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ATTENTIONAL INERTIA IN CHILDREN'S EXTENDED LOOKING AT TELEVISION

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In this chapter we consider sustained visual attention in children and adults. We not only focus on children's looking at television but we also consider sustained play with toys. Our work indicates that sustained looking at television or during play reveals attentional processes that have not been apparent in standard experimental studies of attention to static visual displays. In the child's typical environment, attention is drawn to interesting, informative, and important aspects of the real world. The sensory and cognitive properties of such objects are often meaningful to the child and incorporate movement and change over time. We believe that often television programs and movies, and probably play with toys, mimic these types of stimuli and reveal patterns of attention that are not typically found in laboratory studies. In the present chapter, we focus on a phenomenon we call *attentional inertia*, which is a progressive increase in the attentional engagement as a look is sustained.

This view of attention differs from that typically used to study attention in infants and young children. For example, studies of visual attention in infants and very young children usually involve repeatedly presenting a static visual stimulus until looking times become shorter and shorter. Depending on the study, the experimenter may introduce a change in the stimulus to see whether looking time increases in response to the change. Theories to explain these phenomena are generally variants of Sokolov's broad formulation: the child gradually forms a neural or mental representation of the stimulus and compares that representation to subsequent encounters with that stimulus. As the representation comes to match the perceptual input, attention to the stimulus wanes. When a discrepancy is detected, attention increases.

As important as the phenomenon is, habituation likely accounts for a small portion of the variability of sustained visual attention in the real world. The aspects of the environment to which attention is drawn are not static. Rather, attention is engaged with meaningful events that change dynamically. In addition to sensory-perceptual changes (movement, appearance), events that provide changes in information over time also easily attract attention in young children. Except for inhibition of attention to the unchanging aspects of the child's environment, habituation likely accounts for little of the dynamics of attention in the real world. We believe that a model of attention that stresses an increase in attentional engagement over time may be more realistic for the child's real environment than one that stresses a decrease in attentional engagement.

Television is not the real world, but it is like the real world insofar as it provides meaningful, audiovisual stimulation that changes over time. There is little opportunity for habituation of looking because the images are not ordinarily static or repetitive. Even when television programs are repeated exactly, children's looking does not decline with subsequent viewings. At home, children watch videotapes over and over (Mares, 1998) with little or no loss of attention, at least at younger ages. In an experiment with 3- to 5-year-olds, children were shown the same episode of the preschool program *Blues Clues* on five consecutive days. Only 5-year-old boys showed a slight drop of looking across the repetitions. All the children showed a great increase in overt interaction with the program (e.g., talking to the TV, pointing, laughing), as repetitions increased (Crawley *et al.*, 1999). Similarly, infants between 12 and 15 months of age actually showed increased, not decreased, looking at baby videos as a function of 30 or more repetitions (Barr *et al.*, 2003).

What accounts for looking at television? The onsets of looks appear to be elicited by auditory features, visual movement, and other forms of visual change that may be detected in peripheral vision as the child plays with toys or engages in other nonviewing activities (Alwitt *et al.*, 1980; Anderson & Levin, 1976). These onsets of looks are usually accompanied by orienting reactions as indexed by heart rate decelerations (Lang, 1990; Richards & Cronise, 2000). If other viewers are present, a child may also look at the screen because he or she sees another child turn toward the television (Anderson *et al.*, 1981b). In this chapter, we are primarily concerned with what happens once a look is initiated; why are looks subsequently sustained or terminated?

Our efforts in this chapter to answer this question take three forms. In Section I we review past work that shows attentional inertia during television and toy play. This review emphasizes work that has studied the distribution of look durations and has hypothesized that this distribution implies an increasing attention engagement across the course of a look. Section II consists of the analysis of look durations using data from a wide range of testing ages (3-month-olds to adults!). The purpose of this section is to show that the distribution of looking is very similar across the ages. This similarity implies that the same cognitive processes guide look duration at different ages. Finally, in Section III we present two quantitative models that account for extended looking during television viewing. These models account for the unique statistical distributions shown in Section II for look durations during television viewing. They provide some theoretical mechanisms that aid in our understanding of attentional inertia.

I. Theories of Sustained Looking at Television

Theories of looking at television posit two phases in the course of looks (Anderson & Lorch, 1983; Huston & Wright, 1983). Once a look has begun, it is assumed that viewers quickly evaluate the content by determining the presence of particular auditory and visual features that signal relevant, comprehensible, and entertaining content. The theories posit that through experience with television, young children learn which auditory and visual features are most predictive of content that is relevant to them. If there is a peculiar voice and a puppet, for example, a young child judges that the content is intended for children and will sustain looking beyond the initial, orienting phase into a phase of more sustained cognitive processing of content. If instead, an adult male is sitting at a desk and talking with a serious expression on his face, the child judges that the content is intended for adults and quickly looks away. Additionally, if the child has previously judged that the content is uninteresting, he or she will occasionally look at the TV to see whether anything has changed. If, upon looking, he or she finds the same characters and setting as before, the look ends quickly (Huston & Wright, 1983).

Theoretically, the cognitive processing of the narrative or other content drives the sustained phase of the look. The theoretical details of this processing are beyond the scope of this chapter, but are generally thought to parallel in most respects the cognitive processing of spoken or text narratives (Neuman, 1991). A look at the television eventually terminates when the viewer reaches the end of a unit of content, when he or she encounters an external distraction, when the content becomes uninteresting, or the viewer fails to comprehend.

