theatrical Release)	1997	94	1352	3.83	5.5	Cel Animated
Cats Don't Dance (Warner Bros., Theatrical Release)	1997	120	1122	3.68	4.5	Cel Animated
Hercules (Disney, Theatrical Release)	1997	92	1617	3.21	6	Cel Animated
The Land Before Time 5: The Mysterious Island (Universal, Direct-to-Video Release)	1997	74	925	4.51	3	Cel Animated
A Bug's Life (Disney/Pixar, Theatrical Release)	1998	96	1617	3.27	4.5	CG Animated
Mulan (Disney, Theatrical Release)	1998	88	1332	3.61	4.5	Cel Animated

Film Title (Distributor, Release Venue)	Release Year	Length (min)	Number of Shots	Average Shot Duration (s)	Intended Age[1]	Type
The Rugrats Movie (Paramount, Theatrical Release)	1998	81	1166	3.83	3	Cel Animated
Pokemon: The First Movie (Warner Bros., Theatrical Release)	1999	96	963	4.36	5	Cel Animated
Tarzan (Disney, Theatrical Release)	1999	88	1581	3.12	5.5	Cel Animated
Toy Story 2 (Disney/Pixar, Theatrical Release)	1999	92	1423	3.56	3	CG Animated
Chicken Run (DreamWorks, Theatrical Release)	2000	84	1540	3.06	5.5	Claymation*
The Emperor's New Groove (Disney, Theatrical Release)	2000	78	1158	3.73	5.5	Cel Animated
Rugrats in Paris (Paramount, Theatrical Release)	2000	78	1249	3.46	3	Cel Animated
Jimmy Neutron: Boy Genius (Paramount, Theatrical Release)	2001	82	1268	3.71	6	CG Animated
Monsters, Inc. (Disney/Pixar, Theatrical Release)	2001	90	1403	3.57	5	CG Animated
The Princess Diaries (Disney, Theatrical Release)	2001	114	1445	4.56	6	Live Action
The Santa Clause 2 (Disney, Theatrical Release)	2002	105	1890	3.09	5	Live Action
Spirit: Stallion of the Cimarron (DreamWorks, Theatrical Release)	2002	82	1680	2.69	6	Cel Animated
The Rookie (Disney, Theatrical Release)	2002	129	1971	3.75	6.5	Live Action
Brother Bear (Disney, Theatrical Release)	2003	85	1212	3.84	4.5	Cel Animated
Finding Nemo (Disney/Pixar, Theatrical Release)	2003	104	1440	3.82	4.5	CG Animated

Film Title (Distributor, Release Venue)	Release Year	Length (min)	Number of Shots	Average Shot Duration (s)	Intended Age[1]	Type
The Jungle Book 2 (Disney, Theatrical Release)	2003	88	1183	3.32	3.5	Cel Animated
The Land Before Time 10: The Great Longneck Migration (Universal, Direct-to-Video Release)	2003	84	981	3.95	3	Cel Animated
Clifford's Really Big Movie (Warner Bros., Theatrical Release)	2004	73	1465	2.79	3	Cel Animated
The Polar Express (Warner Bros., Theatrical Release)	2004	100	869	6.27	5.5	CG Animated
The Princess Diaries 2: A Royal Engagement (Disney, Theatrical Release)	2004	113	1320	4.88	6	Live Action
Chicken Little (Disney, Theatrical Release)	2005	81	1281	3.41	6	CG Animated
Herbie Fully Loaded (Disney, Theatrical Release)	2005	92	2228	2.55	5.5	Live Action
The March of the Penguins (Warner Independent, Theatrical Release)	2005	85	575	7.96	6	Live Action
Cars (Disney-Pixar, Theatrical Release)	2006	116	1688	3.83	3.5	CG Animated
Charlotte's Web (Paramount, Theatrical Release)	2006	94	1428	3.61	5	Live Action
The Santa Clause 3: The Escape Clause (Disney, Theatrical Release)	2006	98	1535	3.28	5	Live Action
Meet the Robinsons (Disney, Theatrical Release)	2007	92	1657	3.13	6	CG Animated
Mr. Bean's Holiday (Universal, Theatrical Release)	2007	90	1257	3.77	6	Live Action
Ratatouille (Disney-Pixar, Theatrical Release)	2007	111	1627	3.72	5	CG Animated
High School Musical 3: Senior Year (Disney, Theatrical Release)	2008	100	1625	3.89	7	Live Action

