სამაგისტრო პროგრამა „მედიაფსიქოლოგია და კომუნიკაციები“

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Media Psychology

CHAPTER 22

Media and Cognitive Development

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OVERVIEW

American children spend large amounts of time with electronic screen media, including television, computers, game consoles, and mobile screen devices. Most children are exposed to media both in the foreground (i.e., as they pay active attention to media) and in the background (i.e., as they are exposed to media passively while other family members use it or as when a television set is left running even when no one is actually watching). Although some children experience relatively little electronic media (e.g., children from religious groups that intentionally avoid popular culture or technology), for most contemporary children the sheer time of exposure means that media constitute one of the greatest potential influences on cognitive development. There has been correspondingly widespread concern about the possible impact of media on brain development, social and emotional development, health, education, and many other outcomes. While, on one hand, school personnel, librarians, and government funders enthusiastically encourage the use of media content thought to be beneficial, on the other hand, writers of popular books for parents and advocacy groups warn of potential negative effects of using media. Special concern has arisen with respect to very young children. In 1999, the American Academy of Pediatrics issued its first of several recommendations against television use for infants under 2 years of age (American Academy of Pediatrics, 1999, 2011).

Much of both enthusiasm and concern has focused on the influence of screen media on cognitive development and academic achievement. Screen media come in two broad forms: first, television and television-like recorded video, and second, interactive screen media. This chapter reviews what is known and not known about the role of screen media in cognitive development.

Scope

In this chapter we focus on screen media. We are not concerned here with purely text-based or audio media. Screen media are available in two broadly different forms depending on whether use of media requires active overt behavior by the user. Television and its variations (including cinema) can be used without operating any controls once the system is switched on. The programming progresses over time whether or not the user is watching, listening, or even present. Ordinarily, the user has no control over the video content other than to change the programming channel or to use functions such as pause and rewind for prerecorded or streaming video. In contrast, interactive media typically require some form of response by the user that in turn determines the particular content that will be subsequently experienced. In other respects, the media share similar screen and audio technology and can overlap in various ways. Many users of media view television or television-like programs on their computers, game consoles, and mobile devices. Many Internet sites and computer games make use of television characters and stories. It is also the case that multiple media may be used at the same time, for example, as TV viewers comment on a television program in real time using mobile text devices.

We are primarily concerned with cognitive processes underlying children's use of screen media and the impact of screen media on cognitive development and education. Except where relevant to cognitive development and education, we do not consider the extensive research and theory that concerns the effects of screen media on social behavior or physical health (e.g., pro- and antisocial behavior, sexual behavior, obesity, physical fitness, sleep). Neuroscience-based research on media and brain function, especially during development, is rare and does not yet constitute a coherent field of research. We discuss neuroscience research only as it relates to specific topics relevant to use of media and cognitive development.

We begin by reviewing some of the popular and historical concerns about media impact on cognitive development. We note that much of the discussion about both positive and negative effects arises from beliefs that cognitive processes that do and do not occur while using media directly affect cognitive development. We then review empirical research on the attention and cognitive processes underlying children's use and comprehension of screen media. With this background we examine what is known about the immediate and longer-term impact of screen media on cognitive development.

POPULAR CONCERNS ABOUT MEDIA IMPACT

Every communication medium used by children has been viewed with hope and concern by social critics and educators, although concerns have been predominant. For example, in the 18th and 19th centuries, reading novels was seen as inducing laxness of thought, moral turpitude in youth, and competition with more intellectually productive activities. These concerns dissipated over time, and today, children are encouraged to read novels. Similar criticisms were raised, successively, about radio, popular recorded music, comic books, movies, television, computer games, and social media. For example, most popular criticisms of children's television viewing have parallel criticisms that were applied 25 years earlier to comic-book reading such as the claim that the medium trains eye-movement behaviors that are inimical to reading (cf. Moody, 1980; Wertham, 1954). The most prominent concerns have been directed at violent, antisocial content in all of these media, with concerns about cognitive development usually raised only after the medium becomes well-established and popular (e.g., Reeves & Wartella, 1985; Wartella & Robb, 2008).

In contrast, especially when they are new, media have been greeted with hope and high expectations for enhancing learning and cognition. Before it became widely adopted, television was seen as holding the potential of being "children's window on the world," and it was frequently identified as something that would raise the national intelligence (Barnouw, 1990). Similar hopes were expressed about the potential cognitive and educational impact of interactive digital media. Successively, schools rapidly adopted television and computers as useful tools in education. Similar enthusiasm is currently being directed at touch-screen tablets. Optimism for interactive educational screen media, such as digital games, has been far-reaching, including directives from the White House and the National Academies of Science (Fenichel & Schweingruber, 2009) and from professional organizations of early childhood educators (National Association for the Education of Young Children & Fred Rogers Center for Early Learning and Children's Media, 2011).

The Media Debate: The Example of *Sesame Street*

In the United States the educational potential of television was explored first by means of a national network of educational television broadcast stations, allowing live or recorded educational programs (usually standard teacher-based "lessons") to be shown in schools as well as in homes. This evolved into the Public Broadcasting System (PBS). PBS was the first television network to broadcast preschool educational programming that was systematically based on a curriculum and modern television production techniques. This was quickly followed by educational programs for older children. The preschool programming, most notably *Sesame Street* and *Mister Rogers' Neighborhood*, was also designed to be entertaining to young children. The combination of education and entertainment soon proved to be controversial.

Sesame Street, first broadcast in 1969, rapidly became popular with young children and their parents. The program has evolved over the decades, but when first broadcast, it consisted of approximately 40 segments averaging about 90 seconds in length. The segments were in a variety of formats, including live-action, animation, slow motion, and pixilation (speeded-up action). Characters ranged from human adults to nonhuman puppets. With its curriculum focused on school readiness skills such as letter and number recognition, most parents and many educators saw it as a positive force in children's lives. Popular commentaries about *Sesame Street* and its cognitive and educational impact on children are similar in many ways to those made about all media used by children, including contemporary digital interactive media. In later sections, we discuss research on *Sesame Street* impact, but for now, we focus on journalistic and opinion commentaries.

Although initial publicity and much continuing commentary surrounding *Sesame Street* was highly favorable, supported by early large-scale research evaluations of the program (Ball & Bogatz, 1970; Bogatz & Ball, 1971), a contrary view rapidly emerged. This view, initially voiced by Dorothy Cohen, a preschool educator (Cohen, 1972), coalesced in the popular book, *The Plug-In Drug* (Winn, 1977). Subsequent books by Mander (1978), Moody (1980), and Healy (1990) continued the drumbeat of alarm about *Sesame Street* in particular and television in general. Each of these books was commercially successful, went through multiple printings, and became part of the national debate about media and children. The books were supplemented by numerous newspaper and magazine articles. None of the books and articles was substantially based on research with children, although all of them cited some research or interviews with researchers.

Unlike prior critiques originating in the 1950s and 1960s that focused on television content as provoking aggressive, antisocial behavior in children, the critiques of *Sesame Street* focused on children's cognition during viewing and the program's presumed effects on cognitive development. Although some of the criticisms were specific to *Sesame Street*, most could be (and still are) applied to television viewing more broadly. The general conclusion from the critiques was that if *Sesame Street* is the best thing television can offer for children, then children should not watch television. More generally, the argument was that television is bad for cognitive development.

The most fundamental argument by critics of educational television was that television viewing is cognitively passive. What cognitive passivity during TV viewing meant to these writers was never well-defined but was often contrasted to reading, which was universally viewed by these writers as being cognitively active. Moody (1980), for example, described child TV-viewers as "mesmerized," "spaced out," "zombie"-like, or "drugged." Television, moreover, taught children to move their eyes in ways contrary to good reading practice. The consequences of watching TV were seen as suppressing cognitive reflection, memory encoding, planning, and connected comprehension of discourse. Because it provides explicit visual images, it was claimed that TV provides no opportunities for the use of imagination or inference, as would be the case during reading. Most of these writers argued that television viewing led to reduced attention spans and hyperactivity. In contemporary cognitive terms, television was seen as interfering with the development of executive function.

The underlying argument in support of these assertions was based on the innovative use by *Sesame Street* of modern, professional techniques for video production. The nearly one-hour program was constructed as a magazine format consisting of approximately 40 content segments, including some as brief as about 10 seconds. Much of the concern emanated from the idea that the program presented too much information too rapidly. The visual and auditory changes, it was argued, elicited an automatic attention reaction without associated active cognition (e.g., J. L. Singer, 1980). In effect, the child viewer of *Sesame Street* was seen as mesmerized, with an essentially blank mind.

Additionally, the argument was frequently made that because *Sesame Street* was entertaining to children during their preschool years, they would expect all learning situations to be equally entertaining. They would therefore be disappointed by school, which could not possibly be as entertaining as a professionally produced television program. Finally, the argument was made that because television is easy to watch and understand, but reading is initially difficult, children would therefore prefer to watch TV rather than read.

On the one hand, during the 1970s and 1980s there were many favorable commentaries about *Sesame Street* and its positive effects on school-readiness skills, and on the other, there were highly charged arguments that the show damaged cognitive development. Nevertheless, the program remained extraordinarily popular with young children and their parents. At the social-policy level, supporters of *Sesame Street* argued that important supplementary education could be provided to millions of children at home at a relatively low cost per learner. This led to the subsequent development of many other educational TV programs (and later, digital interactive content) directed at preschoolers and older children. Conversely, claims about negative effects of viewing *Sesame Street* were broadly applied to viewing television generally. These claims continue today. For example, a website (Buzzle.com, post by Muktar Gaikwad, 2011) listed the following effects of watching television: addiction to the audiovisual, lapse of thinking power, short attention span, and reduced brain development.

In the remainder of this chapter, after we discuss some of the difficulties of research on screen media, we examine contemporary time estimates of children's exposure to screen media. We then consider the cognitive activities that take place while using screen media. In particular, we examine attention to and comprehension of screen media by children. Following the sections on attention and comprehension, we propose several pathways of media influence and then examine research on immediate and longer-term impact of screen media on cognitive development.

PRACTICAL LIMITATIONS ON RESEARCH

There are numerous limitations on the conclusions that can be drawn from research on children and media. Contemporary children use and are exposed to a wide variety of screen media, including television, computers, console and handheld video games, and touch-screen telephones and tablets. Screens range from just a few centimeters to more than a meter in width, subtending a large portion of the visual field. Visual resolution ranges from crude to high-definition and, increasingly, 3D (three-dimensional). Audio ranges from monaural to surround sound. Visual imagery ranges from live-action created with highly sophisticated production techniques to animations that in turn can range from abstract to highly realistic. User interfaces include those that merely afford watching and/or listening to those that take user input from button pushes, voice responses, or movements in space. Content ranges from dry and informative to wildly fanciful.

The early part of the 21st century has seen a rapid evolution of electronic media that continued as this chapter was written. This evolution has occurred not only in the technologies and interfaces used by children, along with their parents and teachers, but also in the types of content and user responses to that content. These rapid changes in media pose difficult problems for researchers and theorists. It is almost impossible to track the impact of media in anything like real time when the media themselves change so rapidly. Research with children takes a great deal of time to conduct, especially longitudinal research that is important for understanding developmental impact. Consequently, many of the most pressing questions about the impact of today's media can only be answered by focusing on the impact of yesterday's media. The heavy emphasis in this chapter is on television because it remains the most-used medium by children and may therefore have the greatest influence. Moreover, the empirical literature on television remains more coherent, with more defensible working conclusions, than is the widely scattered empirical literature on the interactive screen media.

The research on television is more coherent due in part to television being an older medium, entering American homes beginning in 1948. While television has technologically evolved from its early days, the changes are not nearly as dramatic and rapid as have been the changes in digital interactive technologies, which began to enter homes and schools in the 1980s. As a consequence, one can be more confident about generalizing from research done with television 40 years ago than one can be about generalizing from research done with interactive screen media 20 years ago. While we emphasize research on television, we also describe research on varying forms of interactive media when it is possible to draw generalizable conclusions.

We first consider amount of exposure to screen media by children and then review what is known about the developmental and cognitive processes underlying this exposure. We then begin consideration of developmental impact of media by examining various pathways of potential influence on development. In the light of those pathways of influence we examine what is known from empirical research.

CHILDREN'S TIME SPENT USING MEDIA

A vast amount of research asks the question, usually of parents, about how much television a child watches (per day or week). Similar questions are asked about use of other media. The answer to the question then becomes the independent variable in many studies of media impact. Although in common use, this type of question presents serious problems of interpretation. For example, the term *watch television* is almost never defined for the parent. A parent could interpret it as meaning time spent in the room with a TV set in use, time spent actually looking at the screen, time spent paying sustained attention (based on a parent's judgment), or something else, such as time the child spent with favorite programs. The failure to define what is meant by *watching television* has important consequences for interpreting research findings. Similarly, interactive media can be used by children in a variety of ways, including simultaneous use of multiple media or multiple sources of content within the same medium. Variability in time estimates due to definitional confusion is likely to contribute to a large amount of error, especially with respect to particular hypotheses about the pathways of impact (Salomon & Cohen, 1978). For example, a parent may not count the child's presence during a sports program as time spent watching television because the father chose the program and because the child paid only sporadic attention to it. Another parent might well count it.

Simple time estimates, moreover, ignore program content. An hour of an adult-directed horror movie, for purposes of analysis, is considered equivalent to an hour of an age-appropriate educational program. An hour of web surfing would be considered equivalent to an hour of story creation on a fan-fiction website. The underlying assumption behind time as an independent variable is that use of media is an undifferentiated experience. Statistical analyses that use this approach, therefore, adopt a dose–response logic common in medical research as in investigations of the association between amount of television viewing and school achievement. This type of analysis ignores the important effects of content. This is particularly problematic given that some studies find that total media time is confounded with content consumed (i.e., the more television children watch, the more likely they are to watch violent or otherwise age-inappropriate content; Fetler, 1984).

By analogy, consider a program of research on nutrition. For most health-related purposes, it would be considered laughable to measure food intake by weight only, as if a kilogram of doughnuts were equivalent to a kilogram of carrots. It is far more informative to consider *diet* both in nutrition and media (D. R. Anderson & Hanson, 2009). Unfortunately, the amount of research that actually examines children's media diet by categories of content is quite limited. Research that takes media diet into account typically employs media diaries. These divide the day into blocks of time that contain spaces for several items of information, including type of media and name of program. Respondents (usually parents if the children are young or the children themselves if they are literate) fill out the diaries on a daily basis. Some time-use research has respondents recall use of media from the day prior. Other research simply asks parents to identify frequently watched programs from lists provided by the researchers. Media diaries have been largely limited to television viewing.

An additional problem in estimating children's use of media is that the most thorough-going research using nationally representative panels is done for commercial purposes by companies such as Nielsen Media Research. The data are proprietary and are not routinely open to academic analysis or methodological critique. Academic estimates of media exposure commonly depend, therefore, on a small handful of time-use studies and media surveys conducted by universities or charitable foundations. Estimates from countries other than the United States use a wide variety of methodologies and are conducted by a wide variety of organizations.

With respect to television, estimates of American children's total exposure vary with age and socioeconomic status as well as race/ethnicity. Not surprisingly, they also vary with season of the year and day of the week. Generally speaking, TV use increases with age during the preschool years, reaching its peak from about age 4 to 11 years, and declining during the adolescent years. Children from lower-income families as well as African American and Latino American minority groups watch more television than do children from European American families and from affluent homes. Use of interactive media steadily increases from very low levels during infancy to relatively high levels during early adolescence. At all ages there are great individual differences in reported use of media, with some children spending little or no time with media and others watching TV and using interactive media more than 60 hours per week (for reviews and examples of these studies, see Comstock & Paik, 1991; Neuman, 1995; Rideout, 2011, 2013; Rideout, Foehr & Roberts, 2010; Rideout & Hamel, 2006).

Not surprisingly, given different measurement methodologies and different sampling strategies, specific numbers for children's exposure to media vary considerably across studies. The following numbers for children aged 8 years and younger are taken from a national telephone survey conducted during May and June of 2013 by Common Sense Media (Rideout, 2013). The television set remains the dominant platform for media consumption, accounting for half of children's time with screen media; their remaining screen media time is spent using DVD players (19%), mobile devices such as tablets and smartphones (13%), computers (10%), and video-game players (handheld and console, 9%). While television remains the dominant platform for media consumption, there has been a rapid increase in young children's use of interactive, mobile devices, especially in affluent families. For example, 72% of children 8 years and younger in the 2013 survey had at least sometimes used a mobile device, compared to only 38% of children just 2 years earlier (Rideout, 2011). Children have access to Internet-enabled mobile devices (e.g., smartphones, tablets) in 61% of homes earning less than $30,000 annually, 73% of homes earning between $30,000 and $75,000 annually, and 91% of homes earning more than $75,000 annually (Rideout, 2013).

Despite this increase in access to mobile devices, there has been little indication that time spent with interactive screen devices (including computers, game consoles, and mobile screen devices) has displaced time with TV and recorded videos. Rather, the time spent with interactive screen media appears to occur in addition to time spent with TV. Moreover, interactive screen devices (e.g., computers, tablets) are often used to view television content and other recorded video, thus there has been a great shift in the devices that children use to view television content, not a substantial decrease in viewing. In a "typical day" children 8 years and younger spent more than threefold as much time with TV and recorded videos (on any device) than with interactive digital media (Rideout, 2013). This is approximately the same ratio as was found 2 years earlier (Rideout, 2011). Nonetheless, there is some evidence to suggest that television viewing may be starting to decline, particularly for the older children in these samples. Among 5- to 8-year-olds, interactive media constituted 35% of all screen media exposure in 2013, compared to only 28% in 2011.

Consistent with all previous national surveys, Rideout (2013) reported that children from lower-income families and racial/ethnic minorities engaged in greater total exposure to media (especially television) than affluent and European American children. Poorer children (family income less than $30,000) watched television for an average 67 minutes per day, whereas more affluent children (family income greater than $75,000) watched television for an average 46 minutes per day. With respect to race and ethnicity, African American children watched television for 77 minutes per day, Latino American children watched for 66 minutes per day, and European American children watched for 53 minutes per day. With respect to educational program content, most children experienced it from television, especially so for less affluent children. Relatively affluent children tended to use more educational game content with interactive digital devices than did less affluent children.

Daily use of media also increases with age (Rideout, 2013). For instance, in a typical day TV viewing occurred for 31% of children younger than 2 years of age, 67% of the 2- through 4-year-olds, and 64% of the 4- through 8-year-olds. The amount of time with media also increases with age, starting at 58 minutes in a typical day for children younger than 2 years of age and increasing to 98 minutes per day for 2- to 4-year-olds and 92 minutes for 5- to 8-year-olds. In contrast, smaller percentages of children used computers, console games, or mobile devices on a typical day, although there is enormous growth with age in using these media. Children used interactive screen media for only 2 minutes per day on average during the first 2 years of life, 20 minutes per day between 2 and 4 years of age, and 49 minutes per day between 5 and 8 years of age. While the use of interactive screen devices increases with age, television and recorded video remain the dominant media both in terms of cumulative time and frequency of use.

For children older than 8 years, use of media continues at high levels with steadily increasing usage of interactive digital media along with continued high levels of TV viewing, according to another large, national telephone survey (Rideout et al., 2010). From 8 to 18 years of age, TV remained the dominant medium, averaging 227 minutes a day, whereas interactive media averaged 53 minutes. It should be noted that the Rideout et al. (2010) report was based on data collected in 2009, a time when use of mobile media was greatly increasing among older children and adolescents. Thus current time with interactive screen media may be substantially higher than that reported in the most recent surveys. Age differences in middle childhood and adolescence are not nearly as pronounced as the shift from infancy through the early elementary school years. For 8- through 10-year-olds, TV was used 221 minutes in a typical day, whereas interactive media were used 107 minutes. For 11- through 14-year-olds, the numbers were 303 minutes per day for TV and 191 minutes for interactive media. For 15- through 18-year-olds, the figures were 262 minutes for TV and 167 minutes for interactive media. Note that these numbers are substantially greater than those for children younger than 8 years of age. These numbers do not consider the use of audio media that are quite popular with older children. For example, 15- through 18-year-olds reportedly used audio media more than 3 hours per day.

To summarize, use of electronic media increases with age, peaking in early adolescence. The proportion of media that is interactive also increases with age, representing less than 5% of all exposure to screen media before 2 years of age but more than 35% of exposure to screen media after

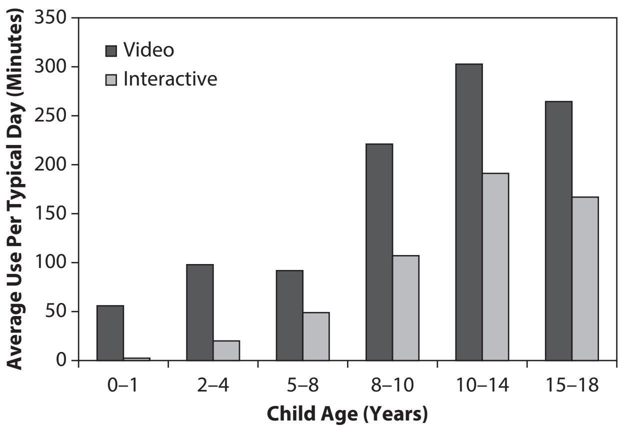

Figure 22.1 Average minutes spent viewing video (on any device) and using interactive media (websites, video games, etc.) in a typical day as a function of age.