Evidence in support of these theories is reviewed elsewhere (Anderson & Burns, 1991; Huston & Wright, 1989). Briefly, features of TV that are correlated with child-oriented content (e.g., children's voices, peculiar voices, animation, puppets, etc.) are also associated with sustained looking whereas features correlated with adult-oriented content (especially men and men's voices) are associated with terminations of looking (Alwitt *et al.*, 1980; Anderson & Levin, 1976; Campbell, Wright, & Huston, 1987; Schmitt, Anderson, & Collins, 1999). Evidence indicating that looking is related to cognitive processing of content is provided in a variety of investigations (e.g., Anderson *et al.*, 1981a,b; Campbell, Wright, & Huston, 1987; Lorch, Anderson, & Levin, 1979; Lorch & Castle, 1997; Lorch *et al.*, 2004; Pingree, 1986). For example, preschool children look substantially less at *Sesame Street* when the content has been rendered more difficult to understand by ordering the shots randomly, or by making the audio incomprehensible by, for example, running utterances backwards or presenting them in a foreign language (Anderson *et al.*, 1981a). Note that each of these manipulations leaves the typical visual and auditory features of television unchanged, so that the reduction in looking at the screen is caused by a decrease in comprehensibility of the content indicating that looking is driven at least partly by cognitive processing of content.

In summary, the theories of television viewing suggest a phase of looking that consists of an initial evaluation of content and a phase of looking that involves sustained content processing. However, they do not necessarily imply that there are changes in the level of content processing during the sustained processing. Nor do they account for the unique distribution of look durations found in several studies (Section I.B), or what happens once a look is initiated. Attentional inertia

is a progressive increase in attentional engagement the longer a look at television is sustained. As a theoretical concept, attentional inertia has historical precursors.

A. PRECURSOR CONCEPTS

Historically, a number of observers have argued for processes that are analogous to attentional inertia. William James (1890) noted that as a person engages in thought about some interesting topic, he or she shifts the focus of attention from idea to idea while staying within a broad mental framework. The person may become increasingly engaged over time, becoming less distractible by the outside world. He considered this kind of attentional engagement as being effortless and labeled it "passive intellectual attention."

Donald Hebb (1949) argued that in many if not most task situations the focus of attention must necessarily shift from one component of the task to another. To complete the task, however, attention must be engaged broadly with the task as a whole. He referred to this broad attentional engagement as "attitude" (as in the attitude or orientation of an airplane as it flies in three-dimensional space).

More directly relevant to present concerns, Hochberg and Brooks (1978) argued that when a person who is viewing a film encounters a cut, that is, two distinct shots that occur successively, some underlying process must drive attention forward in time. They referred to this underlying process as "visual momentum." Without such a process, one might suppose that a person would simply look away when a scene disappears and is replaced by a different succeeding scene. Hochberg and Brooks suggested that this process is based in some way on the viewer's knowledge that the shots are all part of one film and that they must be connected.

All these theorists argue for a process that drives attention forward in time, but note that this process differs from the processes involved in paying attention to a specific visual scene. In other words, attention is maintained to a topic, a task, or a communication medium even as the focus of attention is constantly changing. However, despite their compelling descriptions of attention, these theorists provided little or no evidence to support the existence of such a form of attention.

B. HAZARD ANALYSES OF LOOK DURATIONS

The distribution of look durations during television viewing has a characteristic shape. During television viewing there are many short looks, an intermediate number of medium-length looks, and a few long looks. For example, when preschool children watch television in a setting that affords other activities, such as toy play, they look at and away from the screen many times in the course of an hour, averaging about 150 looks (Anderson & Levin, 1976). The majority of these looks are quite short, under 3 sec in length, but some are quite long, up to about 60 sec or more, producing a highly skewed distribution of look lengths (Anderson *et al.*, 1979). This skewed distribution of look lengths is not limited to preschoolers; infant and adult television viewers produce similar distributions (Burns & Anderson, 1993; Richards, 2000; Richards & Cronise, 2000). A major emphasis of this chapter is to establish the validity of this distribution across a wide range of studies (Section II) and provide a quantitative model for the distribution that has theoretical implications for the understanding of extended television viewing (Section III).

This distribution of look durations during television viewing has some interesting probability relations. Anderson *et al.* (1979) coined the term attentional inertia to describe a pattern they had observed in 3- and 5-year-old children's looks at television. The children were videotaped watching *Sesame Street* in a room that contained attractive toys. Videotapes were coded for start and stop times of looks at the TV screen from which look lengths were calculated. Anderson *et al.* (1979) noted that as looks at television became longer, they became less likely to terminate. For example, given that a look was initiated, it had a probability of about 0.57 of terminating within the first 3 sec; a look that survived the first 3 sec had a probability of 0.34 of terminating in the interval 3–6 sec; a look that survived to 6 sec had a probability of 0.24 of terminating in the interval 6–9 sec. Analyses of group data showed smooth, negatively accelerated decreasing curves describing the hazard of a look terminating in each successive 3-sec interval. A look was seemingly fragile early in its existence, and easily terminated. However, looks that survived beyond about 15 sec were robust and increasingly likely to survive through each successive period of time. Once set in progress for a substantial amount of time, a look metaphorically developed its own inertia. This pattern did not just represent an artifact of averaging across individuals. Rather, these same curves were found in the data of each of nearly 300 three- to five-year-olds studied.

One way to illustrate this finding is with curves from "hazard function" analysis. The hazard function is the conditional probability that a look will terminate (i.e., "die") in a given interval given the probability of its surviving to that interval. A hazard function for adults' looks during television viewing (which are distributed in a manner similar to children's looks; Burns & Anderson, 1993) is shown in Figure 1.The hazard increases from 0 sec to a peak at a short interval (i.e., 1–2 sec) followed by a decrease in the hazard over time. In other words, at very short intervals adults often looked away, but at longer look intervals looking away was much less likely.