Film Title (Distributor, Release Venue)	Release Year	Length (min)	Number of Shots	Average Shot Duration (s)	Intended Age[1]	Type
Horton Hears a Who? (Fox, Theatrical Release)	2008	88	1504	3.15	3	CG Animated
The Little Mermaid: Ariel's Beginning (Disney, Direct-to-Video Release)	2008	70	1297	3.22	4.5	Cel Animated
Wall•E (Disney-Pixar, Theatrical Release)	2008	97	1398	3.84	4.5	CG Animated

Hollywood Film Release Variables

Film Title (Distributor, Release Venue)	Release Year	Length (min)	MPAA Rating	Average Shot Duration (s)	Intended Age[3]	Type
Back to the Future (Universal, Theatrical Release)	1985	116	PG	4.95	7.5	Live Action
Cocoon (Twentieth Century Fox, Theatrical Release)	1985	117	PG-13	5.89	12.5	Live Action
The Jewel of the Nile (Twentieth Century Fox, Theatrical Release)	1985	106	PG	3.97	12.5	Live Action
The Color Purple (Warner Bros., Theatrical Release)	1985	154	PG-13	7.49	13.5	Live Action
Out of Africa (Universal, Theatrical Release)	1985	161	PG	5.13	12.5	Live Action
Police Academy 2: Their First Assignment (Warner Bros., Theatrical Release)	1985	87	PG-13	5.13		Live Action
Rambo: First Blood Part II (Artisan, Theatrical Release)	1985	96	R	2.99	15	Live Action
Rocky IV (MGM, Theatrical Release)	1985	91	PG	2.49		Live Action
Witness (Paramount, Theatrical Release)	1985	112	R	6.33	14	Live Action
Spies Like Us (Warner Bros., Theatrical Release)	1985	102	PG	3.89		Live Action
Dick Tracy (Touchstone, Theatrical Release)	1990	105	PG	3.97	9.5	Live Action
Total Recall (TriStar, Theatrical Release)	1990	113	R	3.66	16	Live Action
Ghost (Paramount, Theatrical Release)	1990	127	PG-13	5.1	13.5	Live Action
The Hunt for Red October (Paramount, Theatrical Release)	1990	134	PG	7.02		Live Action

Film Title (Distributor, Release Venue)	Release Year	Length (min)	MPAA Rating	Average Shot Duration (s)	Intended Age[3]	Type
Dances with Wolves (Orion, Theatrical Release)	1990	181	PG-13	5.45	13	Live Action
Home Alone (Twentieth Century Fox, Theatrical Release)	1990	103	PG	4.33	6.5	Live Action
Die Hard 2 (Twentieth Century Fox, Theatrical Release)	1990	124	R	3.03	15	Live Action
Teenage Mutant Ninja Turtles (New Line, Theatrical Release)	1990	93	PG	4.56	7	Live Action
Goodfellas (Warner Bros., Theatrical Release)	1990	146	R	6.81	18	Live Action
Pretty Woman (Touchstone, Theatrical Release)	1990	119	R	6.08	14	Live Action
Jumanji (TriStar, Theatrical Release)	1995	104	PG	3.53	9.5	Live Action
GoldenEye (MGM, Theatrical Release)	1995	130	PG-13	3.58	12.5	Live Action
The Usual Suspects (MGM, Theatrical Release)	1995	106	R	5.5	17	Live Action
Batman Forever (Warner Bros., Theatrical Release)	1995	121	PG-13	3.92	11.5	Live Action
Casper (Universal, Theatrical Release)	1995	100	PG	6.51	6	Live Action
Apollo 13 (Universal, Theatrical Release)	1995	140	PG	4.88	11.5	Live Action
Sense and Sensibility (Columbia, Theatrical Release)	1995	136	PG	6.58	10.5	Live Action
Ace Ventura: When Nature Calls (Warner Bros., Theatrical Release)	1995	90	PG-13	4.71		Live Action
Mission: Impossible II (Paramount, Theatrical Release)	2000	123	PG-13	2.5	13	Live Action