Source: Created from data in Rideout (2013) and Rideout et al. (2010).

11 years of age. While the media landscape is beginning to shift with the proliferation of mobile devices, television viewing (including recorded video) remains predominant at all ages (see Figure 22.1).

Media surveys such as those just described do not typically characterize the content children are viewing or interacting with. Television use may include anything that is telecast or recorded on video. Use of interactive media may include games, exercise programs, shopping, homework assignments, social media, e-mail, or anything else that can be presented on interactive screen devices. All we can know from these surveys is that American children consume a great deal of television and interactive media. Especially with respect to available public domain surveys of exposure to interactive media, researchers know almost nothing about children's media diet. This, of course, does not apply to media and advertising companies where a vast amount of proprietary information that concerns children's media diets is available.

Media Multitasking

A relatively recent trend in use of media—and one that has sparked notable concern—is simultaneous use of different media, often referred to as media multitasking. Rideout et al. (2010) reported that youth between 8 and 18 years of age spend approximately 7.5 hours per day consuming media, but about 29% of that time is spent in media multitasking (e.g., listening to music while browsing the Internet, watching television while playing a handheld game). Younger children also engage in media multitasking, with 23% of 5- to 8-year-olds engaging in media multitasking "some" or "most" of time that they are using media (Rideout, 2011).

When comparing survey data from 1999 to 2009, it is clear that children's time spent using individual forms of media as well as time spent multitasking have increased substantially (Rideout et al., 2010). In 1999, children 8 to 18 years of age used media for an average 6 hr 19 min per day and multitasked for 16% of that time (producing 7 hr 29 min of total media exposure per day); 10 years later in 2009, children in the same age range reported 7 hr 38 min of media per day on average, with 29% of that time spent multitasking (producing 10 hr 45 min of total media exposure per day). The dramatic increases in both overall media consumption and multitasking are due at least in part to the increase in mobile media, making it increasingly easy to do two activities at once (e.g., surf the web while watching TV). Children and youth with relatively unsupervised access to technology (e.g., with a TV or computer in their bedrooms or with their own cell phones) consume more media generally and are more likely to be media multitaskers.

Although time-shared use of multiple electronic media is a relatively new phenomenon, time-shared activities during television use is not. Analysis of time-lapse videotapes recorded in homes during the early 1980s over 10-day periods revealed that time-shared activities were quite common at all ages (Schmitt, Woolf, & Anderson, 2003). As examples, 2-year-olds spent 61% of their time with TV engaged in other activities such as socializing (39%), playing (32%), and eating (8%). These time-shared activities decreased with age until 12 years old, in part because attention to the TV was greater among older children (as described later). Twelve-year-olds, who time-shared TV viewing the least, spent 38% of their TV time engaged in other activities, including socializing (20%), playing (9%), eating (9%), and reading or writing (8.5%). The latter category probably represents doing homework while watching TV. Adult viewers from these families similarly engaged in other activities while with TV, including socializing (17%), playing (1%), eating (6%), reading and writing (16%), and doing chores (9%).

CHILDREN'S COGNITION WHILE USING MEDIA

When children use screen media, they deploy a variety of cognitive capacities and skills, including attention, memory, comprehension, spatial cognition, and theory of mind, among others. An important part of understanding how to make effective media for children, as well as understanding its impact, involves a cognitive analysis of how children actually use media. Here we describe attention to screen media and cognitive processing of media content.

Attention to Media

It has long been understood that "attention" is not a unitary concept but includes multiple kinds of overt and covert perceptual, cognitive, and neural activities (W. James, 1890). With respect to audiovisual screen media, attention includes behavioral orienting toward the screen, eye fixations directed at selected portions of the screen, and listening at a level of comprehension. Attention may also be more or less selective and intensive, with greater processing activities directed toward some portions of the content as it is experienced through time than others. Attention to interactive media may also include behavioral exploration such as using a mouse during Internet navigation, as well as tactile and kinetic forms of attention when vibratory and accelerometer stimulation is part of the interactive interface.

Most research on children's attention to media has been directed at television viewing. Because the interactive media generally have an audiovisual component, including screen and sound system, findings from studies of attention to television presumably have broad applicability to interactive media. Most of the research focuses on visual attention. By comparison, there is little research on auditory attention to television and almost no research on attention to other aspects of interactive media.

Behaviorally, attention to TV, and presumably the interactive media, is episodic with the episodes containing a hierarchical structure. As reviewed in the next subsection, when a TV set is in use, children may exit and reenter the viewing area multiple times during a program; when they are in the viewing area they may look at and away from the TV screen repeatedly; while they are looking, they scan different portions of the screen; and while looking they may attend with greater and lesser intensity. Less is known about auditory attention, but the evidence indicates that it is also episodic. This hierarchical structure of attention found with television is presumably applicable to interactive media—users may leave the media area and return (or temporarily stop using a mobile device), look at and away from the screen, scan different portions of the screen, and attend or listen with greater or lesser intensity.

Exiting and Entering During TV Viewing

Observers of family television viewing at home have long noted that viewers frequently get up and leave the viewing area for brief periods of time (e.g., C. Allen, 1965). This probably happens because viewers get something to eat, go to the bathroom, or do a variety of other mundane activities. Based on time-lapse video recordings of families at home, D. R. Anderson (1987) reported that adults left the room 5.4 times per hour of TV program and 7.2 times per hour of commercial. P. A. Collins (1992) analyzed a subset of the video recordings and found that from age 2 years and older, children exited the viewing area less frequently during programs than during commercials and generally more frequently than adults. For example, 11-year-olds exited 7.2 times per hour of program and 16.2 times per hour of commercials. The arithmetic mean time in the room before leaving is thus about 8.3 minutes during a program, whereas it is only about 3.2 minutes during commercials. The typical time away from the viewing area (if the viewer returned during that period of TV use) was about 90 seconds. Families are often busy and on the move—a child may dash into the room, briefly watch the TV, and dash out again. Average figures are therefore somewhat misleading because the distribution of times in the viewing room is positively skewed. While there are periods of viewing of up to several hours without exiting, these lengthy episodes are infrequent, whereas relatively brief times in the viewing area are most common. Cumulatively, however, most viewing occurs during sessions 15 minutes or more in duration. As these data were collected during the 1980s, it is not known whether or how these phenomena may have changed with increased remote control use and media multitasking. Nevertheless, it is likely that use of media remains episodic in much the same way.

Looks at the Screen and Attentional Inertia

In contrast to the popular image of viewers mesmerized by TV, viewers in fact visually orient toward and away from the screen. Periods of visual orientation toward the screen are referred to as *looks* in the research literature. Although there is great variability, average look lengths are about 15 seconds with about 150 looks per hour (e.g., D. R. Anderson, 1987; D. R. Anderson & Levin, 1976; Burns & Anderson, 1993). Look lengths are distributed as lognormal so that brief looks of about 1 second in duration are most typical (geometric mean is about 3 to 6 seconds), but some relatively infrequent looks may last 10 minutes or more (Richards & Anderson, 2004).

An interesting property of looking at television, called *attentional inertia*, underlies the lognormal distribution of look lengths. Attentional inertia refers to the empirical finding that the longer a look at the TV has already been in progress, the less likely it is to terminate (Anderson, Alwitt, Lorch & Levin, 1979). This can be expressed as a hazard function (i.e., the conditional probability that looks terminate in each successive interval of time as a function of time that they have already been in progress). The hazard function for looking at television rises to an early peak at about one second in duration and then steadily declines (Burns & Anderson, 1993). This general form of hazard function has been found for television viewers ranging from infants less than a year old through adults and with a wide range of content as noted later (Richards & Anderson, 2004).

Experimental studies are consistent with the hypothesis that TV viewers become progressively more engaged as looks are sustained. The longer looks have been continuously sustained, the less effective external distractors become in terminating looking at the screen (Anderson, Choi, & Lorch, 1987; Richards & Turner, 2001). When the distractor is successful in terminating a look at the TV screen, moreover, latency of head turns increases with the length of time the look at TV had been sustained (Anderson et al., 1987). Together these findings suggest that as attention to the screen is sustained, both selective attention to the screen and inhibition of other stimuli increase. Attentional engagement in infants, as indexed by heart rate, becomes greater the longer looks at TV are sustained (Richards & Cronise, 2000; Richards & Gibson, 1997; Richards & Turner, 2001). In older preschool children, greater engagement with increased look lengths is indexed by greater reaction times to a secondary task (Lorch & Castle, 1997). Again, these findings are consistent with increased selective attention to the screen and inhibition of other stimuli as attention to the screen is sustained.

The longer viewers have sustained looks prior to content boundaries (i.e., a complete change in content as from a program to a commercial), the longer they continue to look at the new content (Anderson & Lorch, 1983; Burns & Anderson, 1993; Hawkins, Tapper, Bruce, & Pingree, 1995; Hawkins, Yong-Ho, & Pingree, 1991). This indicates that engagement due to attentional inertia is not specific to the content being viewed insofar as it is not completely "reset" by encountering different content. Comprehension does not appear to be a necessary requirement for attentional inertia, although it is surely a contributor. Attentional inertia is observed in infants' looking at a children's movie as young as 3 months of age (Richards & Gibson, 1997); such infants are unlikely to comprehend the movie in any ordinary manner. Attentional inertia is also found in attention to dynamically changing abstract sounds and visual images that have little temporal structure and nothing obvious to comprehend (Richards & Cronise, 2000). It is found when normal video is rendered difficult to comprehend by randomly ordering shots, using foreign language, and reversing speech. Although these manipulations reduce overall attention to the screen, primarily by reducing the frequency of long looks, the overall finding of attentional inertia to these relatively incomprehensible video stimuli remains (Richards & Anderson, 2004).

Taken together, these findings suggest "sustained attention builds upon itself, producing deepened engagement with whatever stimulation is provided by the TV" (Richards & Anderson, 2004, p. 171). Consistent with this interpretation, as a look at TV progresses through time, information processing of the TV content is enhanced. Burns and Anderson (1993) showed college students 2 hours of primetime television programs and associated commercials. From videotapes of the viewers, the researchers coded the exact video frame during which each look at the screen began and ended; they thus had a complete record of looking. Subsequent to viewing the students were shown 4-second audiovisual snippets taken either from the episodes and commercials that were actually presented or from other episodes in the series and commercials not seen. The question was whether recognition memory was related to how long the student had been continuously looking prior to the point the snippet was taken. If attentional inertia involves deepened engagement and information processing, then recognition memory should be positively related to prior look length. The study found increased recognition memory of both auditory and visual content encountered during long looks (greater than 15 seconds) than during shorter looks or in the early part of long looks. Using a similar methodology, Lorch et al. (2004), studying 7- to 11-year-old boys diagnosed with attention-deficit/hyperactivity disorder, found that narrative deficits ordinarily found in such children were reduced during portions of the program receiving long looks.

Attentional inertia is not uniquely a property of television viewing. It has also been reported for preschoolers' toy play, insofar as the lengths of episodes of active toy play (from the time the child touches the toy until active play and visual regard terminate) are lognormally distributed. Analogous to looking at television, as play episodes become longer, children become less distractible (H. Choi & Anderson, 1991) and attention becomes more focused both behaviorally (Oakes, Ross-Sheehy, & Kannass, 2004) and physiologically as measured by heart rate (Lansink & Richards, 1997). We revisit this topic when we discuss processing of media content later in this section.

There have been no studies of whether attentional inertia occurs while using interactive media; however, it may be analogous (or at least related) to the concept of *flow* that has been applied to use of media, including video viewing and digital-game play (Sherry, 2004). While in a state of flow, individuals are said to lose awareness of their surroundings as they become increasingly engaged in and intensely focused on their primary task. In essence, flow state allows an individual to selectively focus on the primary task while inhibiting other stimuli (Sherry, 2004). William James (1890), in his classic chapter on attention, made similar arguments about effortless attention that he labeled "passive intellectual attention." The connection to information processing may differ across these approaches: While attentional inertia has been conceived as localized in time to single episodes of attention, it has also been seen as facilitative of more in-depth processing (and thus greater learning). In contrast, flow state goes beyond single episodes of attention and is applied to the course of an entire episode with media or other activity. Flow may facilitate information processing via increased motivation due to the intrinsically rewarding experience of flow state. Others have also noted the importance of cognitive engagement for video-game-based learning, particularly when paired with motivational factors. For example, Deater-Deckard, Chang, and Evans (2013) developed a theoretical model of game-based learning that incorporates cognitive, behavioral, and affective engagement.

Content, Comprehensibility, and Age Trends in Looking

There are clear age trends in looking at television. The most extensive investigation of looking at television is based on time-lapse video recordings of television use in homes by 99 families over 10-day periods (D. R. Anderson, Lorch, Collins, Field, & Nathan, 1986). The recordings were made during 1980 and 1981. Across all types of content, looking increased from low levels during infancy to a peak at 11 years, declining somewhat among adults. The only gender difference was among adult viewers wherein men looked at the TV more than did women. Laboratory studies employing child-directed content have also generally found that looking increases from infancy to the early elementary school years (e.g., Alwitt, Anderson, Lorch, & Levin, 1980; D. R. Anderson & Levin, 1976; Field & Anderson, 1985). The laboratory studies indicated that the lengths as well as frequency of looks at the TV increased with age, accounting for the overall increase in percentage of time with TV that was spent looking at the screen.

The principal hypothesis accounting for this increase with age in looking at TV concerns children's comprehension of the content. Lorch, Anderson, and Levin (1979) suggested that comprehension processes drive looking at TV. They proposed that children rapidly determine whether the content is comprehensible to them and stop looking if they judge the content incomprehensible or difficult to understand. They also hypothesized that children monitor the audio when they are not looking at the screen, initiating looking when auditory cues indicate comprehensible (and interesting) content.

The comprehensibility hypothesis was tested by D. R. Anderson, Lorch, Field, and Sanders (1981). In their first study, they focused on the language used in *Sesame Street*. They reasoned that if the referent of an utterance was not immediate, that is, referred to events, objects, or concepts that were not concretely present on screen, then looking would be less by preschool children than if the utterances had concrete, immediate referents. They examined 3- and 5-year-olds' looking at 15 different episodes of *Sesame Street* in which each utterance was coded for immediacy of referent. Children at both ages looked more at the screen during utterances with immediate referents than during utterances with nonimmediate referents. The results were thus consistent with the hypothesis that children's looking at TV is driven in part by comprehensibility of content.

In a second study, D. R. Anderson, Lorch, Field, et al. (1981) experimentally manipulated comprehensibility of *Sesame Street* in three ways: (1) by editing shots so that they occurred in random order; (2) by reversing the dialogue so that each utterance was backward but occupied the same video frames (thus retaining the general voice quality of the speaker); or (3) by using foreign language (Greek) versions of segments. The research employed an experimental design that allowed comparisons of children's looking at each segment type within themselves (within-subject analyses) as well as with other children (between-subject analyses). Compared to normal versions of the same segments, reducing comprehensibility produced lower amounts of looking by 24-, 42-, and 60-month-old children. The language distortions produced the biggest reductions in visual attention, indicating that by 24 months of age, the comprehensibility of the audio is an important determinant of looking at the screen. Taken together, the results show that children as young as 24 months of age were sensitive to the linguistic and sequential comprehensibility of video.

The cognitive and language skills required to comprehend edited and narrated video appear to develop during the 2nd year of life. Pempek et al. (2010) presented infants the program *Teletubbies*, which was originally a British program created for 1- to 3-year-old viewers. Using standard video-editing techniques, the program delivers simple stories of four chubby, nonhuman characters (full-body puppets) who live in a grassy fantasy world. The experiment replicated the D. R. Anderson, Lorch, Field, et al. (1981) study with younger children: In this experiment, 6-, 12-, 18-, and 24-month-old infants watched either normal segments of *Teletubbies* or segments that were rendered less comprehensible by reversing utterances or reediting shots in a random sequence. Six- and 12-month-olds did not discriminate between comprehensible and incomprehensible segments, either by physiological (heart rate) or behavioral (look length) measures of attention. Beginning at 18 months, and greatly increasing by 24 months, infants looked for longer periods of time when video was comprehensible. Similar findings have been reported using comprehensible movie clips versus audiovisual displays that lack comprehensible content (Richards & Cronise, 2000). Importantly, these experiments did not affect formal features (such as visual movement, cuts, and sound effects) that are known to influence attention, thus any reduction in attention can be attributed to the lack of comprehensibility rather than any change in formal feature density.

Given that comprehensibility is a determinant of looking at TV, it is not surprising that content is also a major determinant. Schmitt, Anderson, and Collins (1999), in analyzing time-lapse videotapes recorded in the homes of 50 families, found that 2- and 5-year-old children looked far more at children's programs than at adult-directed programs, a difference of about 30 percentage points. This large difference in favor of children's programs declined by 8 years of age, with a 13-percentage point difference, and approached parity by 12 years of age. Adults biased their looking in favor of adult-directed programs, as compared to children's programs, by 22 percentage points. Thus, as one might expect, TV viewers look most at programs that are appropriately age directed. With respect to programs versus commercials, Schmitt et al. (2003) reported that although 2-year-olds looked equivalently to both types of content, 5-year-olds, 8-year-olds, and 12-year-olds looked more at programs than commercials. Once children are able to comprehend television, content is the major determinant of their overall attention to the screen.

Individual interest and self-identification play a role in looking at TV. Although there are no overall gender differences in looking at television, gender differences emerge in selective attention to televised characters. Two studies have focused on children before or after achieving gender constancy. Gender constancy, achieved roughly between 5 and 7 years of age, is the awareness that one's own gender as well as other people's gender is permanent (Kohlberg, 1966). In an analysis of time-lapse videotapes recorded in homes of 24 five-year-old children over 10 days who either had or had not achieved gender constancy (12 of each), the children who had not attained gender constancy (both boys and girls) looked more at the screen during the presence of female characters rather than male characters. This was true regardless of whether the characters were adults, children, animations, or puppets. The children who had attained gender constancy, however, biased their looking toward characters the same gender as their own, again regardless of character type (Luecke-Aleksa, Anderson, Collins, & Schmitt, 1995). Slaby and Frey (1975) found the same result in an experiment using films: Upon achieving gender constancy, boys biased their attention to the adult male character, whereas girls biased their attention to the adult female character. As discussed in the next subsection, child viewers look more at children, animated characters, and puppets than they do at adult characters; within a given character type, however, gender-constant children bias their looking to the same-sex gender. Gender is just one of several factors about characters that determine looking. Unfortunately, there have not been individual difference studies of attention to child media using attributes other than age, gender, and gender constancy. We do not know, for example, whether children bias their looking at same-race characters or at what age they begin to do so (if they do). The major point here is that content, in terms of its meaning to the individual viewer, as well as its overall comprehensibility, is a major determinant of looking at TV. TV viewers tend not to sustain looking at program content that is incomprehensible or uninteresting to them as individuals.

Although several scholars have noted the importance of attention and engagement for learning from digital games (e.g., Deater-Deckard et al., 2013; Sherry, 2013), empirical quantitative explorations of visual attention to interactive screen media are lacking. Nonetheless, it stands to reason that children's motivation to play digital games is at least partly a function of task difficulty and therefore comprehensibility. In particular, it has been claimed that children will be most drawn to games that are challenging enough to overcome boredom but not so challenging as to induce frustration (Sherry, 2004).

Formal Features

Audiovisual media programming can be described as consisting of both form and content. On television, for example, content consists primarily of messages or meanings conveyed through actions and dialogue—what the programming is about. *Formal features* are attributes of audiovisual programming that can be described without appealing to particular content. Examples of visual formal features are production and editing techniques such as format (e.g., live-action versus animation), cuts, wipes, dissolves, zooms, pans, and others. Auditory formal features include musical underscores, voiceovers, auditory special effects, and the like. Other features may contain aspects of content, such as character type (man, woman, child, puppet), voice quality (male, female, peculiar), pacing (frequency of formal features), and movement. The distinction between form and content should not be overstated; form is employed by producers in particular ways to convey aspects of content. To some extent, formal features are part of the content insofar as certain features are often associated with certain content (e.g., animation in child-directed programming).

Huston and Wright (1983) theorized that formal features play an important role in the development of television viewing. Initially, during infancy, perceptually salient features elicit and maintain attention through processes such as the orienting response. With cognitive maturation and experience with media, however, children come to recognize that formal features play important roles in conveying content. For example, infants may respond to transitions between shots, conveyed by cuts, in the same way they would respond to any sudden visual change (i.e., briefly orienting toward the change). As they become more experienced with television and other similar media, however, children become increasingly aware that shot transitions convey meaning. Rather than responding with reflexive orienting, they initiate and maintain attention in order to process the conceptual relation between the shots. A similar theory was proposed by D. R. Anderson and Lorch (1983), who argued that, with experience, children come to learn that certain formal features are associated with comprehensible and entertaining content.

Empirical studies have found that a variety of formal features are associated with looking at television by children. Such visual features include rapid movement, cuts, pans, visual special effects (such as speeded up movement), animation, puppets, and child characters. Positive auditory features include sound effects, child voices, peculiar voices (e.g., Bugs Bunny), lively music, and auditory transitions generally (as from one speaker to a distinctively different speaker). Only a few features have been found to be consistently associated with reduced looking by children. These include lack of movement, adult male characters, men's voices, and extended zooms (Alwitt et al., 1980; D. R. Anderson & Levin, 1976; Calvert, Huston, Watkins, & Wright, 1982; Demers, Pempek, Kirkorian, Anderson, & Calvert, 2010; Gola, Kirkorian, Perez, Anderson, & Calvert, 2011; Levin & Anderson, 1976; Schmitt et al., 1999; Susman, 1978). As described earlier, some gender-related features, such as adult men on the screen, are less negative for boys than for girls (D. R. Anderson & Levin, 1976; Schmitt et al., 1999).