The shape of the hazard functions for looking at television is similar over a wide range of ages. A hazard function for infants from 3 to 6 months of age (Richards & Gibson, 1997) and for 5-year-old children playing with toys (Choi & Anderson, 1991) also appear in Figure 1. Here too the conditional probability of the look terminating increases for the very short duration looks then decreases

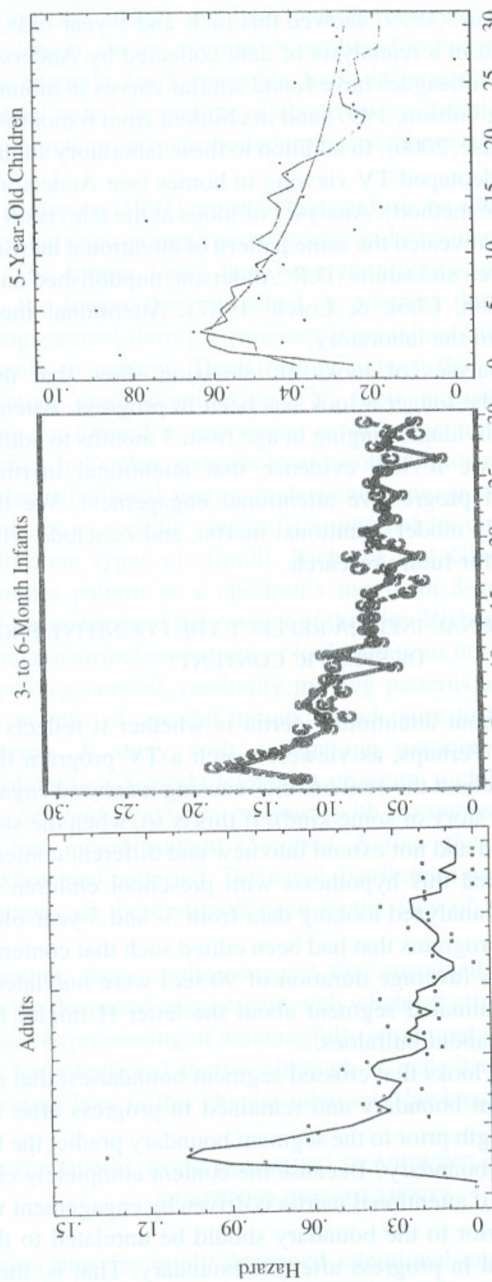

Fig. 1. Hazard function for looking toward television or toys. The hazard is the conditional probability that a look will terminate at a given interval. The data were from adults (left panel, Burns & Anderson, 1993; Figure 3), 3- to 6-month-old infants (center panel, Richards & Gibson, 1997, Figure 2), and 5-year-old children (Choi & Anderson, 1991, Figure 3).

with longer looks. Many other studies of television viewing have shown this in children. Anderson *et al.* (1979) showed this in 3- and 5-year-olds, and in 12- to 24-month-old children in a reanalysis of data collected by Anderson and Levin (1976). Richards and colleagues have found similar curves in infants as young as 3 months (Richards & Gibson, 1997) and in children from 6 months to 2 years of age (Richards & Cronise, 2000). In addition to these laboratory studies, Anderson and his colleagues videotaped TV viewing in homes (see Anderson *et al.*, 1985, for a description of the method). Analyses of looks at the television screen coded from these videotapes revealed the same pattern of attentional inertia in home TV viewing both in children and adults (D.R. Anderson, unpublished analyses; for an example, see Anderson, Choi, & Lorch, 1987). Attentional inertia is not a phenomenon limited to the laboratory.

To summarize, analyses of looks at television show that the hazard of termination declines the longer a look has been in progress. Attentional inertia was revealed in all individuals ranging in age from 3 months to adulthood. In the rest of this chapter we review evidence that attentional inertia reflects an underlying process of progressive attentional engagement. We then describe efforts to quantitatively model attentional inertia, and conclude with comments suggesting directions for future research.

C. DOES ATTENTIONAL INERTIA REFLECT THE COGNITIVE PROCESSING OF SPECIFIC CONTENT?

A basic question about attentional inertia is whether it reflects engagement with specific content. Perhaps, as viewers watch a TV program they build up schematic knowledge about the content, thus causing increased engagement with that content (usually a story of some kind). If this is so, when the story ends, the engagement should end and not extend into new and different content. Anderson and Lorch (1983) tested this hypothesis with preschool children's looking at *Sesame Street*. They reanalyzed looking data from 3- and 5-year-olds who were shown *Sesame Street* programs that had been edited such that content and format of successive segments (average duration of 90 sec) were unrelated (Anderson *et al.*, 1981a,b). An animated segment about the letter H might, for example, follow a film segment about buffaloes.

Of key interest were looks that crossed segment boundaries; that is, looks that began before a segment boundary and remained in progress after the segment boundary. Did look length prior to the segment boundary predict the length of the look after the segment boundary? Because the content completely changed after the segment boundary, if attentional inertia is driven by engagement with specific content, look length prior to the boundary should be unrelated to the length of time the look remained in progress after the boundary. That is, the correlation should be zero. If, instead, attentional inertia drives looks across content boundaries, the correlation should be positive. The analysis revealed a clear positive relation: the longer the look was in progress prior to the segment boundary, the longer, on the average, it remained in progress after the segment boundary. For example, for 5-year-olds, looks in progress for 5 sec prior to the content boundary lasted an average of about 18 sec after the boundary. Looks in progress for a minute prior to the boundary lasted an average of about 40 sec after the boundary.