Film Title (Distributor, Release Venue)	Release Year	Length (min)	MPAA Rating	Average Shot Duration (s)	Intended Age[3]	Type
Charlie's Angels (Columbia, Theatrical Release)	2000	98	PG-13	3.17	12	Live Action
The Perfect Storm (Warner Bros., Theatrical Release)	2000	130	PG-13	4.86	13	Live Action
X-Men (Twentieth Century Fox, Theatrical Release)	2000	104	PG-13	2.81	11	Live Action
Dinosaur (Disney, Theatrical Release)	2000	82	PG	4.01	5.5	CG Animated
Cast Away (Twentieth Century Fox, Theatrical Release)	2000	143	PG-13	9.48	13	Live Action
How the Grinch Stole Christmas (Universal, Theatrical Release)	2000	104	PG	4	5.5	Live Action
Erin Brockovich (Universal, Theatrical Release)	2000	131	R	5.56	14.5	Live Acrion
What Women Want (Paramount, Theatrical Release)	2000	127	PG-13	4.08	14.5	Live Action
Scary Movie (Dimension, Theatrical Release)	2000	88	R	3.72	16	Live Action
King Kong (Universal, Theatrical Release)	2005	187	PG-13	3.44	13	Live Action
Star Wars: Episode III - Revenge of the Sith (Twentieth Century Fox, Theatrical Release)	2005	140	PG-13	3.78	10.5	Live Action
Mr. & Mrs. Smith (Twentieth Century Fox, Theatrical Release)	2005	120	PG-13	4.12	13.5	Live Action
Harry Potter and the Goblet of Fire (Warner Bros., Theatrical Release)	2005	157	PG-13	4.07	11	Live Action
Wedding Crashers (New Line, Theatrical Release)	2005	119	R	3.3	16	Live Action
Hitch (Columbia, Theatrical Release)	2005	118	PG-13	3.87	13	Live Action

Film Title (Distributor, Release Venue)	**Release Year**	**Length (min)**	**MPAA Rating**	**Average Shot Duration (s)**	**Intended Age[3]**	**Type**
Walk the Line (Twentieth Century Fox, Theatrical Release)	2005	136	PG-13	6	13.5	Live Action
The Longest Yard (Paramount, Theatrical Release)	2005	113	PG-13	3.08	13.5	Live Action
Madagascar (DreamWorks, Theatrical Release)	2005	86	PG	4.19	6.5	CG Animated

[1] The "Intended Age" variable is the median value of the lowest "green" age and the circled "target" age from the age meter for a given film on Common Sense Media (http://www.commonsensemedia.org).

[2] Despite critical acclaim in early screenings, *The Brave Little Toaster* did not have an initial distributor, and was released to video and to television. It was later re-released into theaters after attaining a level of home video success ("The Brave Little Toaster (film)," 2014).

[3] The Intended Age variable for the Hollywood film sample more likely approximates the earliest appropriate viewing age.

Appendix B: Source Materials for Children's Films.

Source	**Example Films**
Children's Books	*The Great Mouse Detective* (1986) *The Brave Little Toaster* (1987) *The New Adventures of Pippi Lonstocking* (1988) *The Little Mermaid* (1989) *The Rescuers Down Under* (1990)* *FernGully: The Last Rainforest* (1992) *Homeward Bound: The Incredible Journey* (1993) *The Secret Garden* (1993) *We're Back: A Dinosaur's Story* (1993) *Babe* (1995) *101 Dalmatians* (1996) *The Princess Diaries* (2001) *The Jungle Book 2* (2003)* *Clifford's Really Big Movie* (2004) *The Polar Express* (2004) *The Princess Diaries 2: A Royal Engagement* (2004)* *Charlotte's Web* (2006) *Meet the Robinsons* (2007) *Horton Hears a Who?* (2008) *The Little Mermaid: Ariel's Beginning* (2008)*
Literary Adaptation or Fable	*Oliver and Company* (1988) *Beauty and the Beast* (1991) *Aladdin* (1992) *The Lion King* (1994) *Thumbelina* (1994) *The Hunchback of Notre Dame* (1996) *Hercules* (1997) *Tarzan* (1999) *The Emperor's New Groove* (2000) *Chicken Little* (2005)
Historical Event or Figure	*Pocahontas* (1995) *Anastasia* (1997) *Mulan* (1998) *The Rookie* (2002)
Television Show	*Sesame Street Presents: Follow That Bird!* (1985) *The Chipmunk Adventure* (1987) *DuckTales: Treasure of the Lost Lamp* (1990) *The Jetsons Movie* (1990) *The Muppet Christmas Carol* (1992)* *Muppet Treasure Island* (1996)* *The Rugrats Movie* (1998) *Rugrats in Paris* (2000)* *Mr. Bean's Holiday* (2007) *High School Musical 3: Senior Year* (2008)*