When age trends are examined across the various studies, there are no dramatic discontinuities in the association between formal features and looking. Many of the associations hold at 6 months of age (Gola et al., 2011), although some effects become larger with age, such as enhanced looking to animation, depressed looking at adult men, and greater looking during women's voices (Gola et al., 2011; Levin & Anderson, 1976). It should be understood that analyses of the associations between looking and formal features are bound to the context of content. For example, adult-directed content on television has historically been heavily dominated by adult men both visually and auditorily (e.g., Gunter, 1986). In an analysis of television as experienced by children at home, Schmitt et al. (1999) found that during adult-directed programming men were present on the screen 55% of the time, whereas women were present only 29% of the time. During child-directed programming, in contrast, men were present 13% of the time (women 6%; the remainder of characters were children, puppets, or animations). Child viewers therefore experience an association between adult male characters and content they likely find difficult to understand and in other respects uninteresting to them.

Overall, the findings are consistent with the interpretation that many formal features influence looking by alerting inattentive viewers to changes in screen content. When those content changes signal potentially entertaining and comprehensible content, attention is sustained (e.g., puppets, child voices, peculiar voices, rapid movement). Conversely, attention is lost if those features signal content that is less entertaining, incomprehensible, or adult oriented (e.g., men, men's voices, slow or infrequent movement).

Even when content is held constant, however, children are likely to look more when the content has been produced with formal features and pacing typical of children's programming. T. A. Campbell, Wright, and Huston (1987) produced experimental public service announcements in manners consistent with adult or child programming; in other respects, the content was similar. Children paid substantially more attention to the segments that were produced in typical child formats even when the content was difficult to comprehend. This and other findings (Huston, Greer, Wright, Welch, & Ross, 1984) suggest that children pay attention to programming produced in a manner that suggests it has been made for them. Thus appropriately age-directed formal features, along with content comprehensibility, are important factors in gaining and sustaining child attention.

Much of the research on formal features indicates that children learn that particular features on television predict child-directed and comprehensible content. This learning applies not only to television in general, but also to specific programs within a series. Preschool children unfamiliar with the educational program *Blue's Clues* were shown the same episode on 5 consecutive days. *Blue's Clues* is a mixed-format preschool program featuring a live-action character (a young man) who lives in an animated world. At the time of the research, the program was novel in design insofar as it invited frequent audience participation (answering questions posed by the host of the show, pointing to objects on screen, etc.). Looking during specific educational portions of the content increased over the first three showings, and audience participation increased across the five viewing sessions (Crawley, Anderson, Wilder, Williams, & Santomero, 1999). Changes in attention and audience participation also applied to the series as a whole. Crawley et al. (2002) showed a new episode of the program to preschoolers who were familiar with the series and to preschoolers who had never previously seen the program. Prior experience viewing the series produced systematic differences in patterns of looking as well as audience participation, but only to elements of the content that recurred across episodes. These studies show that children adapt their patterns of attention and audience participation as they become familiar with a new series.

Environmental Factors

Not surprisingly, the environment in which a medium is used influences the amount of attention to the medium. For example, the presence of toys or other children in the viewing environment have been shown to reduce preschoolers' looking at *Sesame Street* compared to viewing the same program alone and without toys (D. R. Anderson, Lorch, Smith, Bradford, & Levin, 1981; Lorch et al., 1979). The presence of other viewers provides social cues as to when to look at and away from the screen. Specifically, preschoolers were substantially more likely to initiate or terminate a look at the screen within a 3-second period following a coviewing peer's look initiation or termination (D. R. Anderson, Lorch, Smith, et al., 1981). Similarly, 1-year-olds followed their parents' look initiations at infant-directed videos (Demers, Hanson, Kirkorian, Pempek, & Anderson, 2013). Moreover, when infants followed their parents' looks at the screen the looks were longer than if the looks were spontaneous and unrelated to their parents' looking. In these studies, analyses corrected for the common influence of the videos on coviewers, indicating that the effect is social, not just a matter of both viewers responding at the same time to the same program features. With respect to interactive media, detailed quantitative studies regarding context and interactive screen media are lacking, although there is a growing qualitative literature on the nature of social interactions during game play. Moreover, digital games (both online and otherwise) afford the opportunity for extensive social interaction and collaborative problem solving with others who may not be physically present (Gee, 2007).

Eye Movements and Fixations on the Screen

Eye tracking is an increasingly common method for studying visual attention and online cognitive processing. Although the focus of a child's attention is sometimes dissociated from overt fixation, this rarely happens under natural viewing conditions (see Henderson, 2003). Eye-tracking technology has advanced substantially, making it possible to record eye movements in infants and young children without requiring head restraint. That said, there are relatively few studies of eye movements during dynamic scene viewing (either video or real-world environments), and the vast majority of research that does exist is limited to adult populations. Nonetheless, research provides a consistent and informative set of conclusions regarding online processing of video content.

Several studies have explored the types of stimulus features that draw visual attention to both static and dynamic scenes. These studies indicate that adults' visual attention is at least partly driven by perceptual salience, such as edges and contrast (Itti & Koch, 2000; Mannan, Ruddock, & Wooding, 1996, 1997; Parkhurst & Neibur, 2003; Reinagel & Zador, 1999). In the case of dynamic stimuli like video, movement is a particularly strong predictor of visual fixation (Mital, Smith, Hill, & Henderson, 2010). Additionally, audio information conveyed through the soundtrack may have a unique impact on eye movement patterns during video viewing (Coutrot, Guyader, Ionescu, & Caplier, 2012).

While these bottom-up, stimulus-driven processes guide eye movements, there is also evidence that top-down, goal-driven processes also guide visual fixation. For example, adults are likely to fixate objects in static scenes (even when those objects are relatively nonsalient), and objects found in semantically congruous contexts (e.g., tractor on a farm) receive shorter fixations than do objects in semantically incongruous contexts (e.g., octopus on a farm; De Graef, Christiaens, & d'Ydewalle, 1990; Friedman, 1979; Henderson, Weeks, & Hollingworth, 1999; Loftus & Mackworth, 1978). Moreover, fixations to dynamic scenes differ by task demands. For instance, adult participants exhibit different patterns of fixation to static images depending on whether they are instructed to explore (i.e., memorize the image in great detail) or to search (i.e., seek out specific objects in the scene; Henderson et al., 1999). When performing a familiar activity (e.g., making tea), adults' fixations to salient objects in the room are relatively infrequent whereas fixations to task-relevant objects are most common (Land, Mennie, & Rusted, 1999; Hayhoe, Shrivastava, Mruczek, & Pelz, 2003). Thus it is reasonable to assume that visual attention patterns to a screen may be quite different during TV viewing, web browsing, and video-game play, given that the task demands may differ substantially across these activities.

We know of only two studies of adults' eye movements while playing video games. They found that game players devote more covert attention to areas with high visual saliency (Jie & Clark, 2008; Seif El-Nasr & Yan, 2006) and those in front of (rather than behind) moving objects (Jie & Clark, 2008). In other words, game players attend to these areas of the screen even when not looking directly at them. However, consistent with studies of adults performing real-life tasks, visual attention was also driven by top-down, goal-directed strategies (Seif El-Nasr & Yan, 2006).

Other studies have explored individual differences in eye movements to the same scene with the assumption that individuals who are employing systematic, top-down processes will tend to look at the same things at the same time as each other. This is predicated in the fact that any given scene has many perceptually salient features but often only one or two focal points that are relevant for comprehending the overarching narrative (see Kirkorian, Anderson, & Keen, 2012). These studies employ different methods for quantifying individual differences across participants who are viewing the same scenes, usually by identifying the exact location of each individual's gaze for each video frame. For instance, researchers may plot each individual's point of gaze on a two-dimensional plane (along *x*- and *y*-coordinates) and then quantify the spatial variability across a group of viewers by conducting a cluster analysis (Stelmach, Tam, & Hearty, 1991) or calculating the spatial area of an ellipse that encompasses the majority of fixations (Goldstein, Woods, & Peli, 2007). If individuals tend to look at the same parts of the screen as each other, then the spatial variability of their fixations, relative to each other at a given point in time, should be low (e.g., as indicated by only a few densely populated clusters of fixations or a relatively small ellipse that can encompass most of the fixations). These studies indicate that adult video viewers tend to look at the same parts of the screen at the same time as each other (Dorr, Martinetz, Gegenfurtner, & Barth, 2010; Goldstein et al., 2007; Kirkorian et al., 2012; Mital et al., 2010; Stelmach et al., 1991; Tosi, Mecacci, & Pasquali, 1997).

There are only a few studies of eye movements during video viewing by infants and children. Findings from these studies are consistent with theories of attention development generally and children's attention to television specifically (e.g., Huston & Wright, 1983; Ruff & Rothbart, 1996). For example, a few studies demonstrate that the relative importance of perceptually salient features declines with age as top-down, strategic attention processes become more common (Frank, Vul, & Johnson, 2009; Takahashi, 1991). Moreover, individual differences in fixations to video decline with age, indicative of more systematic, top-down attention processes in older viewers (Goldstein et al., 2007; Kirkorian et al, 2012). Finally, the relatively large individual differences in infants' fixations to video are greatest immediately following a camera cut to a new scene; these individual differences decline across the duration of a single shot and then increase again following a cut to the next scene (Kirkorian et al., 2012). In general, shots average about 6 seconds in length, but there is considerable variability in shot duration (e.g., D. R. Anderson & Smith, 1984). This decrease in variability of infant visual focus over time into a shot suggests that infants require more time to process individual scenes and are more disrupted than older viewers by frequent scene and camera angle changes (Kirkorian et al., 2012).

As a whole, the research on eye movements to video indicates that both bottom-up and top-down processes are important in directing visual attention, but that the relative importance of these processes varies as a function of age and task demands. Younger viewers may have difficulty fixating the most important information on screen in the face of many perceptually salient features. This ability improves with age due to advances in selective-attention and inhibitory-control skills, experience with video, cognitive schemes for story processing, language comprehension (the dialogue may tell what is important to look at on the screen), and ability to process frequent scene changes. Given that adults' fixation patterns differ by task demands, it is probable that children's eye movements during use of interactive screen media is different from eye movements to video.

Listening

Because auditory attention is difficult to observe in humans, it is not surprising that there are few studies of listening to audiovisual media. Again, the data are largely limited to television. Listening to audiovisual screen presentations apparently occurs relatively young insofar as 6-month-old infants pay less attention to mismatched audio and video in children's TV programs than they do to normal programs (Hollenbeck & Slaby, 1979). Tincoff and Jusczyk (1999) found that 6-month-old infants selectively looked at the appropriate screen showing their mother and father depending on whether a central speaker said "mama" or "papa" (or other term used by the family). These findings indicate that some form of audiovisual integration in attention to screen media is present in infants well before most content becomes comprehensible.

Lorch et al. (1979) hypothesized that children learn to multitask while with television by monitoring the audio when visually engaged in other activities, such as playing with toys. When not looking at the screen, children monitor the audio for formal features signaling comprehensible and interesting content. During such periods of divided attention children are less likely to process the audio at a semantic level, accomplishing little comprehension of the ongoing content. Full auditory attention at the level of meaning occurs primarily when children are also looking at the screen.

In support of the hypothesis, Lorch et al. (1979) found that 5-year-old children were more likely to answer comprehension questions about *Sesame Street* if they were looking at the screen at the time information necessary to answer the question was presented. This was true not only for information that was presented visually but also for information that was audiovisual or auditory only. Field and Anderson (1985) also found these differences for 5-year-olds who were shown a variety of educational programs. They noted, however, that 9-year-olds showed a smaller difference in comprehension of purely auditory information between looking and not looking. They suggested that the older children may be more capable of deploying auditory attention to a source of discourse when they are visually engaged elsewhere. Despite this age trend, Burns and Anderson (1993) found a clear advantage of recognition for brief audiovisual segments of programs in adult viewers if they had been looking at the screen at the time the segment occurred. This could be due to recognition of the visual portion of the segment. If, however, viewers were not looking at the screen when the segment occurred, recognition memory for the audio steadily declined over time following the end of the last look. The authors suggested that this declining recognition over time reflected the progressive withdrawal of auditory attention following the termination of visual attention.

The preceding research inferred auditory attention from comprehension and recognition memory of content. Two studies employing 5- to 8-year-old children attempted more direct estimates of listening by interfering with the normal auditory track (by gradually increasing overlaid white noise) and providing the children the means to restore it (Friedlander & Cohen de Lara, 1973; Rolandelli, Wright, Huston, & Eakins, 1991). Both studies found that children attempted to restore the normal audio indicating that they indeed were listening at least some of the time. Rolandelli et al. (1991) found that restore latencies did not differ depending on whether the children were or were not looking at the screen. Moreover, latencies to restore the audio were shorter for older children. This latter finding is consistent with the hypothesis that children monitor the audio at a superficial level even when they are not looking at the screen, and that this is particularly true of older children.

Processing Media Content

While attention is a necessary component of using media, it is not in itself sufficient to understand cognitive engagement during media use. Once a viewer attends to the screen, he or she must process that information. The extent to which an individual invests mental effort and comprehends media messages varies across time, content, individuals, and viewing contexts.

Depth of Processing and Mental Effort

There is a vast cognitive psychology literature indicating that attention can be deployed with more or less intensity, and with more or less information processing being devoted to the focus of attention. Presumably variation in intensity applies to information processing from media. As noted earlier in the section on attentional inertia, a number of studies have found that depth of processing increases over the time course of looks at television. This has been inferred from heart rate deceleration, increased secondary task reaction time, and better comprehension and recognition memory. Other research on intensity of attention has focused on adults' TV viewing. Briefly, formal features, particularly camera cuts, have been associated with shifts in intensity of attention following cuts, although whether this occurs, and in what direction, depends on the nature of the cut, for example, to a new shot within the same setting or to a new setting (Geiger & Reeves, 1993; Lang, Geiger, Strickwerda, & Sumner, 1993). Essentially, while there is a brief increase in intensity of processing following cuts, the increase is greatest following cuts to new content. Additionally, in research with adults, there is a fairly consistent finding that intensity of attention is greater to portions of content that are central to narrative understanding as well as to more emotionally engaging content than to more peripherally relevant content (Lang, Bolls, Potter & Kawahara, 1999; Meadowcroft & Reeves, 1989).

A somewhat different approach, called *amount of invested mental effort* (AIME), was proposed by Gavriel Salomon (1981, 1983). Because American children watched television primarily for entertainment purposes, he argued that American children would perceive television as "easy," whereas other media used for education, such as text, would be perceived as "hard." This corresponds with child and adult self-ratings of how cognitively demanding they perceive television to be in comparison with other activities, especially reading (Csikszentmihalyi & Kubey, 1981; Kubey & Csikszentmihalyi, 1990; Salomon & Leigh, 1984). Rather than being a property of the demands of a medium per se, AIME self-ratings depend on contextual factors. Israeli children claimed greater AIME during TV viewing than did American children, in part because all Israeli television at the time of the research was educational (Salomon, 1983). Moreover, children claimed greater AIME if they believed they would be tested for their knowledge of televised content (Field & Anderson, 1985). It is reasonable to predict that children and adults alike would rate interactive media as more cognitively demanding and as requiring more mental effort given that these media require responses from the user. However, we know of no empirical support for this hypothesis.

Comprehension

It is much easier to summarize research on children's comprehension of television than it is to summarize comprehension of interactive media. The difference is partly due to the fact that the content of interactive media is so varied. In contrast, television basically presents three types of content: narrative, expository, and advertising, which, structurally, is a combination of narrative and expository content.

By 4 months of age infants may recognize and be influenced by video images along with some audiovisual integration (e.g., Rochat & Morgan, 1998; Spelke, 1976, 1979). By 6 months there is clearly recognition of parents and common objects, as well as integration of video with audio (e.g., Gusella, Muir, & Tronick, 1988; Hollenbeck & Slaby, 1979; Slater, Quinn, Lewkowicz, Hayes, & Brookes, 2003; Tincoff & Jusczyk, 1999, 2003). By 10 months of age action sequences contained within repetitions of single shots are recognized and understood insofar as infants respond to interruptions or changed outcomes (Baldwin, Baird, Saylor & Clark, 2001).

Despite the absence of stereoscopic or motion parallax depth cues, infants initially act as if the TV screen is an entrance to a 3D space that the infant can enter. When shown stationary or moving animated objects on a video screen, 9-month-old infants try to mouth or manually investigate the objects, even adapting hand size appropriate to the size of the object, using a pincer grasp for small objects and two hands for objects that would be too large for the infant to hold with one hand. These behaviors decline by 15 months with older infants more likely to point or vocalize in response to the appearance of the objects (Pierroutsakos & Troseth, 2003).

While it is clear that by approximately 10 months of age infants can recognize familiar objects, people, and actions on a video screen, it is unlikely that they can integrate successive edited shots to create an emergent representation of narrative action sequences. As noted earlier, 6- and 12-month-old infants did not differentiate, by looking or heart rate measures, *Teletubbies* programs that were normal as compared to random shot sequences. Beginning at 18 months, and more so at 24 months, infants looked longer at the normal versions of the programs (Pempek et al., 2010). Combined with the findings that infants' eye movements during viewing are highly variable (Frank et al., 2009; Kirkorian et al., 2012), the question is raised as to how much infants can understand.

Numerous experiments have compared infant and toddler comprehension of simple, unedited video presentations to closely matched live presentations. Taken together, the findings are consistent that infants' comprehension is worse when stimuli are presented via video. This phenomenon has been labeled the "video deficit" (D. R. Anderson & Pempek, 2005) and appears to characterize infants and toddlers up to about 30 months of age, depending on the task.

The video deficit has been demonstrated in several research paradigms, including action imitation, object retrieval, word learning, and perceptual narrowing in the perception of phonemes. Barr and Hayne (1999) showed 12-, 15-, and 18-month-olds either live demonstrations or videos of multistep actions that could be performed on a puppet (e.g., removing a mitten, finding a bell, removing the bell). When, after a 24-hour delay, infants were presented with the puppet, those who saw the live presentation imitated the demonstrated actions to a much greater extent than did those who saw the video. Similar video deficits were observed in 24- and 30-month-old toddlers (Hayne, Herbert, & Simcock, 2003). One technique for overcoming the video deficit is simple repetition. For instance, infants who viewed a video demonstration of a novel behavior were more likely than a baseline group to produce the same behaviors later, but only when they viewed the video demonstration six times (Barr, Muentener, & Garcia, 2007).

The video deficit in object retrieval was demonstrated in 24-month-olds by Troseth and DeLoache (1998). An experimenter hid a toy in an adjacent room. Toddlers watched by either looking through a window (live demonstration) or watching the same event on screen via closed-circuit video. The 24-month-olds were highly successful in finding the toy following the live presentation but were at chance levels of performance following the video demonstration. Thirty-month-olds, however, were successful in both conditions. This object-retrieval procedure was also used by Schmitt and Anderson (2002), who found the video deficit in 24-month-olds and, to a lesser extent, in 30-month-olds; however, no deficit was found in 36-month-olds.

The video deficit has also been found with respect to audio learning from audiovisual presentations. A normal aspect of the development of speech perception is the phenomenon of perceptual narrowing. For example, American 6-month-olds who have never heard Mandarin can accurately discriminate between phonetic contrasts made in Mandarin but not in English; this ability is lost by 12 months of age. Kuhl, Tsao, and Liu (2003) showed that a relatively small amount of exposure to a real-life Mandarin speaker interacting with the infants allowed them to maintain the ability to discriminate between these phonetic contrasts. Equivalent exposure via an audiovisual or audio-alone recording had no effect on the infants, thus revealing a video deficit.

A video deficit for word learning was reported for 15- to 24-month-olds (Krcmar, Grela, & Lin, 2007). Using a fast-mapping procedure to present the names of novel objects, the researchers found that live presentations produced learning that was superior to matched video presentations. Roseberry, Hirsh-Pasek, Golinkoff, and Parish-Morris (2009) found a video deficit for verb learning in children as old as 42 months of age.

These and other studies have firmly established the existence of a video deficit in infants and toddlers. Researchers have proposed several overlapping hypotheses as to why it exists. One proposal (Schmitt & Anderson, 2002) is that infants have difficulty perceiving the correspondence between the 2D image and the 3D real-world space in which the infant is tested. The screen image does not support stereoscopic depth perception or motion parallax. It provides positive illumination of represented objects and surfaces (as opposed to reflected light) and reduced resolution compared to real-world images. Similarly, children have learned that the screen reveals an apparent space that cannot be entered, reducing perceived affordances for physical actions on depicted objects (cf. Milner & Goodale, 1995). Taken together, all these elements of screen images make depicted objects and events perceptually impoverished and thus more difficult to encode as bases for action in the real world. This perceptual impoverishment, combined with a lack of representational flexibility in infants, should make it more difficult for infants to transfer from 2D to 3D and vice versa (Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009). Nonetheless, the video deficit remains when efforts are made to reduce the perceptual difference between on-screen information and real-world events. For instance, the video deficit persists in an object-retrieval task when using a 2D search space with the same dimensions as the screen image (finding a sticker behind felt objects on a flat felt board) or even when only telling (rather than showing) 2-year-olds where an object is hidden in an adjoining room (Schmidt, Crawley-Davis, & Anderson, 2007). In the latter study, the children had little difficulty finding the object if told where it was hidden by the live experimenter, but they were at chance finding the object if the same experimenter told them where it was hidden via closed-circuit video.