Burns and Anderson (1993) repeated this analysis on adults looking data using the boundaries between primetime programs and commercials. They found the same result. The longer looks had been in progress prior to the block of commercials, the longer they remained in progress during the commercials. Attentional engagement during a program is sustained into advertisements that differ immensely in content. These results suggest that as children and adult viewers maintain their attention to TV, their engagement deepens. This engagement is not limited to processing a particular unit of content presented by the television, but rather, extends to any content presented by the television.

The idea that attentional inertia is deepened engagement to the *medium* of television and not to specific content is supported by consideration of studies comparing different types of stimuli. Richards and Gibson (1997) found the attentional inertia pattern to a children's movie in 3-month-old infants who clearly could not understand the content of the film. Richards and Cronise (2000) found the typical distribution pattern of look durations not only to the movie, but also to computer-generated, randomly moving patterns and associated sounds. Not until 18 months of age did infants attend more to the movie than to the random patterns. A study with college-age participants (Richards, 2000) compared looking to a *Seinfeld* television program, a children's movie (*Follow that Bird*), a *Seinfeld* television program with scrambled scene sequences, or stimuli that had mixed content (*Seinfeld*, *Follow that Bird*, and computer-generated audiovisual patterns). The same distribution pattern of look durations was found across all these stimuli even in the face of very disparate looking lengths.

Taken together, these studies suggest that sustained attention builds upon itself, producing deepened engagement with whatever stimulation is provided by the TV. Cognitive processing of meaningfully structured video is not a necessary requirement for attentional inertia although it may itself enhance attentional inertia as we note later in this chapter (also see Hawkins *et al.*, 1995).

D. IS ATTENTIONAL INERTIA DURING TV VIEWING ASSOCIATED WITH DEEPENED ENGAGEMENT?

The analyses thus far imply deepened attentional engagement as a look is sustained, but do not test directly for it. Evidence from at least three types of studies suggests that engagement becomes deeper the longer looking is sustained. First, level of distractibility while looking has been used to test sustained engagement. If viewers become more deeply engaged the longer they sustain looking at TV, they may suppress or inhibit attention to the environment outside the TV program. This is fairly obvious to parents who try to get the attention of children who are engrossed with television, and experimentation confirms this phenomenon. Anderson *et al.* (1987) showed *Sesame Street* to 3- and 5-year-old children. On a rear-projection screen to the side of the TV set, a brief "beep" signaled the appearance of a slide, which was shown for 4 sec. Intervals between slides varied randomly. If children become more deeply engaged the longer a look is in progress, they should be less likely to turn and look at the distractor. In fact, both the 3- and 5-year-olds were more likely to turn toward the distractor when they had been looking at the TV for less than 15 sec as compared to when they had been looking for more than 15 sec. When children did look at the distracting slide, their head turns were slower when they had been continuously looking at the TV for more than 15 sec. Richards and Turner (2001) found similar reductions in distractibility as looks were sustained for infants ranging in age from 6 months to 2 years.

Second, if engagement with TV deepens as a look at television is sustained, and if the hazard of termination curves are a good index of engagement, then a viewer should be slower to respond to a secondary task if a look has been sustained for more than 15 sec than if the look has been sustained for less than 15 sec. Lorch and Castle (1997) showed preschool children *Sesame Street* while they performed a secondary push-button reaction time task. Children were instructed to push a button as quickly as possible on hearing an auditory signal. Reaction times were shorter when the children were continuously looking at the TV for less than 15 sec than if they were looking for more than 15 sec. The authors interpreted this result as indicating that engagement with the TV deepened as a look was sustained.

Third, physiological signs often are used as markers of attention engagement. For example, heart rate changes during attention and these changes have been used to assess attention responses in television viewing (Lang, 1990; Reeves *et al.*, 1985). In infants and young children, sustained attention to stimuli in a number of modalities is accompanied by an initial heart rate deceleration and a sustaining of heart rate as long as attention continues (Richards, 2002; Richards & Casey, 1992). This pattern is evident in the results of studies of children's TV-viewing, shown in Figure 2 (Richards & Cronise, 2000; Richards & Gibson, 1997; Richards & Turner, 2001). Heart rate typically decelerates in the first few seconds of television viewing, and extended looks toward the television are accompanied by increasingly deep heart rate changes.

The heart rate responses are separated by look length in the left panel of Figure 2. Evident in this panel are the short-latency changes associated with