Toy	*The Care Bears Movie* (1985) *The Care Bears Movie II: A New Generation* (1986)* *Pokemon: The First Movie* (1999)
Film Original	*One Magic Christmas* (1985) *An American Tail* (1986) *Benji the Hunted* (1987) *The Land Before Time* (1988) *All Dogs Go to Heaven* (1989) *Prancer* (1989) *All I Want for Christmas* (1991) *An American Tail: Fievel Goes West* (1991)* *The Land Before Time 2: The Great Valley Adventure* (1994)* *Pagemaster* (1994) *Toy Story* (1995) *Cats Don't Dance* (1997) *The Land Before Time 5: The Mysterious Island* (1997)* *A Bug's Life* (1998) *Toy Story 2* (1999)* *Chicken Run* (2000) *Jimmy Neutron: Boy Genius* (2001) *Monsters, Inc.* (2001) *The Santa Clause 2* (2002)* *Spirit: Stallion of the Cimarron* (2002) *Brother Bear* (2003) *Finding Nemo* (2003) *The Land Before Time 10: The Great Longneck Migration* (2003)* *Herbie: Fully Loaded* (2005)* *The March of the Penguins* (2005) *Cars* (2006) *The Santa Clause 3: The Escape Clause* (2006)* *Ratatouille* (2007) *Wall-E* (2008)

[*] Indicates a sequel or the non-first film in a franchise series.

Appendix C: Computed Film Variables for Children's Films and Hollywood Films

Children's Films

Film Title (Year)	**Power Spectra Slope (α in $1/f^{\alpha}$)**	**Visual Activity Index**	**Average Luminance**	**Median Saturation**
The Care Bears Movie (1985)	0.41	0.076	150.71	0.46
One Magic Christmas (1985)	0.33	0.084	77.18	0.39
Sesame Street Presents: Follow That Bird! (1985)	0.26	0.031	131.87	0.39
An American Tail (1986)	0.72	0.063	115.71	0.45
The Care Bears Movie II: A New Generation (1986)	0.58	0.068	129.37	0.50
The Great Mouse Detective (1986)	0.63	0.102	117.94	0.63
Benji the Hunted (1987)	0.08	0.059	107.62	0.43
The Brave Little Toaster (1987)	0.28	0.053	127.93	0.65
The Chipmunk Adventure (1987)	0.79	0.075	155.58	0.60
The New Adventures of Pippi Longstocking (1988)	0.33	0.059	122.96	0.33
The Land Before Time (1988)	0.74	0.040	125.26	0.45
Oliver and Company (1988)	0.60	0.087	136.95	0.55
All Dogs Go to Heaven (1989)	0.88	0.042	126.05	0.51
The Little Mermaid (1989)	0.76	0.070	123.77	0.57
Prancer (1989)	0.42	0.044	106.81	0.39
DuckTales the Movie: Treasure of the Lost Lamp (1990)	0.39	0.138	138.06	0.59
The Jetsons Movie (1990)	0.56	0.104	119.61	0.53