An influential hypothesis explaining the video deficit posits that infants have difficulty with dual representations of media (Troseth & DeLoache, 1998). Children must learn that symbolic media (e.g., video screens, photographs) are both objects in and of themselves and also symbolic representations of other objects in the world (DeLoache, 1987; Troseth, 2010). Such lack of representational insight may explain why toddlers have difficulty learning from not just video but also other symbolic media such as photographs and 3D scale models (DeLoache, 1987; DeLoache & Burns, 1994).

An additional explanation for the video deficit concerns the lack of social interaction by TV characters with the young viewer. Several studies demonstrate that making video socially relevant can alleviate the video deficit. For instance, toddlers are more likely to imitate familiar people and television characters than unfamiliar experimenters or puppets (Krcmar, 2010; Lauricella, Gola, & Calvert, 2011). Moreover, providing socially relevant and contingent interactions on screen (e.g., via video chat) produces improved screen-based learning among very young children. For example, toddlers performed better on the object-retrieval task after interacting with an experimenter via closed-circuit video (Troseth, Saylor, & Archer, 2006). In the interactive videos, the experimenter provided contingency (responding to children's behavior) and socially relevant information (e.g., using the child's own name and asking questions about the child's family members). Importantly, search performance was at chance levels when children viewed a "yoked" video of the experimenter interacting with a different child, which presented the same types of social cues but with mismatched timing and incongruent personal information. Similar findings have been reported for word learning from video (Roseberry, Hirsh-Pasek, & Golinkoff, 2013). Experience with contingency via video may itself contribute to overcoming the video deficit. Toddlers were better able to succeed in the televised object-retrieval task if they had experience at home seeing themselves on a video screen as they engaged in activities before the camera (Troseth, 2003).

The importance of contingency raises questions about the potential educational value of interactive screen media. A few studies suggest that interactivity in and of itself (i.e., in the absence of socially or personally relevant information) improves toddlers' learning from screens (Kirkorian & Pempek, 2013). For example, Lauricella, Pempek, Barr, and Calvert (2010) reported that 30- and 36-month-olds were more likely to find hidden objects when they pressed a computer key to see videos of the hiding events than when they simply viewed the videos without interacting with the computer. Similarly, toddlers were more likely to succeed in word-learning and object-retrieval tasks when prompted to interact using a touch screen (K. Choi & Kirkorian, 2013; Kirkorian, Choi, & Pempek, 2013). It seems plausible that the contingency afforded by interactive screen media may facilitate learning by very young children, but more research is needed to establish whether and how this occurs.

As children come to comprehend the associations between successive shots and formal features, and as they otherwise overcome the video deficit, it is fairly clear that they understand most simple television programs by about 2.5 years of age. For example, 3-year-olds were able to reproduce brief stop-animated stories that were presented as shot sequences equally well with presentation as one continuous shot. Four-year-olds showed substantial comprehension (evidenced by successfully reproducing stories) of shot transitions that represented relations of time, space, implied actions, and character point-of-view (R. Smith, Anderson, & Fischer, 1985).

By 4 years of age children clearly understand short (several minutes or less) segments from television. Four- and 7-year-olds showed considerable comprehension of audiovisual stop-animated segments as indicated by both reproduction and verbal recall. The older children showed relatively greater recall of dialogue than did younger children, with both groups accurately recalling character actions in both audiovisual and audio-only versions of the stories (Gibbons, Anderson, Smith, Field, & Fischer, 1986). Five-year-old children recalled 92% of content from brief educational television segments that adults had identified as of central importance (Lorch, Bellach, & Augsbach, 1987). The recall was selective insofar as the children were more likely to recall content of central relevance than content of peripheral importance.

Although comprehension and recall of content from age-directed TV content is fairly good by 4 years of age, it becomes substantially better in older children and adults. In a detailed analysis of children's and adults' recall after watching segments from *Sesame Street*, adult recall was organized around characters' goals and intentions as well as causal connections in the narrative, whereas children's recall was organized around events (van den Broek, Lorch, & Thurlow, 1996). In general, adult narrative recall is more structured around causal–motivational content. As was found by Gibbons et al. (1986), younger children focused on character actions, whereas adults were much more likely to report dialogue.

While preschoolers are able to comprehend narrative content (e.g., Pingree et al., 1984), their comprehension of age-appropriate content over a longer (22-minute) episode is far from complete. Three- to 5-year-olds' comprehension of an episode of *Blue's Clues* greatly increased with five viewings of the episode. This increase included far transfer of problem-solving strategies to situations not depicted in the episode, suggesting that children were able to grasp relatively abstract concepts with repeated viewing (Crawley et al., 1999). Preschooler comprehension also benefits from prior familiarity with the characters and series as a whole (Crawley et al., 2002).

Although young children can comprehend well-produced, age-directed content in an extended narrative of a half hour or more, they are nevertheless far from being able to fully comprehend content intended for adult audiences. For example, they tend to be confused by subplots as commonly employed in adult-directed, narrative programs (W. A. Collins, 1983; Weiss & Wilson, 1998). Eight-year-old children had difficulty identifying centrally important content (W. A. Collins, 1970), and in particular, had difficulty making plot-relevant inferences that are essential to understanding the narrative as a whole (W. A. Collins, Sobol, & Westby, 1981; W. A. Collins, Wellman, Kenniston, & Westby, 1978; Low & Durkin, 1997, 1998, 2000; Newcomb & Collins, 1979). Because character motivations and intentions are important in comprehending narratives such as detective stories, these findings of comprehension failure for adult-directed content are consistent with the van den Broek et al. (1996) conclusions that younger children focus on actions, whereas adults focus more on character motivations, intentions, and causal connections between events. In general, children's comprehension of adult-directed, narrative content approaches adult levels of comprehension by about 12 years of age (W. A. Collins, 1983). Various production strategies help increase comprehension. In addition to repetition and appropriate use of child-typical formal features, topical organizers can be provided by a narrator and wrap-up commentaries can help with overall comprehension and recall (Calvert et al., 1982).

Comprehension of video content depends somewhat on children's pre-viewing expectations, which, in turn, depend on family and other contextual factors. An experiment in the early 1980s, at a time in the United States when expectations about gender roles were rapidly changing, explored the impact of children's gender stereotypes on recall of televised events. The researchers showed 8- and 9-year-old children a drama in which characters behaved according to sex-role stereotypes (e.g., mother engaged in domestic chores and interactions with three children) or opposite to stereotypes (e.g., female surgeon who is leader of a medical team). The children were also tested for their expectations of sex-role stereotypes. After viewing the videos, the children were tested for recognition memory, including false items that were consistent or inconsistent with sex-role stereotypes. The children who were high in sex-role stereotypes showed greater correct memory for both stereotyped and counterstereotyped character behaviors. This advantage was not found for recall of information that was unrelated to gender roles, indicating that the children who had the greatest stereotyped expectations showed the greatest sensitivity to, and memory for, sex roles (List, Collins, & Westby, 1983). Of course, children's family and demographic backgrounds influence more than comprehension. For example, 6- and 8-year-old children were more likely to judge characters' behavior negatively if the characters were heard speaking a foreign language or speaking with a foreign accent. This prejudice was not found among 10-year-olds (Durkin & Judge, 2001).

Other than age-directed, educational programs, there has been relatively little research on children's comprehension of expository content delivered by screen media. S. L. Smith and Wilson (2002) found that kindergarteners through third graders (i.e., 5 to 9 years) showed poor comprehension of televised news stories compared to fourth- through sixth-grade children (i.e., 9 to 13 years). Older children in this study were, however, more frightened than younger children by news of disasters and violence even though the depicted events were geographically distant.

In general, developmental trends in the comprehension of television mirror those found in comprehension of other media such as audio and text (Gibbons et al., 1986; van den Broek et al., 1996; Salomon, 1983). Relative to the use of other receptive media, there is no evidence that television comprehension is more passive or less complete.

As yet there is no comparable body of literature on comprehension of narrative or expository content using interactive screen media. Nonetheless, the consistency of findings across televised, audio, and print narratives suggests that the conclusions are broadly applicable.

Summary and Implications of Research on Cognition While Using Media

It is striking that there is so little research on children's attention to and comprehension of interactive media despite anecdotal claims that interactive media are far more engaging to children than is television. With respect to use of interactive media by children there is almost no publicly available information about the length of periods of active media engagement, looks at the screen and eye movements, listening, depth of processing, or comprehension of content.

In contrast, much more is known about the development of children's attention to and comprehension of television. In unconstrained TV-viewing situations, such as at home, children's viewing is episodic in nature. They frequently leave and return to the viewing area. While in the viewing area, they frequently look at and away from the TV screen. While looking, they frequently shift visual fixation to different parts of the screen. Listening to the TV at the level of content meaning occurs primarily when they are looking, especially for younger children. Attentional engagement grows as looking at the TV is sustained; this attentional inertia is associated with greater memory and comprehension during sustained periods of looking as compared to brief periods of looking.

Factors that are associated with children's sustained looking at television include age, comprehensibility of content, formal features appropriate to child-directed content, content appropriate to individual interests, prior experience with the series or particular episode, and attentional inertia. Depth of processing and mental effort, like visual attention, varies in systematic ways with formal features and content. In addition, contextual factors influence attention to TV; most notably, children follow coviewers' looks at the screen.

The picture that emerges is quite unlike the popular view of children watching television in a reflexive manner, with little cognitive processing of the content. Beginning in the preschool years, attention to television is episodic and selective. Sustained attention to television appears to be in service of gaining access to understandable and interesting content. As children mature and become experienced through exposure to the medium, their attention to television becomes more strategically guided and less directed to salient visual and auditory features. Eye movements become more directed to informative portions of the screen with the consequence that mature viewers tend to look at the same place on the screen at the same time as each other.

In examining attention to television and its development, there is little to support the popular claims that child viewers are mesmerized or entranced like zombies. Rather, attention to television appears to be largely in the service of maximizing comprehension in the context of other activities in which the child might also be engaged, such as toy play and social interaction.

Comprehension of television changes dramatically during development. During the first year of life, infants are capable of recognizing familiar objects, people, and actions on screen. However, it is not until the middle of the second year of life that they begin to demonstrate comprehension of edited sequences of shots. Until about 30 months of age, young children exhibit a video deficit whereby they are less likely to demonstrate learning from video than from a comparable real-life experience. As compared to older children who can comprehend much of what they see, the impact of television on cognitive development likely differs for infants and toddlers because they are less likely to comprehend the content.

The video deficit during infancy is reduced when video is repeated, depicts familiar characters, incorporates socially relevant information and interactions, or affords contingent interactivity (e.g., by requiring children to press a button or touch the screen to play the video). It may be that young children can learn more from interactive media such as video games and mobile applications, but so far research is lacking.

By 3 years of age, preschoolers can comprehend video and demonstrate learning using real objects. Four-year-olds are capable of comprehending simple edited sequences of shots. Comprehension continues to increase throughout childhood, reaching adult levels around 12 years of age, at which time comprehension reflects more complex narrative structure such as character motivations and causal connections between events. The potential educational value of screen media, and best practices for designing effective content, will vary as a function of children's developing cognitive skills related to comprehension.

MEDIA IMPACT ON COGNITION

Early in this chapter we noted that the advent of television, especially educational programming, was greeted with enthusiasm by parents and educators. Criticism grew over time, focused on the notion that television viewing fosters mesmerized, mindless, passive forms of cognition, with much of the criticism focused on *Sesame Street* as exemplifying television in general. Many of the same criticisms have been directed at successive waves of interactive screen media. As reviewed in the preceding sections on attention and comprehension, the underlying assumptions in the concerns about *Sesame Street* are incorrect. By the time they can comprehend TV, children attend selectively and are quite capable of terminating attention as well as viewing sessions. There simply is no evidence that children are mesmerized or mindless when watching television. Patterns of television comprehension, when compared to audio or text, are quite similar (e.g., Gibbons et al., 1986; Pezdek & Hartman, 1983; Pezdek, Lehrer, & Simon, 1984; Pezdek & Stevens, 1984).

Claims by journalists and other commentators about both positive and negative effects of television nevertheless suggest that the medium is influential on cognitive development. Consistent with historical trends, interactive screen media have been subjected to similar popular claims, both positive (e.g., Johnson, 2006) and negative (e.g., Carr, 2011). In the next section we describe pathways proposed by researchers and theorists by which television and the interactive media potentially exert that influence. After introducing the potential pathways of influence, we summarize research on the impact of screen media on cognitive outcomes.

Pathways of Influence

Electronic media can potentially influence cognitive development through both direct and indirect pathways. We discuss each of these in turn.

Hypothetical Direct Influences

Direct pathways are those that stem directly from being in the presence of an electronic device in use and are largely a consequence of events that happen during that time. These influences would not occur if the device were not switched on or if the child were not present during its use by other family members. For example, if a child learns to recognize and say the name of a particular letter while watching *Sesame Street*, the pathway of influence is direct from the TV viewing experience to the cognitive consequence (knowing the letter). We explore potential direct effects before turning to potential indirect effects of screen media on cognitive development.

Knowledge Acquisition. The most obvious direct influence is on children's knowledge. Because television is not inherently an interactive medium, learning from television is largely observational in nature. Producers of educational television have taken for granted that children learn from television viewing in a manner consistent with their observational learning from other life experiences. It is usually assumed that observational learning follows a developmental time course but that it is established at a relatively young age. This assumption underlies the rationale for producing programs that promote school readiness skills, literacy, scientific knowledge, prosocial behavior, and other forms of socially desirable knowledge. As reviewed earlier, comprehension of screen media takes time and experience to develop. The greatest effects of media on knowledge presumably depend on comprehension. Thus, appropriate age-directed programming is likely to have greater effects on knowledge than programming that the child finds difficult to comprehend.

Observational learning can also apply to interactive screen media. Indeed, a great deal of the use of interactive media is directed at watching television or television-like content. In addition, however, is the possible acquisition of skills that involve trial-and-error learning, or other forms of learning that require overt responses and feedback as to the success of those responses. To some degree, depending on the digital-interface devices that are being employed, a child may possibly learn physical skills that have some transfer to real-life situations. These include facility with computer keyboards, vocal skills, musical skills, dance steps, cursive writing skills, certain athletic skills, and many others.

It is not surprising that knowledge acquisition from media depends considerably on the same factors as knowledge acquisition in unmediated environments (so-called real life), including prior knowledge, interests, developmental level, and many other considerations. There is a vast literature, reviewed later, that learning does indeed occur, although what is learned, and how it is manifested in behavior, varies with content type, production techniques, viewing experience, age, parent coengagement, and many other factors. It should be noted that media content, from an adult perspective, is not necessarily educational. Media content routinely consumed by American children includes vast amounts of fiction and fantasy that often contains antisocial behavior, among other things. If children can acquire socially and academically desirable knowledge from television, they can acquire false, irrelevant, and antisocial knowledge as well.

Attention. One of the most common hypotheses is that screen media, especially television, shorten attention span or otherwise negatively influence how children deploy or sustain attention. The assumption underlying this hypothesis is that visual features such as shot changes and movement repeatedly elicit orienting reactions that drive visual attention to the screen and forward through time. This is seen as an involuntary, reflexive form of attention as distinct from effortful attention required in many task situations. Although the exact process of developmental influence has not been specified, it is assumed that repeated elicitation of this more primitive form of attention somehow impedes the development of effortful, sustained attention (e.g., Christakis, Zimmermann, DiGuiseppe, & McCarty, 2004; J. L. Singer, 1980). Based on the previous review of attention to screen media, this formulation most likely applies to children who have not yet learned to comprehend media. Once they comprehend television, for example, children's attentional processes appear to be largely controlled, rather than reflexive, and in service of comprehension.

This consideration produces an alternative formulation that television viewing has little or no direct influence on attention development insofar as attention to television is driven by perceptual and cognitive activities similar to those found in unmediated observational situations. In particular, it has been proposed that in young children, attention to television simply reflects the cognitive activities involved in comprehension of unfolding program content. These activities are similar to those that would be deployed in comprehending unmediated visual action and discourse (D. R. Anderson & Lorch, 1983).

There are no published hypotheses to the effect that television viewing *enhances* attention development. It should be noted, however, that Salomon (1979) argued that specific attention skills can be taught by television programs designed for that purpose.

Discussions in both popular and research literatures on interactive screen media parallel those for television. Some hypotheses suggest that the use of screen media causes attention problems by increasing arousal/excitement and continuously eliciting orienting responses that make other activities seem boring by comparison (Gentile, Swing, Lim, & Khoo, 2012). On the other hand, others posit benefit of video games that are specifically designed to increase attention skills. For instance, video games may provide opportunities to practice executive function skills (e.g., Nouchi et al., 2013) or biofeedback in the form of increased video-game difficulty when attention decreases (Pope & Bogart, 1996).

Disruption Due to Time-Sharing and Distraction. As reviewed earlier, it is common for American children to engage in other activities while using media. Depending on children's age, these activities may be almost anything a child can do at home, but commonly include playing, socializing, eating, grooming, and doing homework. Additionally, especially as children get older, they commonly engage in media time sharing, during which they watch TV or listen to music while using an interactive digital device.

As a background influence, it has been hypothesized that TV (and perhaps other media such as radio) is distracting and disruptive to the primary activity in which the child is engaging (e.g., D. R. Anderson & Evans, 2001). Similarly, it has been hypothesized that media time sharing, as a form of divided attention, results in poorer cognitive processing of each medium involved (e.g., Armstrong & Chung, 2000; Pool, van der Voort, Beentjes, & Koolstra, 2000). It has also been hypothesized that chronic exposure to background television can negatively influence cognitive development, primarily executive function (Barr, Lauricella, Zack, & Calvert, 2010; Schmidt, Pempek, Kirkorian, Lund, & Anderson, 2008).

Comprehension of Discourse and Narrative. During television viewing children do not ordinarily control the flow of information presented by the program, other than by fluctuations of attention to that information. That is, shots, scenes, and auditory information continue through time regardless of whether or how much the child pays attention. It has been hypothesized that children adopt a mindless approach to processing information from television, absorbing images and sounds, but not engaging in inferential activities and failing to comprehend the discourse in a connected, reflective, or thoughtful manner (J. L. Singer, 1980). This, in turn, induces a predominantly passive approach to processing discourse in other forms, such as text.

Alternative formulations generally assume that comprehension activities are similar to those deployed during ordinary, unmediated discourse or in processing of text discourse. An exception is the necessity of comprehension of editing conventions, production techniques, and program constructions specific to movies and television. As described earlier, these conventions and production techniques are usually referred to as *formal features* in the media research literature (Huston & Wright, 1983). Consequently, by these alternative formulations, television viewing, per se, would have little effect on discourse processing abilities in other situations. Salomon (1983) hypothesized that experience with television as a primary source of entertainment induces child viewers to process television discourse superficially, investing little mental effort. He did not, however, argue that this influences deployment of mental effort in other situations.

Discourse of various kinds may be present in interactive-media content ranging from interactive storybooks to elaborate, story-based computer games. In addition, literate children may participate in reading and writing discourse in the form of fan fiction, blogs, or posts on social media. Children may also create audiovisual discourse that they post for public consumption on video-sharing websites. Although some scholars of game-based learning posit that convincing narrative structure is a necessary feature for ensuring motivation and engagement (Dodlinger, 2007; Fisch, 2013), we know of no specific hypotheses regarding the impact of interactive media on comprehension of discourse and narrative in other situations. On the one hand, shorthand forms of discourse often used in social media (e.g., "lol" for "laugh out loud") may enter the child's more extended and formal parlance. On the other, practice with reading and writing may generally facilitate literacy. Similarly, creating videos or games for the Internet may foster other forms of creativity in discourse, whereas playing games and viewing stories that have alternative plot-pathways may teach children a more mindful form of consuming discourse.

Mental Elaboration, Imagination, Creativity. A common criticism of television, particularly compared to text or audio discourse, is that it is explicit, that there is little left to the imagination. So, for example, the viewer knows the way a TV character looks and sounds. Character actions and other events are actually seen, not imagined. It has also been claimed that because actions and events are explicit, there is little room for inferential activities. Because physical, social, and other kinds of problems get explicitly solved in a particular way, television does not foster creativity (e.g., L. Brown, 1986; Greenfield, Farrar, & Beagles-Roos, 1986; J. L. Singer, 1980; D. Singer & Singer, 1990). Over time, this is claimed to reduce mental elaboration, imagination, and creativity more generally. These same criticisms of television are potentially applicable to audiovisual interactive media as well.

An alternative view is that television requires the same amount (but different kinds) of mental elaboration as other media (e.g., D. R. Anderson & Smith, 1984; Gibbons et al., 1986; N. C. James & McCain, 1982; Salomon, 1979). For example, research reviewed earlier showed that children begin to comprehend the continuity of content across shots beginning at about 18 months of age, with inferential comprehension of common editing conventions of space, time, continuity of actions across shots, and character point-of-view firmly established by 4 years of age (e.g., R. Smith et al., 1985). Television, moreover, stimulates imaginative play by providing characters and themes. Content designed to stimulate creativity, furthermore, does so (Salomon, 1979; D. Singer & Singer, 1990). Television may also require other forms of inference about characters' thoughts, emotions, and internal states that may otherwise be explicitly stated in books.