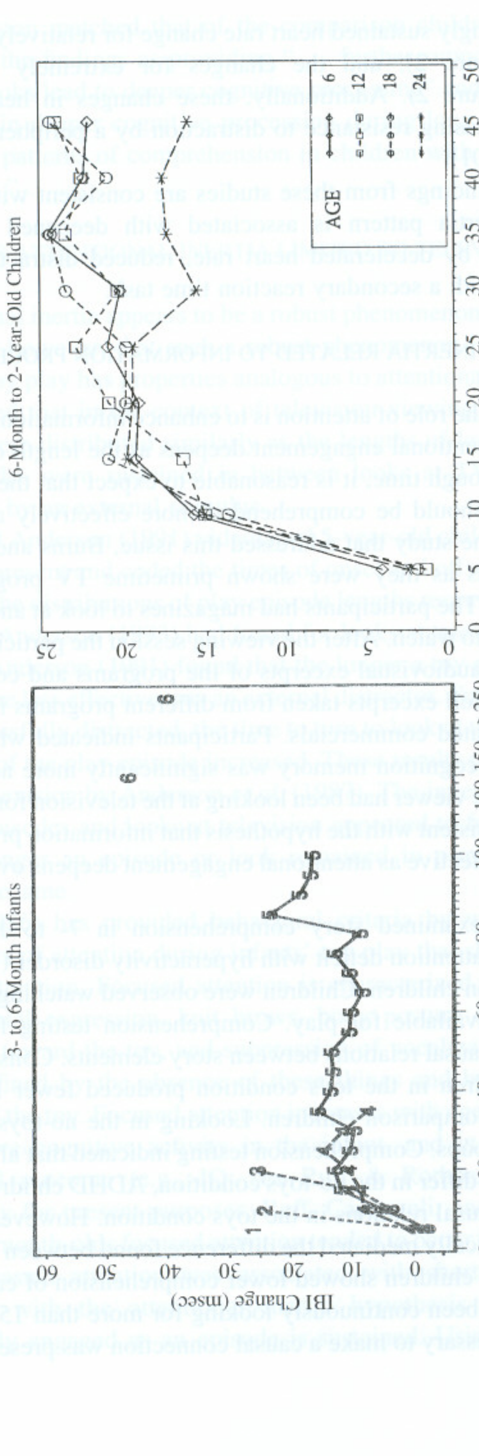

Fig. 2. Heart rate changes in infants and young children during television viewing. The data are plotted as changes in interbeat-intervals (IBI change), with longer IBIs reflecting a deceleration of heart rate. The data were from 3- to 6-month old infants (left panel, Richards & Gibson, 1997, Figure 3) and 6-month to 2-year-old children (right panel, Richards & Cronise, 2000, Figure 5). The left panel separates the heart rate changes by look lengths (1, 0–5; 2, 5–10; 3, 10–20; 4, 20–40; 5, >40; 6, 100 150 and 200 sec).

short looks, the increasingly sustained heart rate change for relatively long looks (> 40 sec, "5" in Figure 2), and the changes for extremely long looks (> 100 sec, "6" in Figure 2). Additionally, these changes in heart rate are associated with an increasing resistance to distraction by a peripheral stimulus (Richards & Turner, 2001).

Taken together, the findings from these studies are consistent with the view that the attentional inertia pattern is associated with deepened attentional engagement as indexed by decelerated heart rate, reduced distractibility, and increased interference with a secondary reaction time task.

E. IS ATTENTIONAL INERTIA RELATED TO INFORMATION PROCESSING?

In nearly all theories, the role of attention is to enhance information processing of selected stimuli. If attentional engagement deepens as the length of a look at television progresses through time, it is reasonable to expect that the content of the television program should be comprehended more effectively as the look progresses in time. In one study that addressed this issue, Burns and Anderson (1993) videotaped adults as they were shown primetime TV programs with associated commercials. The participants had magazines to look at and snacks to eat in addition to the TV to watch. After the viewing session the participants were shown brief 3- to 4-sec audiovisual excerpts of the programs and commercials they watched as well as foil excerpts taken from different programs in the same series along with associated commercials. Participants indicated whether they had seen the excerpt. Recognition memory was significantly more accurate for segments shown when the viewer had been looking at the television for more than 15 sec. This result is consistent with the hypothesis that information processing is more intense and more effective as attentional engagement deepens over the time course of a look.

Lorch *et al.* (2004) examined story comprehension in 7- to 11-year-old children diagnosed with attention deficit with hyperactivity disorder (ADHD) as well as typical comparison children. Children were observed watching television with and without toys available for play. Comprehension testing focused on factual information and causal relations between story elements. Consistent with prior work, ADHD children in the toys condition produced fewer long looks (> 15 sec) than did the comparison children. Looking in the no-toys condition was at ceiling for both groups. Comprehension testing indicated that although the diagnostic groups did not differ in the no-toys condition, ADHD children showed less comprehension of causal relations in the toys condition. However, the time spent in long looks statistically mediated the difference found between diagnostic groups. Although ADHD children showed lower comprehension of causal story relations, when they had been continuously looking for more than 15 sec at the time the information necessary to make a causal connection was presented, their

comprehension matched that of the comparison children. Lorch *et al.* (2004) interpreted the findings as providing "… further support for the interpretation that long looks lead to deeper cognitive processing" and that "… the amount of time spent in deeper cognitive processing during long looks helps explain the differential patterns of comprehension in children with ADHD and comparison children …"

F. IS ATTENTIONAL INERTIA LIMITED TO TELEVISION VIEWING?

Attentional inertia appears to be a robust phenomenon of television viewing. It is unlikely, however, that such a robust phenomenon is limited to TV. In fact, sustained toy play has properties analogous to attentional inertia. Anderson *et al.* (1987) noted that in the context of television viewing, the lengths of toy play episodes were distributed similarly as the lengths of looks at television. As toy play episodes were sustained in between looks at TV, children became less distractible by an external stimulus.

Choi and Anderson (1991) videotaped 5-year-old children's toy play without a television present and coded the times of onset and offset of play episodes. They noted that the distributions of play episode lengths resembled the distribution that Burns and Anderson (1993) had found for looks at television. In a second study, Choi and Anderson (1991) found that the longer a toy play episode remained in progress, the less effective was an external distractor. Furthermore, when children were successfully distracted, the time to turn to look at the distractor increased as the length of the play episode increased. These results paralleled those found for looks at television by Anderson *et al.* (1987). The investigators argued that both toy play episodes and looks at television appeared to follow a time course such that the longer an episode or look remained in progress, the more engaged attention became.