Film Title (Year)	Power Spectra Slope (α in $1/f^{\alpha}$)	Visual Activity Index	Average Luminance	Median Saturation
The Rescuers Down Under (1990)	0.43	0.061	129.73	0.44
All I Want for Christmas (1991)	0.36	0.036	108.54	0.38
An American Tail: Fievel Goes West (1991)	0.63	0.093	118.07	0.58
Beauty and the Beast (1991)	0.80	0.074	131.95	0.64
Aladdin (1992)	0.35	0.075	117.33	0.80
FernGully: The Last Rainforest (1992)	1.17	0.057	126.99	0.51
The Muppet Christmas Carol (1992)	0.32	0.065	104.57	0.41
Homeward Bound: The Incredible Journey (1993)	0.75	0.055	112.79	0.51
The Secret Garden (1993)	0.22	0.044	89.62	0.49
We're Back! A Dinosaur's Story (1993)	0.81	0.075	110.25	0.59
The Land Before Time 2: The Great Valley Adventure (1994)	0.001	0.033	144.03	0.40
The Lion King (1994)	0.27	0.049	132.28	0.63
The Pagemaster (1994)	0.21	0.050	116.94	0.49
Thumbelina (1994)	0.23	0.046	128.21	0.52
Babe (1995)	0.36	0.045	102.31	0.78
Pocahontas (1995)	0.31	0.040	116.73	0.74
Toy Story (1995)	0.36	0.064	132.97	0.45
101 Dalmatians (1996)	0.49	0.072	112.97	0.36

Film Title (Year)	Power Spectra Slope (α in $1/f^{\alpha}$)	Visual Activity Index	Average Luminance	Median Saturation
The Hunchback of Notre Dame (1996)	0.92	0.051	116.14	0.62
Muppet Treasure Island (1996)	0.55	0.103	89.84	0.53
Anastasia (1997)	0.71	0.047	144.72	0.68
Cats Don't Dance (1997)	0.54	0.057	127.57	0.65
Hercules (1997)	1.21	0.071	112.46	0.53
The Land Before Time 5: The Mysterious Island (1997)	0.72	0.037	161.50	0.63
A Bug's Life (1998)	0.48	0.073	144.19	0.48
Mulan (1998)	0.48	0.063	147.75	0.45
The Rugrats Movie (1998)	0.31	0.111	133.52	0.44
Pokemon: The First Movie (1999)	0.28	0.048	149.69	0.54
Tarzan (1999)	0.89	0.056	118.33	0.50
Toy Story 2 (1999)	0.40	0.064	132.97	0.44
Chicken Run (2000)	0.77	0.061	87.95	0.40
The Emperor's New Groove (2000)	0.49	0.038	133.49	0.49
Rugrats in Paris (2000)	0.65	0.089	119.12	0.45
Jimmy Neutron: Boy Genius (2001)	0.78	0.069	114.91	0.46
Monsters, Inc. (2001)	0.36	0.161	88.48	0.54
The Princess Diaries (2001)	0.34	0.033	130.51	0.29

Film Title (Year)	Power Spectra Slope (α in $1/f^{\alpha}$)	Visual Activity Index	Average Luminance	Median Saturation
The Santa Clause 2 (2002)	0.36	0.041	121.39	0.42
Spirit: Stallion of the Cimarron (2002)	0.82	0.068	155.89	0.44
The Rookie (2002)	0.53	0.053	141.29	0.28
Brother Bear (2003)	0.61	0.052	136.37	0.55
Finding Nemo (2003)	0.53	0.060	130.11	0.68
The Jungle Book 2 (2003)	0.38	0.061	129.02	0.60
The Land Before Time 10: The Great Longneck Migration (2003)	0.49	0.020	156.87	0.60
Clifford's Really Big Movie (2004)	0.83	0.051	136.35	0.71
The Polar Express (2004)	0.37	0.099	97.89	0.56
The Princess Diaries 2: A Royal Engagement (2004)	0.47	0.026	124.79	0.39
Chicken Little (2005)	0.65	0.075	131.69	0.50
Herbie Fully Loaded (2005)	0.97	0.075	131.69	0.41
The March of the Penguins (2005)	0.79	0.022	147.23	0.32
Cars (2006)	0.52	0.079	117.99	0.37
Charlotte's Web (2006)	0.31	0.027	122.04	0.53
The Santa Clause 3: The Escape Clause (2006)	0.38	0.048	124.75	0.49
Meet the Robinsons (2007)	0.56	0.058	151.67	0.66
Mr. Bean's Holiday (2007)	0.61	0.062	154.84	0.37