Again, similar arguments can be made with respect to interactive media; however, thus far these arguments have remained largely theoretical and still lack empirical investigation. For instance, scholars advocate that effective video games for learning will facilitate active and critical thinking, provide opportunities for trial-and-error exploration, and allow many different paths to solve problems (Gee, 2007). Others note that the extent to which video-game players store information in long-term memory will likely depend—at least in part—on the extent to which they are motivated to do so (Sherry, 2013).

Spatial, Temporal, and Theory of Mind Cognition. Although not frequently a topic of popular discussions, it has been proposed that television viewing enhances spatial cognition and perhaps other forms of cognition directly related to the comprehension of formal features. This hypothesis stems from the inferential processes required to comprehend editing montage as well as production techniques such as camera angle, camera movements, zooms, and others (e.g., Monaco, 1977). So, for example, if the outside of a building during daytime is shown, followed by a cut to an interior scene of two adults holding a conversation in an office setting, an experienced viewer immediately infers that the interior scene is taking place inside the building shown in the immediately prior shot. The viewer would also assume that the conversation is taking place in the daytime because the prior shot indicated daylight. These spatial and temporal inferences are not logically required by the juxtaposition of shots, but are nevertheless justified by common editing convention (Salomon, 1979). Over time, in order to comprehend ordinary narrative television fare, a child engages in many thousands of such spatial and temporal inferences (D. R. Anderson & Smith, 1984).

Similarly, a great deal of interactive media software requires the user to comprehend and manipulate a variety of spatial representations. These may range from simple geometric games requiring rotation of objects, adventure games that require navigation of an unfamiliar 3D landscape, entering new spaces via doorways or magic portals, or creating one's own maps for future game play. Other kinds of media sequences imply that events are simultaneously happening in two different locations, indicate the passage of time, and so on. Thus some scholars argue that some digital games can influence the development of spatial cognition (e.g., Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Subrahmanyam & Greenfield, 1994).

Yet other sequences require the viewer to infer the mental state of one of the characters, implying cognitive processes related to the viewer's theory of mind. Point-of-view shots require that the viewer understand that the camera is taking the visual point-of-view of a character in the narrative, whereas first-person adventure games require that the player actually maneuver that character and take actions that affect the character's environment and well-being. Flashback sequences require an understanding about a character's memory events; other techniques may indicate a character's psychological state such as that a character is drunk or otherwise impaired, angry ("seeing red"), or in love.

Given the frequency of the inferential activities required by TV and interactive media, it has been proposed that some (especially nonverbal) aspects of cognition may be enhanced by film and TV viewing (Salomon, 1979). This has been proposed as one possible explanation of the Flynn effect (Flynn, 1984, 1987), that is, the observed increase in nonverbal IQ scores across generations (Neisser et al., 1996). Because television and movie fare is often rapidly paced, presenting a great deal of visual and auditory information over sequences of a few or many brief shots, it is also possible that viewing may influence the speed of cognitive processing of external information. Similar arguments have been made for rapidly paced digital games (e.g., Green & Bavelier, 2003).

Hypothetical Indirect Effects

Indirect influences are those that are not produced by the device, per se, but are created as a consequence of the child (or other family members) using the device. If, due to watching television, a child fails to spend time reading books, the consequence (perhaps being slower in learning to read) is an indirect effect of the medium. The slower reading acquisition in this case is not produced directly by watching TV, but instead by lack of experience reading—an indirect effect. After exploring potential indirect pathways, we review the empirical literature on media effects on cognitive development.

Using Acquired Knowledge Beyond the Viewing Situation. Once knowledge is acquired from media, it can be used by children or otherwise affect them in many different ways. Behaviors that result from this acquired knowledge can be both beneficial and negative with respect to development and education. For example, children can use knowledge gained from educational programs as a basis for understanding lessons in school. Children can also use knowledge gained from violent TV programs or computer games to behave aggressively and disrespectfully. Knowledge can appear as delayed imitative behaviors during play with toys or with other children. Children may learn schemes of behavior that become more generalized so that they apply them to situations different than those contained in the original programs (Bandura, 1977, 1994).

While we consider knowledge acquisition itself to be a direct influence, the consequences of acting on that knowledge should be considered indirect influences. Thus, for example, if the child sees many televised portrayals of aggression and imitates that aggression in school, there may be important consequences in terms of injury, peer relations, and teacher opinion. In contrast, children who watch educational programs such as *Sesame Street* may enter school better prepared to succeed than they otherwise might be. By influencing behavior, knowledge, and skills, media can have a delayed influence on schooling as well as other developmentally important contexts. Because this occurs beyond the proximal confines of the media experience itself, we consider it as a distal or indirect influence.

Time Displacement. One of the earliest hypotheses about media concerns time displacement. The underlying assumption is that if children are watching television (or, by extension, using other media), they must be doing less of something else (e.g., Himmelweit, Oppenheim, & Vince, 1958; Schramm, Lyle, & Parker, 1961). This time displacement is a negative influence on development if the displaced activities are developmentally valuable, such as doing school homework or reading books; conversely, time displacement may be positive if the use of media displaces potentially harmful activities such as going out with adolescent friends to smoke cigarettes or drink alcohol.

Alternatively, children (and their parents) may treat use of media as a default activity: something to engage in when there is nothing better or more important to do. From this point of view, media are less likely to displace developmentally important activities (Himmelweit et al., 1958). A corollary of this hypothesis is that use of a particular medium such as television displaces functionally similar activities (Schramm et al., 1961). A child who is fond of fantasy fiction involving magic might, for example, watch a Harry Potter movie on TV rather than play a fantasy-magic-themed console game, or instead read a similarly themed book or web comic. Assuming that the displaced activity is not inherently more valuable or less valuable than TV viewing, time displacement would not be developmentally important. However, when the use of media does displace more academically or cognitively valuable activities, it is likely to have an indirect negative impact on long-term outcomes (e.g., if television viewing displaces early reading, it is likely to reduce subsequent reading comprehension skills).

Other Indirect Effects. Some direct effects of media may indirectly affect cognitive development and education. For example, if television viewing disrupts normal sleep in children, they may have more difficulty in school, thus limiting the cognitive benefits of school (Thompson & Christakis, 2005). If use of media, as mostly sedentary in nature, reduces physical fitness and increases obesity, children may be less likely to participate in organized physical activities such as team sports or martial arts that in turn may benefit aspects of cognitive development such as executive function (Diamond, 2012).

Research on Media Effects

Having described common hypotheses concerning the effects of media, in the following sections we summarize what is known from empirical studies. The studies do not neatly follow the hypothetical pathways of influence, and in fact, any given finding may be the result of multiple pathways in operation at different times during development. We first consider displacement as both an effect of media exposure and a potential mediator of impact. We then discuss media impact on a number of cognitive skills and academic outcomes.

Displacement

The displacement hypothesis states that use of media replaces engagement in other activities that may influence cognitive development. Usually, the displaced activities (e.g., reading) are claimed to be more valuable than the use of screen media itself. There have been two main research strategies used to assess displacement. The first considers cohort analyses of children's time use before and after the medium becomes available. This type of research has, to our knowledge, only been done with respect to the arrival of television and has not been done with respect to the arrival of any form of interactive digital media. The second strategy considers time use as a function of individual differences in use of media.

Studies of the arrival of television are unanimous that television viewing primarily displaced the use of other entertainment media. At a macro scale, once television became available in the United States, radio listening, movie attendance, and comic-book sales plummeted (Barnouw, 1990). Schramm et al. (1961) studied the arrival of television in the American western states and concluded that, with respect to children's time use, television primarily displaced "functionally similar" activities, specifically, listening to radio, attending movies, and reading comic books. Similar conclusions were reached in the United Kingdom (J. R. Brown, Cramond, & Wilde, 1974; Himmelweit et al., 1958), Australia (W. Campbell, 1962; Murray & Kippax, 1978), South Africa (Mutz, Roberts, & van Vuuren, 1993), and Japan (Furu, 1971). There was also a decrease in participation in adult-organized groups outside of school (J. R. Brown et al., 1974; Murray & Kippax, 1978; Williams & Handford, 1986). There were small decreases in time spent sleeping, eating, and doing undifferentiated leisure activities. Most of these studies found little change in reading and doing homework, but when these occurred, they were in the direction of decreasing (e.g., Furu, 1971).

In their own heyday, the activities that were displaced by television were frequently criticized along the same lines that television has been criticized (e.g., Gilber, 1986), so it is difficult to argue that they were cognitively more valuable. However, even small amounts of reduction in reading, especially during the early elementary school years, could be a significant factor in reading acquisition. The main problem in generalizing from these studies to newer media is that, as a novel entertainment medium, television viewing was probably greater in quantity and intensity than it became once its use was firmly established. Use of new media today, such as touch-screen applications, may also induce a period of intense use until they, in turn, become well established. Unlike television, which displaced other entertainment media, however, there is less evidence that new digital media have displaced television. Indeed, newer media have done little to displace children's time spent with television and videos (Rideout, 2013; Rideout et al., 2010). Rather, children have added time with these media to time spent with television, in part because of frequent media multitasking (Rideout et al., 2010).

Contemporary studies of time use have to be interpreted cautiously. Because multitasking is common during the use of media, especially TV, an increase in use of media does not necessarily mean there will be a corresponding decrease in all other activities. For example, homework may be time-shared with TV. Moreover, individual differences in media time are related to demographic and other individual differences. If heavy users of media decrease time spent with media, it does not necessarily mean that the time would be spent doing the things done by light users of media.

In the only recent study relevant to cognitive activities, Lee, Bartolic, and Vandewater (2009) analyzed the associations between TV viewing, computer use, and reading in a U.S. national longitudinal sample of children from infancy through adolescence. There was minimal evidence of contemporaneous displacement of reading by other media. They found that TV use in the preschool years negatively predicted later reading, but early reading did not predict later TV viewing. Early TV use predicted later computer and video-game use. At least with respect to reading, the research does not strongly support contemporary time displacement, but it does suggest that early use of media may affect later reading. As noted later, TV use during early reading development may have a negative influence on reading comprehension (Ennemoser & Schneider, 2007; Koolstra, van der Voort, & van der Kamp, 1997).

A few studies have assessed activities in which children engage when they have been denied television use for a period of time. In a small, random-assignment experiment, Gadberry (1980) reported increased reading. Wolfe, Mendes, and Factor (1984) reported similar findings for heavy-TV viewers who were denied access to television. Both studies found that additional time not spent in reading was occupied by other recreational activities. Various organizations have sponsored “screen-free weeks” in which families agree to forgo electronic screen media. Because parents are encouraged to actively participate in activities with their children during these weeks, generalizations cannot be made easily as to how the children would fill their time if otherwise denied the use of screen media. Moreover, existing research represents only short-term intervention studies, and it is unclear whether immediate effects of eliminating TV would persist over time.

Taken as a whole, time displacement does not appear to be a major factor of cognitive and educational development, with the possible exception of early reading as described in the next section. There is a large amount of research suggesting that use of screen media is negatively associated with physical activity and physical fitness, where time displacement is of current concern (e.g., Institute of Medicine, 2006), but such research is beyond the scope of this chapter.

Reading and Text Comprehension Skills

Much of the research on using screen media and reading focuses on the hypothesis that time spent viewing television or playing video games displaces time spent reading, specifically with books. This preference for television over books is thought to stem from TV viewing being cognitively easier and requiring less mental effort than reading, especially for early readers. There is some correlational evidence in support of this hypothesis. For instance, children’s TV viewing negatively predicted amount of reading 5 years later but positively predicted computer and video-game use (Lee et al., 2009). While correlational support for a linear impact of television viewing on reading skills is mixed (Vandewater, Bickham, & Lee, 2006), television might have a particularly devastating effect on reading for children in very heavy-TV households in which children watch approximately five hours a day or more (Ennemoser & Schneider, 2007; Vandewater et al., 2005). Moreover, television’s impact may depend on the developmental level of the viewer. Ennemoser and Schneider (2007) followed children in Germany for 4 years, beginning either in kindergarten (i.e., 5 to 6 years) or second grade (i.e., 7 to 8 years). In the younger cohort, no differences were found at the start of the study, but groups diverged across the 4-year period as a function of television exposure such that standardized reading comprehension skills for light and medium viewers increased over time, whereas relative comprehension skills for heavy viewers decreased each year. In the older cohort, light and medium viewers had higher comprehension scores than did heavy viewers at the start of the study, and this difference persisted across the 4-year period.

A longitudinal study in the Netherlands with children from second through fourth grade (i.e., 8 to 10 years of age) reported that television viewing during second grade displaced reading of books and comic books, subsequently reducing reading ability and producing less positive attitudes toward reading (Koolstra & van der Voort, 1996). In a study of the arrival of television to a community in Canada, Corteen and Williams (1986) found a pattern of results suggesting a negative impact on reading ability among second-grade children (i.e., 6 to 8 years of age). However, a U.S. longitudinal study found that television viewing did not predict changes in reading ability in children between 3rd and 8th grade (i.e., 7 to 14 years of age) (Ritchie, Price, & Roberts, 1987). Together, findings suggest the impact of television on reading skills may be limited to early reading development, when reading is particularly difficult for children, but that this early impact may persist long term for these younger readers.

One reason for mixed findings may be lack of consideration for program content. Viewing educational TV programs, relative to general entertainment content, predicts greater reading skills and frequency of leisure-book reading, both concurrently (Vandewater & Bickham, 2004) and longitudinally (Anderson, Huston, Schmitt, Linebarger, & Wright, 2001; Ennemoser & Schneider, 2007; Koolstra et al., 1997). Similarly, the associations between early television viewing and individual differences in story knowledge depend on the extent to which the television programs themselves contain a narrative story structure (Linebarger & Piotrowski, 2009).

Content may moderate the impact of television viewing on subsequent reading frequency and skills via direct learning. *Between the Lions*, a television program specifically designed to increase literacy skills in young children, produced improvements in skills such as concepts of print and word building; however, these results were found only for children in kindergarten (not first grade) and for those at moderate or no risk for reading difficulties (not for those at high risk; Linebarger, Kosanic, Greenwood, & Doku, 2004). The use of on-screen text, such as closed captioning, can further enhance literacy skills, particularly among children at risk for reading difficulties (Linebarger, Piotrowski, & Greenwood, 2010).

There have been many anecdotal accounts of movies and television stimulating reading and vice versa. Television shows that feature books, such as *Reading Rainbow*, stimulate sales of those books as well as library requests (Wood & Duke, 1997), and the success of books such as the Harry Potter series greatly heightened interest in the subsequent movies, which in turn helped stimulate further sales of the books. Popular television series such as *Star Trek* have spawned book series that are popular with children and adolescents as well as online participation in fan fiction (original stories created by fans of the series). The long-term impact of this cross-platform synergy on reading is unknown but will likely be an important consideration for future research as educational media continue to spread across many platforms (Fisch, 2013).

As with most cognitive outcomes, there is less research on the impact of interactive screen media on reading. Children's Internet use predicted higher scores on standardized tests of reading ability, perhaps because many websites contain text thereby allowing students to practice reading (Jackson et al., 2006). In contrast, research in the United Kingdom has found that reading on screens has become more popular among 8- to 13-year-old children than reading on paper. However, reading ability was inversely related to proportion of reading that was on screens, likely reflecting the types of material read (Clark, 2012). Video-game play predicted decreased reading time and reading skills (Cummings & Vandewater, 2007; Weis & Cerankosky, 2010). Most of the research is correlational in nature and only a few studies use an experimental design. One randomized control trial assigned 6- to 9-year-old nongaming boys to receive a video-game system either immediately or after a 4-month intervention period. Boys who received the video-game system at the start of the study, relative to boys who did not receive this system until the end of the study, demonstrated lower reading and writing scores after 4 months; these effects were mediated by time spent playing video games during the intervention period (Weis & Cerankosky, 2010). Thus interactive screen media may enhance reading and comprehension skills when content allows users to practice these skills, but these media may reduce literacy skills when they displace opportunities to practice reading. It is important for future research to consider the content and nature of media use.

Knowledge Acquisition

Once children are able to comprehend age-directed, professionally produced video, which happens by about 30 months, there is little question that they acquire knowledge from viewing. Numerous laboratory experiments have found that children learn content from television (e.g., Calvert et al., 1982; Lorch et al., 1979). Many investigations directed at formative and summative evaluations of educational television programs have found, by and large, that children 3 years of age and older learn the intended educational content (Fisch, 2004). The same appears to be true of interactive media, with most of the research emphasizing educational computer games, although the research is limited by a relatively small number of studies with well-controlled experimental designs (Tobias, Fletcher, Dai, & Wind, 2011).

Knowledge acquisition is not limited to educational content. Many investigations have found that children learn brand names and jingles and acquire a desire for advertised products (Calvert, 2008). For example, numerous studies have shown that children are strongly influenced by food advertising, primarily on television (Institute of Medicine, 2006). Digital games are also successful at increasing children's desire for products that are embedded within game content (Pempek & Calvert, 2009). Similarly, social marketing campaigns conducted on television have been at least partially successful in influencing use of seatbelts, reducing tobacco and alcohol use, and decreasing risky behaviors (Evans, 2008). Educational programming, advertising, and social marketing are designed to impart knowledge to young viewers, and they are successful in doing so. There is also a great deal of evidence that unintended learning occurs. Many investigations have shown that children acquire knowledge about aggression and other social behaviors from audiovisual depictions (Murray, 2007), including those that are socially positive (Mares, Palmer, & Sullivan, 2008). Similarly, video games can increase both aggressive (C. A. Anderson, Gentile, & Buckley, 2007) and prosocial (Gentile et al., 2009) behavior. Taken together, the research indicates that knowledge acquisition is a major direct effect of screen media on children's cognitive development.

As noted elsewhere in this chapter, the evidence for knowledge acquisition from video is less certain for children under 30 months of age. Studies of object-retrieval, word-learning, and imitation have found a deficit in learning as compared to equivalent real-life experiences and compared to performance by older children (D. R. Anderson & Hanson, 2010). At this point, it is not yet clear how much of the impact of screen media on very young children is due to knowledge acquisition. There is some evidence (K. Choi & Kirkorian, 2013; Kirkorian et al., 2013) that touch-screen media may enhance knowledge acquisition by very young children relative to ordinary video, but it is too soon to say whether applications from touch-screen devices will have a major impact on very young children's knowledge.

Transfer of Learning

Much less is known about transfer of learning than about knowledge acquisition. Transfer from television to real-life situations is certainly possible. For instance, preschool-age children transfer academic knowledge and problem-solving strategies from professionally produced, educational TV programs. Nonetheless, the likelihood of transfer increases with age, program repetition, and similarity between the test problems and those presented in the TV programs (for review, see Fisch, Kirkorian, & Anderson, 2005).

Empirical research on transfer from interactive media is even sparser than that for TV. Nonetheless, transfer from video games to school or other real-life contexts is possible and can be long-lasting, at least in some cases. Most of the existing literature is limited to adolescent and adult populations, and mixed results are likely due to substantial variation in methodology across studies, such as the nature of comparison groups and the content and design of games. Many studies lack scientific rigor, relying heavily on anecdotal evidence and often lacking comparison conditions, making it difficult to draw general conclusions. Nonetheless, it is clear that some individuals transfer from some games in some situations (for review, see Tobias et al., 2011).

Fisch (2000, 2004) proposed a capacity model for comprehension of and transfer from educational television that draws on theories of limited capacity to process information (e.g., Baddeley, 1992; Broadbent, 1958). This model is grounded in a large body of literature on transfer of learning more generally, although it has been subjected to relatively little empirical testing. Fisch proposed several reasons for transfer failure, including difficulty comprehending the original lesson, inadequate mental representation of the solution, and inability to apply the solution to the transfer situation. According to Fisch's model, educational content should be integrated with narrative content as much as possible to ensure that the two are not competing for working memory resources; otherwise children will likely ignore educational content in favor of the story. Regarding representation, children must extract the lesson from the context in which it was delivered. Overly contextualized representations will prevent transfer (Bransford & Schwartz, 1999; Eich, 1985; Gott, Hall, Pokorny, Dibble, & Glaser, 1993). One solution to this problem is to present many different examples of the lesson in a variety of contexts so that children are better able to extract the lesson itself, free of its contextual surrounding (Salomon & Perkins, 1989). This varied repetition may increase the time necessary for children to master a lesson, but the end result will be a more flexible mental representation that can be applied broadly (Chen & Mo, 2004). Application of the solution will also depend on perceived similarity between the original source of information and the new problem (Fisch, 2004; Salomon & Perkins, 1989).