Ruff (1986) has provided behavioral criteria by which to distinguish two components of attention during infants' toy play that she labeled "focused" and "casual" attention. Focused attention is characterized by looking at the toy, a serious facial expression, knit brows, body posture oriented toward the toy, leaning in toward the toy, and suppression of vocalizations. Casual attention is largely defined by the absence of these things and by mouthing or repetitive banging of the toy. Focused attention increases with age, appears to be indicative of extensive cognitive activity in the infant, and is positively predictive of intellectual outcome (e.g., IQ; see Ruff & Rothbart, 1997 for a review). Importantly for present purposes, Ruff, Capozzoli, and Salterelli (1996) found that in 10-month-olds focused attention tended to occur during long play episodes whereas casual attention was associated with short play episodes. This is consistent with the attentional inertia hypothesis that attention becomes increasingly engaged as an episode is sustained. Using the external distractor technique developed by Anderson *et al.* (1987), Ruff, Capozzoli, and Salterelli (1996) found that infants were less distractible from play when they were engaged in focused attention. If they were successfully distracted during focused attention, they were slower to turn their heads toward the distractor. Like the Choi and Anderson (1991) results with 5-year-olds, Ruff, Capozzoli, and Salterelli (1996) found an inverse relation between distractibility and length of play episode at the time the distractor was presented.

As in the studies described previously, Oakes, Ross-Sheehy, and Kanass (2004) found that $6\frac{1}{2}$- and 9-month-old infants became less distractible the longer toy play episodes were sustained. Also, focused attention was more likely to be observed in the latter portions of long episodes. Of considerable interest, focused attention and length of play episode, although correlated, independently predicted resistance to distraction. Focused attention, when it occurred early in a play episode, did not reduce distractibility as much as it did when it occurred later in a play episode. Oakes, Ross-Sheehy, and Kanass (2004) suggested that focused attention (by the behavioral criteria of Ruff, 1986) and attentional inertia might reflect different but interacting underlying mechanisms of sustained attention.

Why would looks at television and play with toys be so similar with respect to the time course of engaged attention? Television viewing involves purely receptive perceptual and cognitive processing whereas toy play involves productive sensorimotor and cognitive activity. Both television viewing and toy play, however, require shifting foci of attention embedded within an overarching activity that extends in time. It is not unreasonable to suppose that both draw on the same underlying mechanism of engagement that allows variability of attention within a larger frame of reference.

II. A Distribution Analysis of Looking at Television

A second goal of this chapter is to examine age-related changes in the distribution of looks to television in children from a wide range of ages. There were two reasons for doing this analysis. One reason was practical. We have investigated television viewing with similar procedures across a wide range of ages, including 3–6 months of age (Richards & Gibson, 1997), 6 months to 2 years of age (Richards & Cronise, 2000; Richards & Turner, 2001), 2–5 years of age (Anderson *et al.*, 1981a,b), 3–5 years (Crawley *et al.*, 1999) and in college-aged adults (Anderson & Lorch, 1983; Burns & Anderson, 1993; Richards, 2000). However, a study of extended looking during television viewing has not been done over this entire age range. This chapter provides the opportunity to collate data from multiple experiments to investigate the age changes that may occur in looking at television.

The second reason for examining data from a wide range of ages is theoretical. Previously, we described the hazard function analysis as it applied to looking during television viewing (Anderson *et al.*, 1987; Burns & Anderson, 1993; Choi & Anderson, 1991; Hawkins *et al.*, 1991; Richards & Cronise, 2000; Richards & Gibson, 1997). This hazard function, shown for three studies in Figure 1, had an increase from 0 sec to a peak at some short interval (i.e., 1–2 sec), and then a decrease with increasing look duration. In other words, looking away was highly probable at very short intervals but much less likely at longer look intervals. This type of hazard function should result in a lognormal distribution for the look intervals (Section II.D). However, the presence of this distribution in looking duration data was tested with quantitative and statistical tests only in a few studies (Burns & Anderson, 1993; Richards, 2000; Richards, 2002; Richards & Anderson, 1999; Richards & Casey, 1992; Richards & Cronise, 2000; Richards & Gibson, 1997; Richards & Turner, 2001). We wished to apply a quantitative test of this distribution to some of these previous studies.

There are three important motivations for assessing the distribution of the look durations. First, as mentioned, the pattern of many short looks, an intermediate number of medium-length looks, and only a few long looks, has been used to infer that attentional inertia is occurring. This pattern leads to a characteristic distribution in a number of studies that have been done. This implies that the attentional inertia phenomenon is widespread in television viewing. We further examine the implications of this distribution with quantitative models that provide some theoretical mechanisms that aid in our understanding of attentional inertia. The second implication concerns the apparent similarity of these distributions across a wide age range despite changes in average look duration. This similarity suggests that the same cognitive process is guiding look duration at different ages. If we can characterize the quantitative properties of the distribution, we may be able to detail what changes in television viewing in young children. Finally, in Section III we present two quantitative models that account for extended looking during television viewing. These models account for the unique statistical distributions shown in Section II for look durations during television viewing. They also provide theoretical mechanisms that aid in our understanding of attentional inertia.

We combined data from several sources to examine developmental changes in extended looking at video across the preschool years in a single analysis. These studies included participants from ages of 3 months (Richards & Gibson, 1997) to $6\frac{1}{2}$ years (Hawkins, Yong-Ho, & Pingree, 1991). Following this analysis, the combined data were examined for their fit to several hypothetical probability distributions that have been used to explain looking and reaction time in psychological research. Finally, we chose the best distribution that fits the data, the lognormal, and compared the parameter estimates for children at different ages. We also fit and compared distributions for comprehensible and incomprehensible stimuli.

A. STUDY SELECTION

Five studies of extended television viewing with preschool children and infants were used: Anderson *et al.* (1981a,b), Crawley *et al.* (1999), Hawkins, Yong-Ho, and Pingree (1991), Richards and Cronise (2000), Richards and Gibson (1997). We also used two studies with college-age participants: Burns and Anderson (1993), Richards (2000). The characteristics of these studies are presented in Table I.