Film Title (Year)	**Power Spectra Slope (α in $1/f^{\alpha}$)**	**Visual Activity Index**	**Average Luminance**	**Median Saturation**
Ratatouille (2007)	0.59	0.044	112.41	0.47
High School Musical 3: Senior Year (2008)	0.34	0.068	122.41	0.57
Horton Hears a Who? (2008)	0.72	0.069	148.86	0.42
The Little Mermaid: Ariel's Beginning (2008)	0.55	0.041	132.53	0.52
Wall•E (2008)	0.71	0.043	135.71	0.38

Hollywood Films

Film Title (Year)	**Power Spectra Slope (α in $1/f^{\alpha}$)**	**Visual Activity Index**	**Average Luminance**	**Median Saturation**
Back to the Future (1985)	1.0	0.053	111.82	0.36
Cocoon (1985)	0.75	0.029	110.02	0.35
Jewel of the Nile (1985)	0.53	0.107	145.03	0.36
The Color Purple (1985)	0.29	0.034	116.00	0.37
Out of Africa (1985)	0.48	0.021	134.60	0.46
Police Academy 2: Their First Assignment (1985)	0.31	0.048	111.83	0.39
Rambo – First Blood: Part II (1985)	0.67	0.065	117.67	0.32
Rocky IV (1985)	0.90	0.081	114.07	0.31
Witness (1985)	0.45	0.024	117.58	0.40
Spies Like Us (1985)	0.39	0.018	142.70	0.31
Dick Tracy (1990)	0.58	0.029	88.25	0.59
Total Recall (1990)	0.69	0.065	109.97	0.36
Ghost (1990)	0.39	0.034	105.29	0.39
The Hunt for Red October (1990)	1.09	0.025	87.02	0.51
Dances with Wolves (1990)	0.63	0.044	130.10	0.40
Home Alone (1990)	0.41	0.020	107.57	0.41
Die Hard 2 (1990)	1.06	0.062	105.43	0.41
Teenage Mutant Ninja Turtles (1990)	0.78	0.045	81.99	0.52

Film Title (Year)	Power Spectra Slope (α in $1/f^{\alpha}$)	Visual Activity Index	Average Luminance	Median Saturation
Goodfellas (1990)	0.55	0.050	98.82	0.43
Pretty Woman (1990)	0.92	0.038	111.04	0.48
Jumanji (1995)	0.5	0.046	104.56	0.38
Goldeneye (1995)	0.82	0.040	102.45	0.43
The Usual Suspects (1995)	0.42	0.022	112.46	0.34
Batman Forever (1995)	0.66	0.081	90.50	0.62
Casper (1995)	0.72	0.036	104.73	0.39
Apollo 13 (1995)	0.66	0.043	116.16	0.40
Sense and Sensibility (1995)	0.58	0.010	114.05	0.39
Ace Ventura: When Nature Calls (1995)	0.52	0.050	123.89	0.55
Mission: Impossible II (2000)	0.81	0.068	108.88	0.35
Charlie's Angels (2000)	1.08	0.081	133.07	0.50
The Perfect Storm (2000)	0.90	0.100	111.00	0.36
X-Men (2000)	0.50	0.048	94.21	0.42
Dinosaur (2000)	0.37	0.063	121.40	0.46
Cast Away (2000)	0.56	0.047	103.57	0.33
How the Grinch Stole Christmas (2000)	0.36	0.045	118.67	0.37
Erin Brockovich (2000)	0.39	0.018	136.69	0.59

Film Title (Year)	Power Spectra Slope (α in $1/f^{\alpha}$)	Visual Activity Index	Average Luminance	Median Saturation
What Women Want (2000)	0.68	0.031	109.51	0.47
Scary Movie (2000)	0.29	0.060	122.34	0.38
King Kong (2005)	0.67	0.085	108.74	0.44
Star Wars: Episode III- Revenge of the Sith (2005)	1.14	0.036	103.17	0.40
Mr. & Mrs. Smith (2005)	0.40	0.080	96.98	0.45
Harry Potter and the Goblet of Fire (2005)	0.61	0.060	87.96	0.52
Wedding Crashers (2005)	0.64	0.027	153.50	0.33
Hitch (2005)	0.45	0.033	130.99	0.33
Walk the Line (2005)	0.28	0.044	111.06	0.55
The Longest Yard (2005)	0.63	0.090	134.94	0.47
Madagascar (2005)	0.28	0.067	113.21	0.46

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