While Fisch's (2000, 2004) capacity model was developed for learning from educational television, many of its basic principles likely apply to interactive media as well. Several other scholars emphasize the importance of reducing cognitive load to maximize learning from games (e.g., Moreno, 2006; Wouters, Pass, & van Merrienboer, 2008). For instance, Moreno's (2006) cognitive theory of learning with media, which applies to any medium and in many ways parallels Fisch's capacity model, emphasizes the importance of supporting learners' processing of target educational content and minimizing extraneous materials that detract from learning. Other scholars have paralleled Fisch's principles for game design by emphasizing such features as decontextualized lessons and varied repetition (Gee, 2007; Wouters et al., 2008), seamless integration of educational content with game play (Egenfeldt-Nielsen, 2007), and similarity between cognitive processes used in the game and in real-life situations (Mayer, 2011). Interactive media also afford many opportunities that are not immediately present in TV. These include controlling the learning experience, experimenting with the nature of feedback provided, adapting game difficulty in accordance with user ability and performance, allowing multiple solutions to a given problem, and encouraging collaboration and competition with others who may be geographically distant. However, most of the existing empirical literature is concerned with comparing learning across media platforms (e.g., computer game versus classroom instruction versus no instruction) rather than with specific attributes of individual games that help or hinder learning (Mayer, 2011). Thus detailed principles to enhance learning and transfer from interactive media remain theoretical with little or no empirical support.

Impact of Media Multitasking

A trend in media habits—and one that has sparked notable concern—is media multitasking, particularly among youth. One concern is the impact that media multitasking may have on academic achievement. For instance, completing homework in front of television may reduce the quality of work completed or the extent to which students learn material at the deepest, most elaborated levels of long-term memory. The Rideout et al. (2010) report on media among 8- to 18-year-olds indicates that nearly one third (31%) of survey respondents said that they used at least one form of media (e.g., watching TV, texting, listening to music) "most" of the time they were completing homework. In contrast, only 19% of respondents said that they "never" used other media while completing homework.

A small set of studies demonstrates an effect of background television on some types of primary activities. When both the primary and secondary (television-viewing) tasks are relatively simple, or when one of them requires relatively little cognitive effort, the impact may be minimal. However, performance on a primary task may be substantially reduced when that primary task requires a high investment of cognitive resources (e.g., comprehending text or completing complex math problems) and when the secondary task is particularly salient or demanding of resources (e.g., a television program with dialogue/narration that requires sustained attention in order for the viewer to follow the plot). For instance, Armstrong and Greenberg (1990) demonstrated that background television interfered with adults' performance on difficult and complex tasks (e.g., problem-solving tasks such as Tower of Hanoi) but had less of an effect (if any) on relatively simple tasks. Similarly, Pool et al. (2000) asked eighth graders (i.e., children 13 to 14 years of age) to complete both simple and complex reading and math problems while a television played in the background. For half of the children, the background television program was of a popular teen soap opera; for the other half, the background television consisted of foreign-language music videos that presumably lacked comprehensible language. Children's performance was negatively influenced by background television (either by a decrease in accuracy or an increase in time to completion), but only when the television program was presumed to require more cognitive resources (the soap opera) and only on the more difficult reading and math problems. Others have reported similar findings insofar as performance on the primary task varies as a function of interest in and motivation to comprehend the television content (Lin, Lee, & Robertson, 2011). Research has not yet elucidated whether children can learn to ignore background television with chronic exposure.

A different but related question addresses the quality of learning that takes place under conditions of multitasking. Even if behavior were not affected by multitasking (e.g., if accuracy or time to completion were equal in the presence and absence of background television), there may be differences in how information is stored in memory under these conditions. Several studies have reported that difficult secondary tasks during encoding reduce subsequent memory for the primary task (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Foerde, Knowlton, & Poldrack, 2006). Moreover, neuroimaging results suggest that different memory systems are engaged during single and dual tasks: Foerde and colleagues reported that medial temporal lobe activity (associated with storage of flexible, declarative knowledge) predicted adults' performance on single tasks, whereas striatal activity (associated with habit learning) predicted performance under conditions of distraction (i.e., when adults completed two cognitive tasks concurrently). In other words, learning during multitasking may result in context-specific memory, whereas focusing on a single task may result in more flexible memory that can be applied in a wide range of new contexts.

There is also concern over the potential long-term impact of frequent task switching on cognitive skills more generally. There is little research that bears on this concern, even as mobile technology is increasingly integrated with traditional forms of media consumption. The studies that do exist focus on the distinction between individuals with tendencies toward breadth-biased and focused cognitive control. Individuals with breadth-biased processing tend to monitor two or more streams of information simultaneously, whereas individuals with focused processing attend to one stream of information while inhibiting other stimuli (Lin, 2009). Research on the impact of these two processing styles is mixed. On the one hand, initial research suggested that frequent multitaskers performed worse than infrequent multitaskers on cognitive tasks that, from the perspective of researchers, required multitasking insofar as participants were required to inhibit irrelevant information while selectively attending to relevant information (Ophir, Nass, & Wagner, 2009). However, others have argued that there are some types of tasks where a breadth-biased processing style may lead to advantages. For example, Lui and Wong (2012) found that frequent multitaskers performed better than infrequent multitaskers on a multisensory-integration task in which auditory information that was synchronized with changes in visual information facilitated performance on visual change detection. The integration of multisensory information increased as a function of participants' trait multitasking behavior, suggesting that these individuals may in fact have an advantage when tasks require one to integrate different streams of information.

This begs the question whether frequent multitaskers can actually process multiple information sources simultaneously (parallel processing) or whether they are simply better at switching between two or more tasks quickly (serial processing). Alzahabi and Becker (2013) compared frequent and infrequent multitaskers on their ability to complete two tasks simultaneously or to switch between the two tasks. Trait multitasking tendency did not predict performance when two tasks were performed simultaneously—both groups performed equally well on dual tasks. However, frequent multitaskers outperformed infrequent multitaskers when asked to switch between the two tasks; though a switching cost existed for everyone, the size of cost was negatively correlated with trait multitasking behavior. In other words, adults who frequently multitasked were better able to switch quickly between different streams of information. It is noteworthy that some research finds that the cognitive burden of multitasking may be reduced with overly practiced behaviors, (e.g., Ruthruff, van Selst, & Johnston, 2006), likely by increasing processing speed in prefrontal cortex, allowing two tasks to be processed quickly, albeit in succession rather than in parallel (Dux et al., 2009). This may explain why frequent multitaskers appear to perform better at task switching in some studies.

This is a relatively new area of research that does not yet point to clear impacts of multitasking. Moreover, there is almost no research focusing on development, nor is there prospective research that examines children or adults before media multitasking has begun as a chronic activity. Consequently, there is no indication as to whether there is an adaptation or learning process whereby media multitaskers systematically change in their ability to process media or in their cognitive abilities more generally. Nonetheless, if multitasking does have an impact on cognitive processing style, it will have implications for formal education in the future of a society that increasingly enables—and arguably encourages—individuals to manage several streams of information concurrently.

Attention and Executive Function

As noted earlier in this chapter, authors have posited that the rapid pacing of television produces attention-deficit-like symptoms in children. Two experiments have been reported that examined immediate effects of TV viewing on attention and executive function tasks in preschool children. In one experiment (D. R. Anderson, Levin, & Lorch, 1977), a group of 5-year-olds were shown a 40-minute version of *Sesame Street* that contained only rapidly paced segments, including frequent shot changes, rapid character movement, and fast music. A second group was shown a version that contained only slowly paced segments. A third group had stories read to them by a parent. Subsequently, children were given the Matching Familiar Figures Test (a measure of impulsivity), a demanding jigsaw puzzle, and a free-play period. No differences were observed in impulsivity, perseverance, or time spent with a toy before shifting activity. The authors suggested that there was no immediate effect on attention-related behavior from watching a rapidly paced television program. The second experiment (Lillard & Peterson, 2011) showed 4-year-old children a rapidly paced entertainment cartoon for 9 minutes (*Sponge Bob SquarePants*) or a more slowly paced educational program (*Caillou*). A third group of children spent 9 minutes drawing. Following the experimental experience, the children were given two tests of executive function (Tower of Hanoi; Head-Toes-Knees-Shoulders). The group that watched the entertainment cartoon performed at a lower level than the other two groups, an effect that the authors interpreted as being due to watching rapidly paced TV. It should be noted that since there was no natural baseline measure for the executive function tasks, it is equally possible that drawing and watching an educational TV program increased executive function and that the rapidly paced program had no effect. Moreover, the two programs differed not only in pacing but also in content. Taken together, these short-term, experimental studies provide no certain conclusion about the immediate effects of watching rapidly paced television.

Speculation about the long-term effects of viewing rapidly paced TV has often focused on orienting responses elicited by visual and auditory changes. These presumably result in “rewiring” of the brain, causing children to become bored and inattentive in relatively slow-paced settings like classrooms (e.g., Christakis et al., 2004; J. L. Singer, 1980). Some correlational studies provided evidence in support of these claims. For instance, Christakis and colleagues (2004) analyzed data from the National Longitudinal Survey of Youth and reported that children’s television viewing at 1 and 3 years of age predicted attention problems at 7 years of age. Miller, Miller, and Halperin (2009) found a significant association between parent reports of preschooler TV viewing time and teacher ratings of inattentive and impulsive behavior. Similar findings have been reported for childhood television viewing and adolescent attention problems (Landhuis, Poulton, Welch, & Hancox, 2007). However, findings from other studies have been mixed (Obel et al., 2004; Miller et al., 2009; Mistry, Minkovitz, Strobino, & Borzekowski, 2007; Stevens & Mulsow, 2006). In addition to methodological differences between studies, few used clinical diagnoses of attention disorders and many relied on older data sets collected at a time when high-quality, educational programming for preschoolers was scarce and when infant-directed programming was nonexistent. Additionally, the analyses do not make clear whether attention problems cause greater television viewing or the reverse. That is, children with attention-deficit symptoms may be more attracted to television than are typical children, or parents of such children may find television useful as a way to manage their children’s behavior. Moreover, several studies that employed appropriate statistical controls (e.g., for parent education and access to TV in bedrooms) found no meaningful relation between television exposure and attention problems, either cross-sectionally (Acevedo-Polkavich, Lorch, Millich, & Ashby, 2006) or longitudinally (Foster & Watkins, 2010). If such a relation does exist, it is equally possible that the effect is bidirectional, that television viewing is a marker for other environmental determinants of attention problems, or that early attention problems cause a subsequent increase in use of media (Gentile et al., 2012; Mazurek & Engelhardt, 2013; Miller et al., 2009).

Other studies suggest that any impact of early television viewing on attention skills depends on the content viewed and the age of exposure. For example, Zimmerman and Christakis (2007) reported that the relation between early TV viewing and subsequent attention problems exists only for exposure prior to 3 years of age (not later during the preschool years) and only for violent and nonviolent entertainment content (not educational content). Some studies suggest that indicators of self-regulation and executive function increase after preschoolers view educational programming but decrease after viewing purely entertainment or violent content (C. C. Anderson & McGuire, 1978; Friedrich & Stein, 1973; Salomon, 1979). Similarly, one longitudinal study reported that exposure to adult-directed (but not child-directed) television programing at 1 and 4 years of age predicted lower scores on measures of executive functioning at 4 years of age (Barr et al., 2010).

Regarding interactive media, one cross-sectional study found a correlation between self-reported use of video games and attention problems in children, adolescents, and adults (Swing, Gentile, Anderson, & Walsh, 2010). However, computer games that are intentionally designed to enhance attention and executive function skills are effective. For example, 4- and 6-year-olds showed greater improvements in executive attention and intelligence after 5 days of attention training on a flanker task that is commonly used in tests of executive function (identifying the direction a central fish is pointed while ignoring the directions of flanking fish) compared to children who did not get this training (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005). Others have reported similar findings for adults (e.g., Nouchi et al., 2013). Moreover, computerized training to increase working memory subsequently reduced parent-reported symptoms of inattention, hyperactivity, and impulsivity in 7- to 12-year-old children with attention-deficit/hyperactivity disorder (Klingberg et al., 2005). Though more research is needed to elucidate the possible causal role of screen media in the long-term development of attention and executive control skills, it is clear that any such study must incorporate age of exposure and television or game content consumed, not just amount of time with media.

There is a small but growing body of literature on the impact of interactive media, particularly high-action video games, on visuospatial attention skills. In one of the most widely cited studies, Green and Bavelier (2003) compared adults who frequently play high-action, first-person video games to nongamers. They found that expert gamers outperformed nongamers on all tasks. For instance, gamers were more accurate at remembering the locations of objects briefly presented in peripheral vision, and they processed visual information more quickly. Most notably, Green and Bavelier conducted a training experiment in which novice gamers played one of two games 1 hour per day for 10 consecutive days. Half of the participants played a high-action, first-person game with complex visual displays that required tracking of multiple objects on screen and fast responses to new objects; the other half played a puzzle-solving game that required mental rotation for a single object at a time. Results indicated that action gamers showed greater pretest to posttest gains than did puzzle gamers on measures of visual attention, consistent with the hypothesis that the expert-gamer advantage seen in previous research is at least partly attributable to a causal effect of game play. Similar findings have been reported by others (e.g., Feng, Spence, & Pratt, 2007). However, extensive and/or frequent gaming experience may be necessary to see these advantages in visual-attention skills (Boot et al., 2008).

Spatial Cognition

Comprehension of edited video requires viewers to make frequent inferences regarding (among other things) spatial relations between shots. For example, if an exterior shot shows a person approaching a door into a building followed by cuts to the person walking in an interior corridor, viewers must make inferences about the spatial relation between these actions (i.e., that the person is inside of the building that was shown in the first shot) even if the transition of the person walking from outside to inside is not explicitly shown. Even preschool-age children are capable of making spatial inferences based on edited video, although they make more errors than do older children (R. Smith et al., 1985). Making these inferences is a complex cognitive process. D. R. Anderson, Fite, Petrovich, and Hirsch (2006) recorded changes in blood flow in the brain (using functional magnetic resonance imaging) while adults viewed edited video. When viewing normal sequences of shots (as compared to random sequences of shots), they found activation of right, inferior parietal cortex among other areas. They interpreted this finding as indicating adults' activation of neural circuits associated with allocentric representation of the space in which the on-screen actions occurred.

There is some evidence to suggest that viewing edited video can enhance visual search and spatial skills, such as relating visual detail to the whole, at least in the short term (Salomon, 1974; Salomon, 1979; Salomon & Cohen, 1977). Rovet (1983) developed animated films that represented block designs (used in tests of spatial abilities such as the Wechsler Intelligence Scale for Children). Third-grade children (i.e., 8 to 9 years of age) watched films that showed 16 examples of either full, partial, or no rotations of the block designs in space. Additional groups manipulated real block constructions or had no training at all. The children who saw the full rotation film performed as well on tests with different block designs as children who had training with real block constructions. Both of these groups, in turn, were superior to the group that saw the partial rotation film, which in turn was superior to the group that saw the film with no rotation as well as the control group that did not receive training. These effects were found both with immediate testing and after 2 weeks.

On the other hand, Harris and Williams (1986) assessed spatial cognition (WISC block design subtest) in children before and 2 years after television came to a small city in Canada. There was no difference in spatial cognition when comparing performance before and after television's inception in that city or when comparing to cities that already had television. Taken together, the small amount of evidence suggests that television and film designed to promote spatial skills can do so, but watching television, per se, has no systematic effect on spatial cognition.

There is relatively more research on the impact of interactive screen media on spatial cognition, although little of it is with children. Such studies often focus on video games that require the use of visuospatial working memory such as mental rotation. For example, Boot and colleagues (2008) reported that adults who were assigned to play Tetris, a puzzle-solving game requiring rotation of block designs, showed larger posttest gains on measures of spatial ability than adults assigned to play a high-action, first-person video game that did not require such extensive mental rotation. Notably these game-induced improvements in spatial ability were limited to the specific type of skill practiced through game play (mental rotation) and did not extend to other measures of visuospatial ability (e.g., spatial n-back task, Corsi block-tapping task). Similar findings have been reported by others (for review, see Uttal et al., 2013).

Other research demonstrates more general impacts of video-game training: Feng et al. (2007) reported that adults who played an action video game for 10 hours showed gains in spatial attention and mental rotation compared to controls who played a 3D maze/puzzle game. Some studies have reported improvements on various tests of spatial ability after short-term video-game intervention in an experimental design (e.g., Dorval & Pepin, 1986), whereas others only found support for correlations between preexisting, long-term game experience and spatial skills (with the direction of causality unknown; e.g., Sims & Mayer, 2002). Both correlational and experimental studies with children and adolescents report similar findings (De Lisi & Wolford, 2002; Dye & Bavelier, 2004; Subrahmanyam & Greenfield, 1994). Importantly, Feng and colleagues also found that females showed greater posttest gains than did males, while Subrahmanyam and Greenfield (1994) observed that gains were greatest for children with relatively low pretest scores for spatial skills, thus providing a unique opportunity for video games to decrease preexisting gender gaps and to improve skills among those children who most need intervention.

Additional research is needed to explore the impact of screen media on spatial skills across development, especially given that the majority of studies focus on adult populations and few incorporate experimental designs allowing researchers to establish the direction of causality. Taken together, however, it appears that interactive screen media can influence visuospatial skills and such attention skills as visual search. Effects on children, especially long-term developmental effects, are as yet unknown.

Vocabulary and Language Skills

There is a substantial literature on the impact of television on language, including lab experiments on word learning from video and longitudinal studies on associations between early media exposure and subsequent language skills. Moreover, the research addresses different language skills, such as learning specific vocabulary versus complex syntactical rules. As with other media effects, the impact of television on language development depends on both the age of the viewer and the specific content viewed.

Studies exploring the impact of television's arrival in specific geographical regions have found that vocabulary size was positively associated with television use, especially at younger ages (e.g., Harris & Williams, 1985; Schramm et al., 1961). These findings may be limited to the period when television was a novelty and may be due in part to more affluent families being relatively early adopters of the medium. Among established viewers, the association between TV viewing and vocabulary is slightly negative (Selnow & Bettinghaus, 1982). However, watching educational programming, particularly *Sesame Street*, during early childhood predicts both concurrent vocabulary size and subsequent growth in vocabulary (Rice, Huston, Truglio, & Wright, 1990; Selnow & Bettinghaus, 1982; Wright et al., 2001).

Experimental evidence demonstrates that children can learn new words from television by at least 36 months of age (Rice & Woodsmall, 1988). By about 36 months of age, children are just as likely to learn names of novel objects and actions when they are labeled on screen or in person (Allen & Scofield, 2010; Krcmar et al., 2007; Roseberry et al., 2009; Troseth et al., 2006). Yet while television may be a useful tool for teaching specific vocabulary, it may not be suitable for teaching more complex aspects of language, such as syntactic structure; case and correlational studies find little evidence of TV effects on syntax usage and comprehension (Gola, Mayeux, & Naigles, 2011; Van Lommel, Laenen, & d'Ydewalle, 2006).

With respect to second language learning, the Internet is replete with anecdotal accounts of children and their parents learning English from watching television. An evaluation experiment of the preschool children's program *Dora the Explorer* found that English-speaking viewers showed significant learning of Spanish vocabulary from the program (Linebarger, 2001). Although viewing television programs or playing video games in a second language predicts second language skills (Kuppens, 2010), it is unclear whether media exposure causes improved language skills or whether the reverse is true, that is, that children with more well-developed skills in the second language are thus more likely to watch television or play video games that feature that language. Moreover, it is unclear whether such improvements extend to improved syntax or simply reflect increased vocabulary given that many language-skill assessments capture both. To our knowledge there have been no studies of media content that are specifically designed to teach grammar.

As noted earlier, research is less clear on screen-based word learning before 30 months of age. A small number of studies report that even 24-month-olds can learn words from screens (e.g., Vandewater, Barr, Park, & Lee, 2010); however, most studies demonstrate a video deficit before 30 months of age whereby toddlers do not learn words from screens even though they readily learn from the same demonstration in person (Krcmar, 2010; Krcmar et al., 2007; Troseth et al., 2006). This video deficit may last longer for verbs than for nouns (Roseberry et al., 2009). Moreover, there is mixed evidence for the utility of commercially available videos designed to increase vocabulary among infants. For example, one study using *Baby*

Wordsworth (from the Baby Einstein video series) reported that infants showed greater vocabulary gains after viewing the video at home for several weeks (Vandewater et al., 2010), whereas other studies find no benefit of this video (DeLoache et al., 2010; Robb, Richert, & Wartella, 2009), especially when compared to infants whose parents were asked to directly teach the words without the use of video (DeLoache et al., 2010). Moreover, research suggests that the video deficit applies to even the most basic language skill, phoneme perception: As described previously in this chapter, Kuhl et al. (2003) reported that American infants maintained discrimination of phonemes found in Mandarin (but not in English) only when exposed to a live speaker. Infants exposed to video or audio recordings of the Mandarin speaker showed typical decline in making these phoneme distinctions by 12 months of age.

Longitudinal research indicates that the impact of early video viewing on subsequent vocabulary may depend on content. Linebarger and Walker (2005) reported that viewing some programs (e.g., *Teletubbies*) between 6 and 36 months of age predicted lower expressive vocabulary scores at 36 months, whereas early viewing of narrative-based television programs (e.g., *Blue's Clues*, *Dora the Explorer*, *Dragon Tales*) predicted greater vocabulary and expressive language gains. Like other such correlational studies, it is difficult to know whether language-gifted infants may be more attracted to different types of TV content than are less-gifted infants, or whether the programs themselves enhance language development. It is also possible that television influences language development indirectly insofar as television may reduce the language input that children receive from their parents (Kirkorian, Pempek, Murphy, Schmidt, & Anderson, 2009; Zimmerman et al., 2009). In fact, Zimmerman et al. (2009) argued that the entire negative effect of television on early language development is mediated by reductions in parent language directed at the child while a television is in use.