The selection of these studies was guided by several considerations. Each had an extended presentation of a television show, or other stimuli, on a TV. These presentations lasted for at least 20 min and as long as 120 min in one of the studies. Given the theoretical role for the effect of the comprehensibility of the material on television viewing (Introduction to Section I), each study also had stimuli that varied in level of comprehensibility. For the comprehensible stimuli, the studies by Richards (Richards, 2000; Richards & Cronise, 2000; Richards & Gibson, 1997) used the movie *Follow that Bird* that involves *Sesame Street* characters. The incomprehensible stimuli in those studies were computer-generated visual geometric patterns accompanied by computer-generated music clips. Two studies (Anderson *et al.*, 1981a,b; Hawkins, Yong-Ho, & Pingree, 1991) used a special compilation of *Sesame Street* segments that included comprehensible normal segments, randomly edited segments, segments with backward speech, and segments with foreign language. These studies reported that looking was depressed in the presence of random edits and incomprehensible language. The remaining study with preschool children used a Nickelodeon *Blues Clues* episode and a *Busy World of Richard Scarry* episode. Because it received relatively low attention, this latter episode has been included in the analyses of the "incomprehensible" video stimuli. The studies with college-age participants used episodes of *Magnum, P.I.* and *Cagney and Lacey* (Burns & Anderson, 1993), or *Seinfeld* as well as portions of the movie *Follow that Bird* (Richards, 2000).

In each study, the participants were recorded on videotape. These videotapes were then viewed subsequently by observer(s) who judged when the participant was looking toward and away from the TV. The times of each look, and look away, were recorded with approximately one video frame (33 msec) resolution.

Some of these studies presented both "comprehensible" and "incomprehensible" stimulus presentations. The comprehensible presentations included cartoon characters or actors, dialogue, and a story that linked multiple segments of the presentation. The incomprehensible segments had no story line across shots, or the story line was obscured by incomprehensible language. In the studies of Richards (Richards, 2000; Richards & Cronise, 2000; Richards & Gibson, 1997)

TABLE I

Characteristics of Experiments

Study	Participant age	Session duration	Stimulus	Other
Richards & Gibson, 1997	3, 4.5, 6 months	20 min	*Follow that Bird* Computer-generated	Stimuli repeated factor
Richards & Cronise, 2000	6, 12, 18, 24 months	20–45 min	*Follow that Bird* Mixed: *Follow that Bird*, and computer-generated	Stimuli repeated factor
Crawley *et al.*, 1999	3, 4, 5 years	22 min	*Blues Clues*, 1 session *Busy Town* *Blues Clues*, 5 sessions	Stimulus between-factor
Anderson *et al.*, 1981a,b	2, 3.5, 5 years	60 min	*Sesame Street* Segments, comprehensible and incomprehensible	Single session
Hawkins *et al.*, 1991	3.5, 5, 6.5 years	27 min	*Sesame Street* Segments, comprehensible and incomprehensible	Single session
Burns & Anderson 1993	College-age	2 h	*Magnum, P.I.* TV show	Single session, computer games present
Richards, 2000	College-age	45 min	*Seinfeld* TV show *Follow that Bird* *Seinfeld*, scrambled scene sequences Mixed: *Seinfeld*, *Follow that Bird*, computer-generated	Stimuli repeated factor, *Seinfeld* TV show session 1, Other stimulus session 2

the "incomprehensible" stimuli consisted of computer-generated audiovisual patterns. These stimuli were presented during the entire session in Richards and Gibson (1997), were intermingled with randomly presented segments of *Follow that Bird* in a 2:1 ratio of durations in Richards and Cronise (2000), and intermingled with *Follow that Bird* and *Seinfeld* in a 2:1:1 ratio of durations in Richards (2000). The incomprehensible stimuli in Anderson *et al.* (1981a,b); Hawkins, Yong-Ho, and Pingree (1991) were language-degraded or randomly edited segments of *Sesame Street*. The language-degraded segments had backward speech or foreign language tracks. The "incomprehensible" stimuli in these studies interfere with the accumulation of story-like meaning from the stimuli, and thus should produce patterns of looking different than those stimuli that are understandable media. The study of Crawley *et al.* (1999) did not use incomprehensible stimuli. However, this study used *Blues Clues*, which received high levels of looking as well as a *Busy World* episode that received less looking. The looking patterns to the *Busy World* episode parallel those found in the incomprehensible stimuli and were compared to those.

We should note at the outset that there were important methodological differences between the studies from Richards' lab and the studies from Anderson's lab. In Richards' lab, participants were shown TV in a relatively impoverished environment—there was little to do or look at besides the television. Consequently, levels of looking toward the television were quite high. In Anderson's lab, participants had a variety of other activities available, such as toys to play with. Consequently, the levels of looking toward the television were much lower. Comparisons of parameters across studies should be viewed in context of this methodological difference.