Television may have only limited value for language development before 3 years of age. However, there may be some situations in which toddlers can learn new words from video. For example, O'Doherty et al. (2011) found that toddlers were more likely to learn novel words from video when watching a reciprocal social exchange (i.e., between two characters on screen); thus very young children may be more likely to acquire vocabulary when television characters interact with each other rather than address the audience directly. Furthermore, some studies suggest that toddlers may be able to learn new vocabulary from interactive screen media (e.g., Kirkorian et al., 2013; Roseberry et al., 2013). Interactive computer programs may have particular utility for teaching new vocabulary to children with autism (Moore & Calvert, 2000). As in other areas, however, there is little research that systematically explores the association between use of interactive media and subsequent language development.

Educational Achievement

In principle, media could affect educational achievement by influencing cognitive development. In addition, media could affect interests, motivation, time use, and compliance to the expectations implicit in a formal educational environment. Many studies have explored the association between media, especially television, and educational achievement. Most of these have been simple correlational investigations that examine total amount of current media consumption and performance on a state or national assessment of educational achievement. Few studies take media content into account, and the few that do are open to problems of content self-selection (e.g., more intelligent children may choose to watch educational content).

The typical finding from simple correlational studies of media time with achievement is a curvilinear, inverted-U-shaped function with higher achievement at moderate levels of media consumption (usually 1 to 2 hours per day) and lower achievement at either low or high levels of media consumption (for reviews, see Comstock & Paik, 1991; Neuman, 1995).

As noted earlier, children's use of media varies considerably in relation to a large variety of demographic factors such as age, socioeconomic status (SES), ethnicity, family size, and many others (e.g., Lee et al., 2009); most of these factors are also related to educational achievement. When these factors are taken into account, the association between media-use time and educational achievement changes, and when many of these are statistically controlled, the association is often null. For example, Comstock and Paik (1991) examined results from a yearly assessment of achievement conducted in California. They noted that among children from lower-SES families, the association was positive, that is, the more the children watched TV, the better they did in school; conversely, among high-SES children, the association was negative. For middle-SES children the association was a bell curve, with moderate levels of TV viewing associated with greatest achievement.

Use of media on school days may have a unique influence on academic achievement. In a cross-sectional study, self-report data showed that the odds of poorer school performance among children in Grades 5 through 8 (i.e., 10 to 14 years of age) increased with greater weekday TV time but was unrelated to weekend TV viewing (Sharif & Sargent, 2006). Note that this finding is suggestive that TV viewing may displace homework during the week, either by reducing the total amount of time spent doing schoolwork or by reducing the quality of schoolwork done concurrently with TV viewing. As we have already noted, media multitasking, including doing homework while watching audiovisual media, leads to poorer task performance. The finding that weekend TV viewing is unrelated to school performance is inconsistent with the idea that use of media reduces cognitive functioning more generally.

Studies based on total use of media ignore media diet and treat all media content as being equivalent across levels of media use. In fact, heavy users of media tend to consume different types of content than do light users (e.g., Fetler, 1984). Thus, this research strategy ignores the possibility that some types of media content may facilitate educational achievement, whereas other types of content may impede it, and these differing types of content vary across levels of media use.

The relatively few studies that have taken into consideration media content have found that content consumed, rather than time with media generally, has the greatest relation with educational achievement. A good deal, although not all, of educational media content is deliberately designed to teach academically relevant content and skills. A reasonable question, therefore, is whether children's consumption of educational media content is positively related to academic achievement. Although many program-evaluation studies have found that specific academic content is learned from educational media and that near and far transfer occurs (Fisch, 2004), only a few studies have actually investigated the association between consumption of educational media and measures of general academic success such as grades or achievement test scores.

In the United States, *Sesame Street* is the longest running preschool program that is specifically designed to enhance school readiness. In a study of children participating in the preschool-education program Head Start, investigators found that watching *Sesame Street* at home predicted better preparation for school entry (Zill, Davies, & Daly, 1994; Zill, 2001). In 4-year-olds, viewing once a week or more was associated with telling better connected stories when pretending to read, recognizing letters of the alphabet, and counting to 20 or more. Relative to nonviewers, the associations with these measures of academic readiness were greatest among children from the most impoverished families. In first and second grade (i.e., 6 to 8 years of age), children who had been preschool viewers of *Sesame Street* were better readers than were nonviewers.

In an investigation known as the Early Window project, Wright et al. (2001) longitudinally studied two cohorts of children from relatively impoverished circumstances. Children were 2 or 4 years of age at the beginning of the study and were followed for 3 years during which parents maintained detailed media-use diaries. For the younger cohort, after controlling for quality of home environment, the more children watched educational television or videos early on, the better they performed on later tests of reading, math, vocabulary, and other types of school readiness. These effects were not significant for the older cohort, suggesting that educational media may have been most influential during the early preschool years or when the narrative and educational content were well matched to the viewers' developmental level. When other types of media content were considered, general-audience entertainment programming was negatively related to cognitive outcome in both cohorts, whereas animated child entertainment content was largely unrelated to outcome. Taken together, this important study is suggestive that educational content is positively related to early academic achievement, especially when that content is consumed during the early preschool years. On the other hand, general-audience entertainment content is negatively related to early academic achievement. An interesting subsidiary finding from this study is that early cognitive development predicted later use of media. Children who were more cognitively competent were more likely to later consume educational media, whereas less cognitively competent children were more likely to consume general-audience entertainment content. Taken together, the findings suggest that the connection between media and cognitive development is bidirectional and dependent on content.

Preschool TV viewing of educational content predicts much longer term outcomes. In a study referred to as the "Recontact Study" (Anderson et al., 2001), individuals who had participated in extensive studies of media consumption as preschoolers in Springfield, Massachusetts, and Topeka, Kansas, were contacted again as adolescents and asked for permission to examine their high school transcripts. Among other findings, the study revealed that viewing educational TV as preschoolers predicted better high school grades in English, math, and science, especially for boys. At the time the research participants were preschoolers, there were only a few educational preschool

TV programs available to watch. Of these, the program most consistently associated with higher grades was *Sesame Street*, the program that most emphasized school readiness. Without taking content into account, total TV viewing as preschoolers was a positive predictor for boys and a negative predictor for girls; however, after content was taken into consideration, total amount of TV viewing as preschoolers did not predict high school performance. Preschool viewing of general-audience programming (not including action/violent programs) was unrelated to high school grades, but viewing action/violent programs predicted lower grades, particularly for girls. The main conclusions to be drawn from this study are that content viewed during preschool (but not total TV-viewing time) is the prime determiner of later academic outcome, and that boys and girls are influenced somewhat differently. The authors interpreted the latter finding as consistent with poorer school readiness in general among boys, so that educational TV programming during the preschool years helps boys improve school readiness. Action/violent programming, on the other hand, may cause girls to be less compliant in school, setting the conditions for long-term consequences of poorer academic achievement.

With respect to interactive media, cross-sectional correlational studies find that adolescents with high levels of video-game play spend less time reading and completing homework (Cummings & Vandewater, 2007) and have lower school performance (Gentile, 2009). However, not all cross-sectional studies find such a relation (Sharif & Sargent, 2006). In the case of violent content, the relation between video-game play and academic performance was mediated by adolescents' hostility, such as self-reported conflict with teachers and physical fights at school (Gentile, Lynch, Linder, & Walsh, 2004). In the absence of longitudinal data, these findings are difficult to interpret. For instance, adolescents' positive academic orientation predicted their Internet use 2 years later (Willoughby, 2008), suggesting that any contemporaneous relation between use of media and academic achievement may be confounded by individual differences in attitude toward education. Unlike video games, Internet use positively predicted subsequent academic performance among low-income youth (Jackson et al., 2006). Thus it appears that use of interactive media may be associated with academic achievement. However, the direction of influence remains unclear. Any effect likely depends on content and nature of media use.

To date all studies of the effects of media on academic achievement are correlational. The chief problem with such studies is that to a great extent, children self-select the media content that they consume. Even though correlational studies statistically adjust for factors such as SES, it is always possible that children's self-selection of media determines the results. So, hypothetically, children who are academically inclined may prefer to watch programs such as *Sesame Street* that emphasize academic content. Such children might well have done better in school regardless of their media diet. In fact, Wright et al. (2001) interpreted their results as bidirectional insofar as media influenced cognitive ability, which in turn influenced children's media preference. What is clearly needed is a program of experimental research that randomly assigns children to a diet of educational media in comparison to untreated controls. One major study has taken such an approach although not with a focus on education. This was accomplished via multiple encouragements to parents of young preschool children to replace aggressive content with high-quality prosocial/educational content (rather than reducing overall use of media; Christakis et al., 2013). After 6 months they found improved social behavior based on parent assessments. However, the researchers did not examine academic achievement or school-readiness skills. Until a major clinical trial of this sort is conducted with respect to achievement and cognitive skills, the evidence on the impact of media diet (and total amount of media exposure) is open to question.

Taken together, the research suggests that media have both direct and indirect effects on academic achievement. Direct effects are primarily due to positive effects of educational content. Negative effects are likely indirect and due to displacement of early reading, displacement of or multitasking during homework, and enhancement of noncompliance and impulsivity, primarily from violent, antisocial content.

COMMENTS AND CONCLUSIONS

There is little question that contemporary children spend vast amounts of time with screen media, although there is considerable variability across children. With respect to television, infants pay some attention, but with less comprehension than they have for equivalent real-life situations. Children probably do not understand most television programming until about 30 months of age. Popular commentaries to the effect that children are mesmerized by ever-changing images, viewing with essentially blank minds, are clearly incorrect. Children enter and leave viewing areas, look at and away from the screen frequently, and engage in active inferential comprehension activities while they view. As one might expect, comprehension develops throughout early and middle childhood, with essentially adult-level comprehension being reached by about 12 years of age.

The most obvious and well-documented direct impact of television is on knowledge. Children acquire both intended and unintended knowledge from educational and entertainment programming as well as from advertising. Some of this knowledge transfers to academic tasks and other situations in real-world settings. Knowledge acquisition probably underlies the positive association between educational television viewing and subsequent academic achievement. Not much is known about knowledge acquisition from interactive media, especially in early childhood, but many evaluations of educational software indicate that children are quite capable of gaining knowledge from interactive media. In particular, there appears to be a synergy in learning across media platforms.

One form of knowledge acquisition is reflected in language comprehension and use. Here, the evidence is mixed. Before 2 to 3 years of age, there is little evidence that media are a positive influence on language development. In fact, the influence may be negative, in part because families that are heavy users of media may be more limited in their interpersonal communications with their very young children. The evidence is fairly clear that by their third birthdays, children acquire vocabulary, but not syntax, from using media, especially educational media. Although there is a great deal of anecdotal commentary about second-language learning from television, the research is limited.

Background television and media multitasking are mostly associated with negative outcomes. Performance on homework or other tasks that are completed while using media is poorer in quality. Moreover, background television may have a negative impact on executive function and language development. Child research on these issues, however, is limited to only a few studies.

Although other direct effects of television viewing on cognitive development have been widely hypothesized, the evidence is not strong. There have been many claims that television viewing is detrimental to the development of attention skills, but the evidence is mixed and easily open to alternative interpretation. Where use of media has been found to be associated with attention deficits, it is unclear whether attention deficits cause more television viewing or that television viewing causes attention deficits. With respect to cumulative effects of media on children, much the same can be said for spatial cognition, mental elaboration, imagination, creativity, story comprehension, and other cognitive skills. Studies have found associations, but there is no categorical evidence that use of media is either directly harmful or beneficial to these skills. On the other hand, it is fairly clear that video content that is specifically designed to teach cognitive skills can do so, and that spatial cognition and some attention skills can be improved from playing video games.

With respect to indirect effects of media, it is clear that knowledge acquisition has both positive and negative consequences insofar as children's behavior is influenced in real-world situations by what they have learned from media. On the positive side, children clearly can learn academically relevant knowledge from educational content, which likely contributes to their academic achievement. On the negative side, however, they can also learn potentially harmful lessons from irrelevant or antisocial content. For example, unhealthy food preferences can be fostered by television advertising, contributing to obesity, and aggression and disrespectful behavior can be learned from violent programming, contributing to antisocial behavior.

The use of media takes time and therefore leaves less time for other activities. On the whole, research examining the impact of the introduction of television reveals that the time children spent watching television displaced other functionally similar activities with media such as reading comic books or listening to the radio. In contrast, the time children spend with interactive digital media has not been shown to displace television viewing; rather, there has been a substantial increase in the amount of time spent using multiple media simultaneously. With respect to reading, displacement may be of considerable importance. Although the use of electronic media does not displace much reading time in established readers, it may do so for beginning readers. The clearest negative effects of television viewing on reading have been found with respect to TV viewing during first and second grade (i.e., 6 to 8 years of age), when reading is most difficult. It is particularly important that parents prevent use of media from displacing reading during this critical period.

Apart from the evidence on reading, few studies have attempted to determine whether there are critical periods in development during which media exert the greatest impact. The finding by Wright et al. (2001) that *Sesame Street* had its greatest positive impact on 2- through 4-year-olds (compared to older children) is indicative that there may be developmental periods when media may have their greatest impact with respect to particular outcomes. Nonetheless, it is crucial to consider the developmental appropriateness of content as well. Similarly, there are relatively few studies that have examined ethnicity or gender as moderators of cognitive impact, although these factors, along with SES, have frequently been considered in large-scale evaluations of particular TV programs such as *Sesame Street*.

Although there are many claims that the media affect brain development relevant to cognition, these claims are fundamentally circular and not based on research. Insofar as media influence cognition and behavior, ipso facto they influence the brain. It remains for future research to show whether and how media influence the growth and differentiation of neural tissue, gene expression, or particular aspects of brain physiology. To date, such research does not exist, although there have been some interesting studies of neural activity during use of media by adults.

Despite the central place of interactive screen media in the contemporary adult world, including in the economy, work, social interactions, and entertainment, we remain impressed by the continued power of television. At all ages during childhood, television remains the dominant medium, with about twice as much use as the interactive media. This is particularly surprising since the audiovisual electronic media are otherwise so similar to television. Of course, this state of affairs may be temporary insofar as screen media technologies are rapidly evolving and many of the most attractive interactive devices are not yet available to many children.

Nevertheless, the relative power of television during childhood is due in part to the difficulty for children of using standard computer-interface devices, especially mouse and keyboard. Typically, children do not master these tools until 4 years of age or older with fluent skill requiring both motor maturity and some degree of literacy. With the advent of touch-screen technologies, motion capture, voice and speech recognition, as well as other user interfaces, this state of affairs has been changing rapidly. It remains to be seen whether the relative balance of children's use of media changes as devices incorporating these interface technologies become increasingly available to children.

Nevertheless, there is a fundamental difference between television (and movies) compared to interactive devices. The television screen presents a sequence of images and sounds that unfold according to a carefully constructed cinematic montage that children substantially comprehend by about 3 years of age. Image and audio change fairly frequently, inducing bottom-up orienting to novelty that is seamlessly combined with top-down comprehension activities. Taken together, paying attention to television feels effortless, and the viewer is constantly being invited to find out what happens next. Once attention has been sustained for about 15 seconds, viewers enter a state of attentional inertia wherein both comprehension and memory are enhanced, with reduced influence from the world outside of the screen. The viewer may enter a state of flow (Csikszentmihalyi & Kubey, 1981) that is experienced as pleasant and that may to some extent allow viewers to manage their moods (Anderson, Collins, Schmitt, & Jacobvitz, 1996).

Interactive media, on the other hand, usually require choices and actions. It is possible that these features can afford more opportunities for flexible learning, for instance, through trial-and-error problem solving. However, depending on program design, these choices and actions may serve to break the flow of integrated bottom-up and top-down cognition that is so characteristic of television viewing. As a consequence, attentional inertia may not emerge in the same manner as it does in television and toy play. As new interface technologies make choices and actions more natural to children, however, the interactive media may facilitate cognitive flow and eventually become predominant.

As a final comment, despite the time children spend with media, and despite its demonstrated impact on cognitive development, there is in toto relatively little research on the cognitive processes underlying children's media use or its effects. In contrast, there is a vast literature on the cognitive processes underlying development of reading. The relative lack of research on screen media is partly due to rapid changes in media technology and partly due to the fact that media researchers are scattered across a wide range of disciplines, including communication, education, marketing, pediatrics, psychology, public health, and sociology. It is also due to the general tendency to pay more attention to social processes and to health outcomes (Calvert & Wilson, 2008; Comstock & Paik, 1991; D. Singer & Singer, 2001; Valdivia & Scharrer, 2013) than to cognitive outcomes. Nevertheless, contemporary children's time and minds are immersed in a world of electronic media that are surely having a sustained impact on their thinking and on their development. It would be well for both the field and for children if future research were to extend current knowledge about the many ways that media affect cognitive processes and outcomes.

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Content Feature Extraction in the Context of Social Media Behavior

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Abstract. Twitter accounts are used for a multitude of reasons, including social, commercial, political, religious, and ideological purposes. The wide variety of activities on Twitter may be automated or non-automated. Any serious attempt to explore the nature of the vast amount of information being broadcast over such a medium may depend on identifying a potentially useful set of content features hidden within the data. This paper proposes a set of content features that may be promising in efforts to categorize social media activities, with the goal of creating predictive models that will classify or estimate the probabilities of automated behavior given certain account content history. Suggestions for future work are offered.

Keywords: Twitter, Social Media, Content Feature Extraction

1 Background

1.1 Introduction

Social media activity data, in the case of this paper Twitter account activity, can be understood as consisting of two primary components, metadata or demographics, and content data. Metadata involves external characteristics such as time of activity, time of account creation, location, type of platform used for activity, number of friends, followers, and more. Content data involves syntactic and semantic characteristics. The focus of this paper is on content data, in particular, content feature extraction that can be implemented on a large set of text data in order to enable categorization of types of activities and classification of activities as automated versus non-automated.

1.2 The Content Data Elements and Their Encoding

Below are some linguistic features that can be extracted from the text content generated by Twitter users. These features can be used to generate mathematical "signatures" for different types of online behaviors. In this way, they augment account demographic features to create a rich, high-fidelity information space for behavior mining and modeling.

1. *The relative size and diversity of the account vocabulary*
   Content generated by automated means tends to reuse complex terms, while naturally generated content has a more varied vocabulary, and terms reused are generally simpler.
2. *The word length mean and variance*
   Naturally generated content tends to use shorter but more varied language than automatically generated content.
3. *The presence/percentage of chat-speak*
   Casual, social users often employ simple, easy to generate graphical icons, called emoticons. Sophisticated, non-social users tend to avoid these unsophisticated graphical icons.
4. *The presence and frequency of hashtags*
   Hashtags are essentially topic words. Several hashtags taken together amount to a tweet "gist". A table of these could be used for automated topic/content identification and categorization.
5. *The number of misspelled words*
   It is assumed that sophisticated content generators, such as major retailers, will have a very low incidence of misspellings relative to casual users who are typing on a small device like a phone or tablet.
6. *The presence of vulgarity*
   Major retailers are assumed to be unlikely to embed vulgarity in their content.
7. *The use of hot-button words and phrases ("act now", "enter to win", etc.)*
   Marketing "code words" are regularly used to communicate complex ideas to potential customers in just a few words. Such phrases are useful precisely because they are hackneyed.
8. *The use of words rarely used by other accounts (e.g., tf-idf scores)*
   Marketing campaigns often create words around their products. These created words occur nowhere else, and so will have high tf-idf scores, which is the term frequency–inverse document frequency score.
9. *The presence of URL's*
   To make a direct sale through a tweet, the customer must be engaged and directed to a location where a sale can be made. This is most easily accomplished by supplying a URL. URL's, even tiny URL's, can be automatically followed to facilitate screen scraping for identification/characterization.
10. *The generation of redundant content (same tweets repeated multiple times)*
    It is costly and difficult to generate unique content for each of thousands of online recipients. Therefore, automated content (e.g., advertising) tends to have a relatively

small number of stylized units of content that they use over and over. The result is an account with "redundant" content.

2 Method

2.1 Data

Twitter account activity data is available through the Twitter API (application program interface) which returns requests for random samples of data in the JSON (JavaScript Object Notation) data structure containing both demographics and content.

Content data (tweets) are returned (in the JSON structure) as character strings of length 1 to 140 characters. They may be in any language or no language at all. Tweets can contain any combination of free text, emoticons, chat-speak, hashtags, and URL's. Twitter does not filter tweets for content (e.g., vulgarisms, hate speech).

For this study a sample of the activities of 8845 Twitter accounts containing the content of 1,048,395 tweets was collected for content analysis.

2.2 Procedures

A vector of text features is derived for each user. This is accomplished by deriving text features for each of the user's tweets and then rolling them up, i.e. summing and normalizing the data. Therefore, one content feature vector is derived for each user from all of that user's tweets.

The extraction of numeric features from text is a multi-step process:

1. Collect the user's most recent (up to 200) tweet strings into a single set (a Thread).
2. Convert the thread text to upper case for term matching.
3. Scan the thread for the presence of emoticons, chat-speak, hashtags, URL's, and vulgarisms, setting bits to indicate the presence/absence of each of these text artifacts.
4. Remove special characters from the thread to facilitate term matching.
5. Create a Redundancy Score for the Thread. This is done by computing and rolling up (sum and normalize) the pairwise similarities of the tweet strings within the thread using six metrics: Euclidean Distance, RMS-Distance, L1 Distance, L-Infinity Distance, Cosine Distance, and the norm-weighted average of the five distances.
6. The thread text feature vector then contains as vector components user scores based on features such as the emoticon flag, the chat-speak flag, the hashtag flag, the URL flag, the vulgarity flag, and the Redundancy score.

A list of 23 potential content related features was created and calculated for each of the 8845 Twitter accounts in the sample.

Table 1. Sample of Raw Data

	Feature	Set 1	Set 2	Set 3
	UserID	22821737	22822092	22823578
1	**tweets**	10	190	133
2	**adj**	1.7	2.247368	1.774436
3	**adv**	0	0.2684211	0.09774436
4	**art**	0.1	1.994737	1.338346
5	**commnoun**	4.2	1.215789	1.736842
6	**conj**	0.6	0.6947368	0.3458647
7	**interj**	0	0.005263158	0.007518797
8	**prep**	0.6	0.3736842	0.3383459
9	**pron**	0	0.368421	0.03759398
10	**Propnoun**	1.4	1.931579	1.699248
11	**verb**	0.4	1.215789	0.6315789
12	**stopword**	0	0.06842105	0.04511278
13	**vulgar**	0	0.01578947	0
14	**hash**	0.6	0.4894737	0.1052632
15	**urls**	1	0.1473684	0.9774436
16	**case**	0	0	0
17	**punc**	1	0.9842106	1
18	**emo_chat**	0	0	0
19	**good_len**	82.2	74.14211	70.9624
20	**good_cnt**	13.3	16.08947	12.59398
21	**bad_len**	0.7	1.394737	1.233083
22	**bad_cnt**	0.1	0.2	0.1954887
23	**redund**	0.7686407	0.7453661	0.740773

Table 2. The List of 23 Features for Analysis

	Feature	Description
1	**tweets**	Number of tweets up to 200
2	**adj**	Number of adjectives per tweet
3	**adv**	Number of adverbs per tweet
4	**art**	Number of articles per tweet
5	**commnoun**	Number of common nouns per tweet
6	**conj**	Number of conjunctions per tweet
7	**interj**	Number of interjections per tweet
8	**prep**	Number of prepositions per tweet
9	**pron**	Number of pronouns per tweet

Feature	Description
10 Propnoun	Number of proper nouns per tweet
11 verb	Number of verbs per tweet
12 stopword	Number of stop words matching a list- per tweet
13 vulgar	Number of vulgar words matching a list- per tweet
14 hash	Number of hashtags per tweet
15 urls	Number of urls per tweet
16 case	Relative frequency of usage of both lower and upper case
17 punc	Relative frequency of usage of punctuation
18 emo_chat	Number of emoticons per tweet
19 good_len	Number of *characters* in correctly spelled words per tweet
20 good_cnt	Number of *words* of correctly spelled words per tweet
21 bad_len	Number of *characters* of incorrectly spelled words per tweet
22 bad_cnt	Number of *words* of incorrectly spelled words per tweet
23 redund	Redundancy Score for the Thread

For the purpose of classifying accounts as automated (bots) versus non-automated, a manual rating process of a sample of tweet content coming from 101 active accounts was executed. The sample was divided into 5 subsets with each set being rated by multiple volunteers who read the content of approximately 20 accounts in each subset, each subset containing a few thousand tweets. The rating of each account involved classification as a bot or not and also the assignment of a level of confidence associated with such classification, then a brief explanation of the main reasons was given for the relevant decisions. Of the 101 accounts, 65 were classified as 35 bot accounts and 30 non-bot accounts with a high level of confidence. Those 65 accounts were then assigned a dependent variable value of 1 if identified as a bot, and 0 otherwise.

3 Results

Excel was used to generate a correlation matrix for the 23 content features for the large sample of 8845 feature vectors.

Table 3a. Correlation among the 23 Features of Tweet Data
(Correlation scores above 0.6 are bolded)

	1	2	3	4	5	6	7	8	9	10	11
1	**1.000**										
2	0.029	**1.000**									
3	-0.019	0.044	**1.000**								
4	0.032	0.110	0.436	**1.000**							

	1	2	3	4	5	6	7	8	9	10	11
5	0.094	0.086	0.135	0.292	**1.000**						
6	0.019	0.076	0.407	**0.630**	0.214	**1.000**					
7	-0.041	-0.066	0.031	-0.104	0.104	-0.079	**1.000**				
8	0.040	0.088	0.144	0.417	0.267	0.321	-0.113	**1.000**			
9	-0.078	0.070	0.400	0.339	0.090	0.387	0.043	0.128	**1.000**		
10	0.039	0.054	0.302	0.545	0.533	0.431	0.078	0.322	0.245	**1.000**	
11	0.006	0.115	0.424	**0.701**	0.279	0.544	-0.134	0.381	0.360	0.448	**1.000**
12	-0.007	0.069	0.216	0.263	0.076	0.262	-0.063	0.179	0.285	0.152	0.277
13	-0.052	-0.014	0.072	0.038	-0.031	0.038	0.037	-0.059	0.120	-0.020	0.059
14	-0.010	-0.021	-0.028	0.021	0.119	-0.054	-0.013	0.077	-0.072	0.061	0.068
15	0.299	-0.066	-0.254	-0.216	0.028	-0.257	-0.106	0.059	-0.296	-0.147	-0.199
16	-0.149	0.190	-0.022	-0.093	-0.134	-0.026	-0.001	-0.091	0.010	-0.144	-0.070
17	0.207	-0.009	-0.034	0.123	0.156	0.053	-0.068	0.146	-0.100	0.148	0.069
18	-0.044	0.127	0.011	0.096	-0.006	-0.014	0.014	0.048	0.053	-0.002	0.123
19	0.160	0.101	0.216	0.490	0.590	0.326	-0.026	0.470	0.088	0.580	0.473
20	0.081	0.298	0.390	**0.702**	**0.650**	0.538	0.023	0.502	0.309	**0.752**	**0.665**
21	-0.047	-0.177	-0.131	-0.280	-0.170	-0.183	0.054	-0.134	-0.110	-0.220	-0.254
22	-0.035	-0.172	-0.068	-0.255	-0.105	-0.136	0.079	-0.101	-0.091	-0.166	-0.237
23	0.352	0.178	-0.015	-0.001	0.073	0.011	0.018	0.021	0.001	0.061	-0.027

Table 3b. Correlation among the 23 Features of Tweet Data

	12	13	14	15	16	17	18	19	20	21	22	23
12	**1.000**											
13	0.009	**1.000**										
14	-0.014	-0.054	**1.000**									
15	-0.048	-0.225	0.088	**1.000**								
16	-0.018	0.038	-0.136	-0.264	**1.000**							
17	0.018	-0.158	0.118	0.567	-0.350	**1.000**						
18	0.004	0.025	0.019	-0.037	-0.010	-0.021	**1.000**					
19	0.189	-0.131	0.380	0.313	-0.277	0.433	0.042	**1.000**				

20	0.266	-0.038	0.208	-0.045	-0.159	0.271	0.078	**0.861**	**1.000**			
21	-0.117	-0.029	0.086	0.104	-0.017	0.055	-0.008	-0.102	-0.211	**1.000**		
22	-0.087	-0.030	0.109	0.064	-0.008	0.057	-0.020	-0.009	-0.112	**0.841**	**1.000**	
23	0.027	-0.052	0.007	0.159	-0.187	0.145	0.007	0.103	0.098	-0.007	-0.039	**1.000**

Similarly, correlations between the 23 content features and the dependent variable for the small set of 65 accounts were calculated and sorted based on absolute value.

Table 3. Correlation of the 23 Features to the Dependent Variable (Bot or Not Boolean Value)

Feature		**r score**
23	**redund**	0.602903665143099
15	**urls**	0.552239841627008
19	**good_len**	0.499866059699615
2	**adj**	0.439996556749289
1	**tweets**	0.405312199707016
13	**vulgar**	-0.386187081404597
20	**good_cnt**	0.361167846205383
5	**commnoun**	0.336302040152226
18	**emo_chat**	-0.322361395640107
4	**art**	-0.306464242615507
6	**conj**	-0.266514973936451
12	**stopword**	-0.256512790006307
9	**pron**	-0.23235623235559
17	**punc**	0.22984473910942
8	**prep**	0.217071031951804
10	**Propnoun**	0.215136062319311
7	**interj**	-0.202111817921263
14	**hash**	0.125290858127832
3	**adv**	-0.0933858445685339
16	**case**	-0.0477397194562674
21	**bad_len**	0.0373329649121563
22	**bad_cnt**	0.0035443689757518
11	**verb**	0.0027851841588802

Absolute values of the correlations between features and the dependent variable ranged from 0.003 to 0.603. Ranking such absolute values of correlations resulted in the following list of top predictors of bot-like behavior: “redund", “urls”, “good_len", “adj", “tweets”, “vulgar”, “good_cnt", “commnoun", “emo_chat" and “art”.

Charts were created to examine the distributions of features that were deemed to be significant in terms of their correlation with the dependent variable in the small sample. Charts were created to examine joint distributions. Following some interpretation of the nature of distributions, some hypotheses were made as to potential statistical learning tools that may be useful in modeling based on such content features.

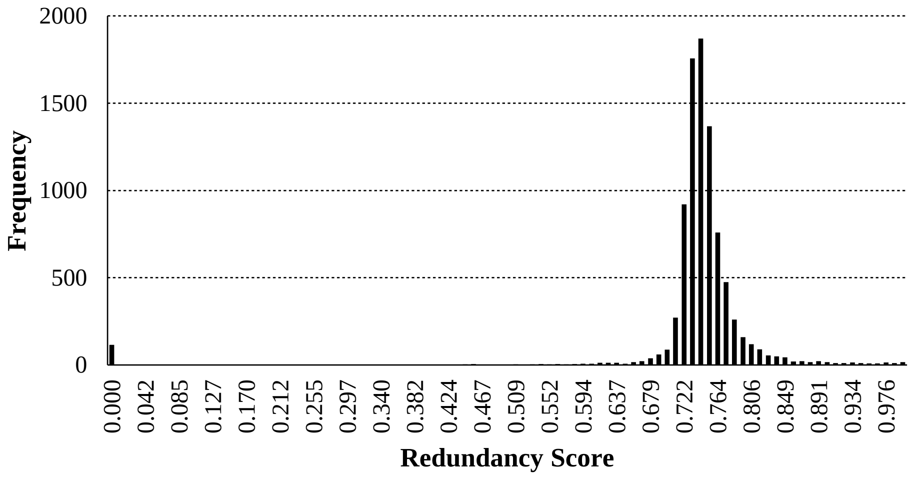

Fig. 1. Histogram of the Distribution of Redundancy Score

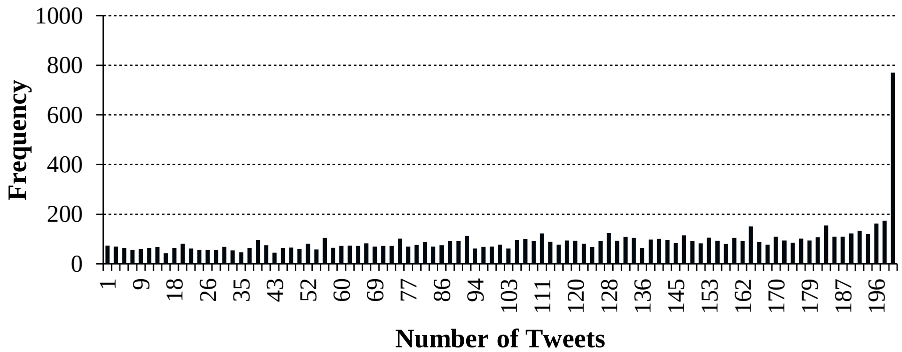

Fig. 2. Histogram of the Distribution of Number of Tweets

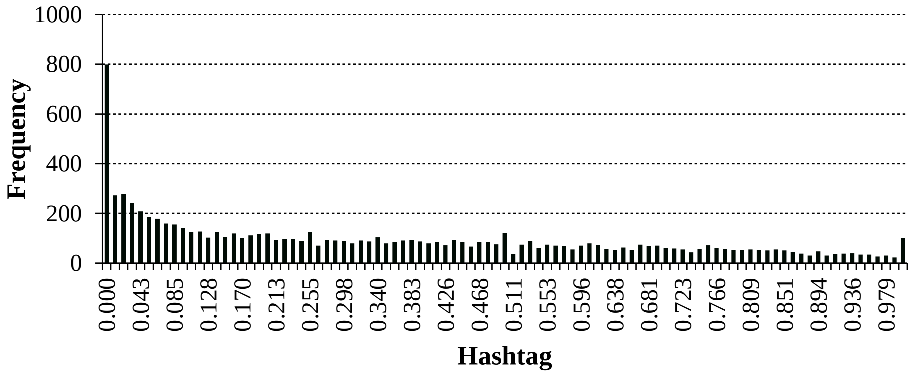

Fig. 3. Histogram of the Distribution of Hashtag

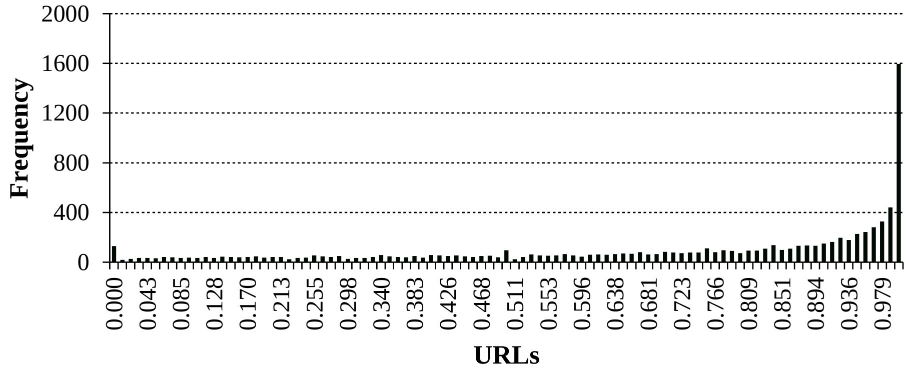

Fig. 4. Histogram of the Distribution of URLs

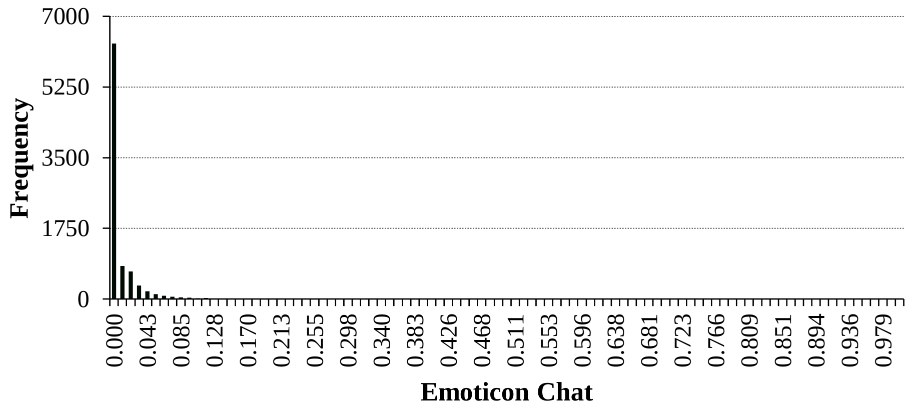

Fig. 5. Histogram of the Distribution of emoticon_chat

Fig. 6. Scatter Plot of Dependent Variable Against Redundancy Score

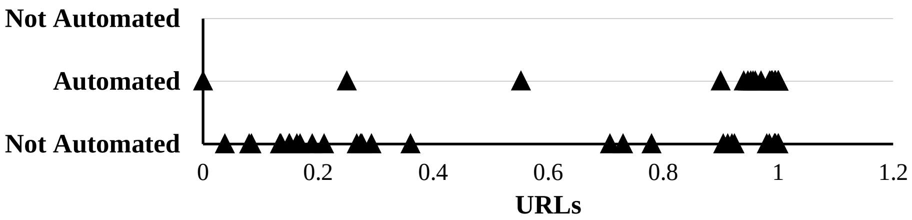

Fig. 7. Scatter Plot of Dependent Variable Against URLs Score

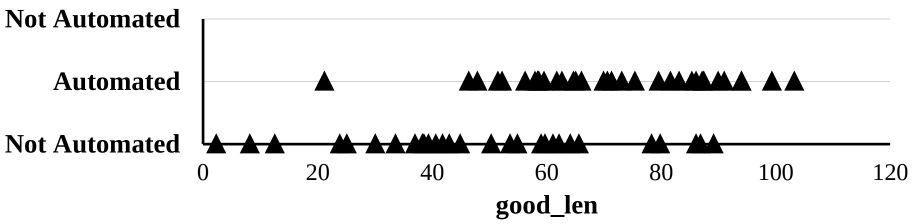

Fig. 8. Scatter Plot of Dependent Variable Against “good_len” Score

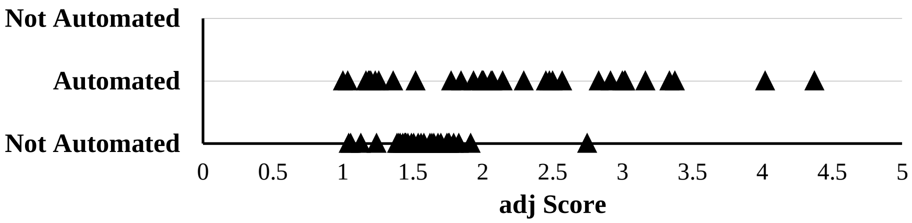

Fig. 9. Scatter Plot of Dependent Variable Against “adj” Score

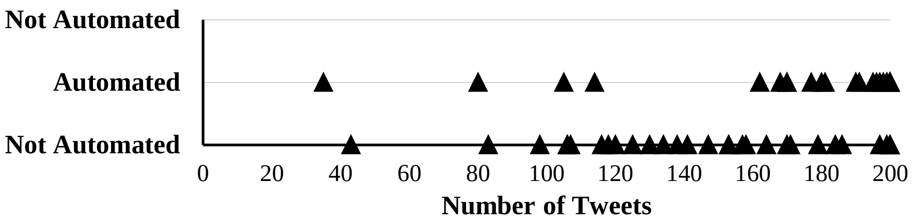

Fig. 10. Scatter Plot of Dependent Variable Against Number of Tweets

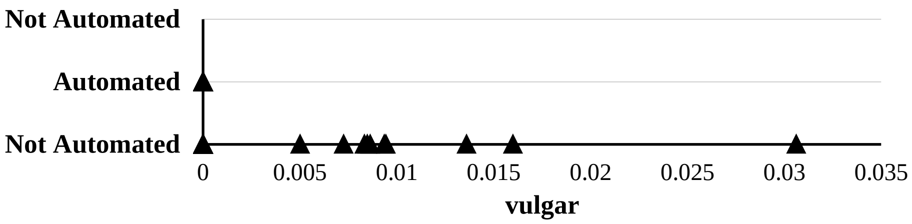

Fig. 11. Scatter Plot of Dependent Variable Against Vulgarism Score

4 Discussion

4.1 Findings

Approximately 10% of the 8845 accounts had the maximum level of activity measured (200 tweets). This may provide some lower bound estimate of the rate of accounts exhibiting bot-like behavior.

Examination of the content features correlation matrix reveals that correlations are generally low with some explainable exceptions. Features such as good_len and good_cnt refer to the number of characters that are part of correctly spelled words and the number of correctly spelled words, respectively. The high correlation of 0.86 is to be expected, and such is the case for bad_len and bad_cnt with a correlation of 0.841 (both highlighted in Table 3b). In both situations, consideration may be given to selecting only one of each pair for the purpose of predictive modeling.

The top ten content features appear to contain discriminating information that may be relevant in an attempt to classify Twitter accounts as bot or non-bot accounts. Separation issues and the skewed nature of the majority of the distributions of content features may justify an expectation that a nonparametric approach may perform better than a parametric one.

The distribution of the redundancy scores appears to be approximately normal, while all other distributions examined are skewed. As in the case of an earlier study of external features, most relevant distributions that quantify social media behaviors do not appear to be normal, a fact that may later support preference for nonparametric modeling techniques or the application of some feature transformations.

Examination of the scatter plots of joint distributions seems to support the selection of the top content features listed above. One can note that in the case of vulgarity score there is no presence of vulgarity among the bot accounts, while non-bot accounts may or may not include vulgar language.

Taking all this into account, a starting set of content features that may be selected for modeling may involve the following nine features: redund, urls, good_len, adj, tweets, vulgar, commnoun, art, emo_chat.

4.2 Limitations

A number of significant limitations must be noted.

First, the data set may not be a representative sample of the current state of affairs when it comes to bot versus non-bot activity in the Twitter medium.

Second, the process of manually classifying a small set of accounts and reaching a consensus in roughly two-thirds of the cases may not be without errors.

Third, a larger sample set from the manual classification process may lead to different conclusions about content features and the type of modeling that may be expected to perform best.

Fourth, concentrating on content, which probably provides the most predictive power, may still ignore some critical external features, and thus may not produce an optimal perspective.

4.3 Further Investigations

Future work may attempt to consider a mix of external features and content features, calculated on a large set of known bot and non-bot accounts for better feature selection, description, and classification. This should enable a much more reliable subset of predictive or discriminating features, which in turn may lead to more reliable descriptive and predictive models.

5 Conclusion

This paper demonstrates one way by which content of social media activities may be processed in terms of mathematical "signatures" of different types of online behaviors that may be used for descriptive and predictive modeling of automated versus non-automated activities.

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