B. LOOK DURATION

The average look duration for the age groups is shown in Figure 3, separately for the comprehensible and incomprehensible stimuli (note that the relatively low-attention *Busy World* is being treated as "incomprehensible" for this analysis). Table II includes more detailed information for these studies. Infants at the youngest ages (3, $4\frac{1}{2}$, and 6 months) had the same average look duration for the comprehensible and incomprehensible stimuli, whereas beyond this age average look duration increased with age toward the comprehensible stimuli, but not for the incomprehensible stimuli. In these data, the standard deviation increased with increases in mean look duration; consequently, there were roughly parallel increases in standard deviation with age and with comprehensibility. These look durations continue to increase in adult participants tested in a similar situation (Table II; Richards, 2000). So, an examination of the typical measures of look duration (average, standard deviation) shows relatively unchanging parameters in the first few months of

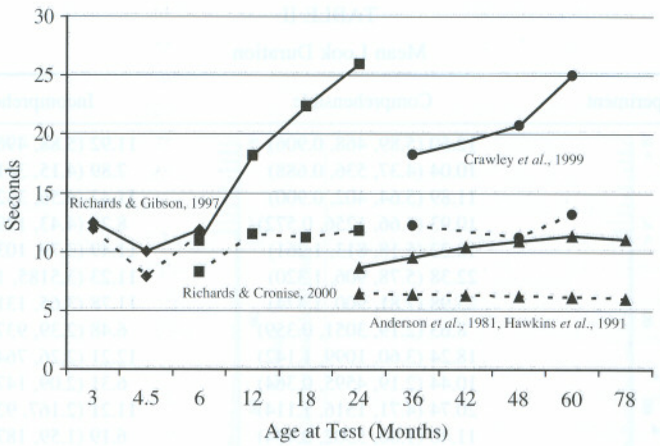

Fig. 3. Average look duration for the comprehensible and incomprehensible stimuli, separately for each testing age. The solid lines in each case represent the comprehensible stimuli and the dashed lines represent the incomprehensible stimuli. Points representing data from the experiments are connected for each experiment.

infancy followed by a steady increase in the duration with which children view television programs.

C. FREQUENCY DISTRIBUTIONS OF LOOK DURATIONS

The distribution of look durations that formed the data for this study are shown in Figure 4, separated for looks toward comprehensible stimuli (top figures) and looks toward incomprehensible stimuli (bottom figures), for both children (Crawley *et al.*, 1999; Richards & Cronise, 2000; Richards & Gibson, 1997) and adults (Richards, 2000). The four distributions shown in Figure 4 do not appear to have a normal distribution, but have a clear skew and kurtosis typical of the lognormal distribution. Two obvious differences between looks toward the comprehensible and incomprehensible stimuli may be seen in these figures. One difference was a preponderance of very short look durations for the incomprehensible stimuli relative to that found for the looks toward the comprehensible stimuli. The second difference was the existence of a larger proportion of looks in the middle range of look durations (e.g., 15–60 sec) for the comprehensible stimuli and the several extended fixations (e.g., looks >2 min). When data are plotted for individual participants, the group distributions clearly reflect individual distributions.

As presented previously (Section I.B), the hazard function for look duration has been plotted for participants across a wide age range. The particular hazard

TABLE II
Mean Look Duration

Age and experiment	Comprehensible	Incomprehensible
3 months[1]	12.50 (5.89, 468, 0.906)	11.92 (5.88, 496, 0.718)
4.5 months[1]	10.04 (4.37, 536, 0.688)	7.89 (4.15, 341, 0.536)
6 months[1]	11.89 (5.64, 402, 0.900)	11.42 (4.56, 332, 1.029)
6 months[2]	10.93 (4.66, 1256, 0.572)	8.26 (4.43, 1293, 0.297)
12 months[2]	18.22 (5.18, 813, 1.261)	11.49 (3.79, 1032, 0.668)
18 months[2]	22.38 (5.78, 906, 1.320)	11.23 (3.5185, 1130, 0.574)
24 months[2]	25.98 (7.81, 900, 1.474)	11.78 (3.65, 1318, 0.564)
24 months[3]	8.63 (2.19, 3051, 0.359)	6.48 (2.39, 937, 0.390)
36 months[5]	18.24 (3.60, 1099, 1.142)	12.21 (2.26, 764, 1.019)
42 months[3,4]	10.44 (2.19, 4595, 0.364)	6.31 (2.09, 1478, 0.330)
48 months[5]	20.74 (4.71, 1516, 1.114)	11.21 (2.167, 927, 1.105)
60 months[3,4]	11.40 (1.80, 5502, 0.434)	6.19 (1.59, 1873, 0.299)
60 months[5]	24.99 (5.98, 1104, 1.557)	14.47 (2.5, 852, 1.179)
78 months[4]	11.07 (2.63, 1242, 0.726)	6.05 (2.24, 541, 0.451)
Adults[6]	64.12 (18.50, 3372, 1.794)	39.54 (7.75, 1147, 2.310)
Adults[7]	22.07 (4.78, 1912, 1.243)	–

Note: median, N, and standard errors are presented in parentheses.
[1]Richards & Gibson, 1997.
[2]Richards & Cronise, 2000.
[3]Anderson *et al.*, 1981a,b.
[4]Hawkins *et al.*, 1991.
[5]Crawley *et al.*, 1999.
[6]Richards, 2000.
[7]Burns & Anderson, 1993.

function that was found should result in the type of distribution as shown in Figure 4. Thus, we should expect that these distributions are similar across these ages. Separating frequency distributions by age and type of stimulus produced very similar pictures to those shown in Figure 4. These functions are shown for children aged 3 months, 1, 2, 3, 4, and 5 years in Figure 5. Each distribution in this figure has the most looks occurring at very short intervals and only a few extended looks. What appears to be changing with age in these distributions is a small decrease in the number of very short looks, an increasing proportion of middle-duration (e.g., 15–60 sec) looks, and an increase in the number of very extended looks at the right-hand tail of the distribution. Our interpretation of the similarity of these distributions, and the associated hazard function for such distributions, implies that attentional inertia occurs at all of the ages we have studied. This similarity is consistent with the idea that the same cognitive process is guiding look duration at these different ages. We explore this in more detail in later sections (Section II.D, III.B, and III.C).

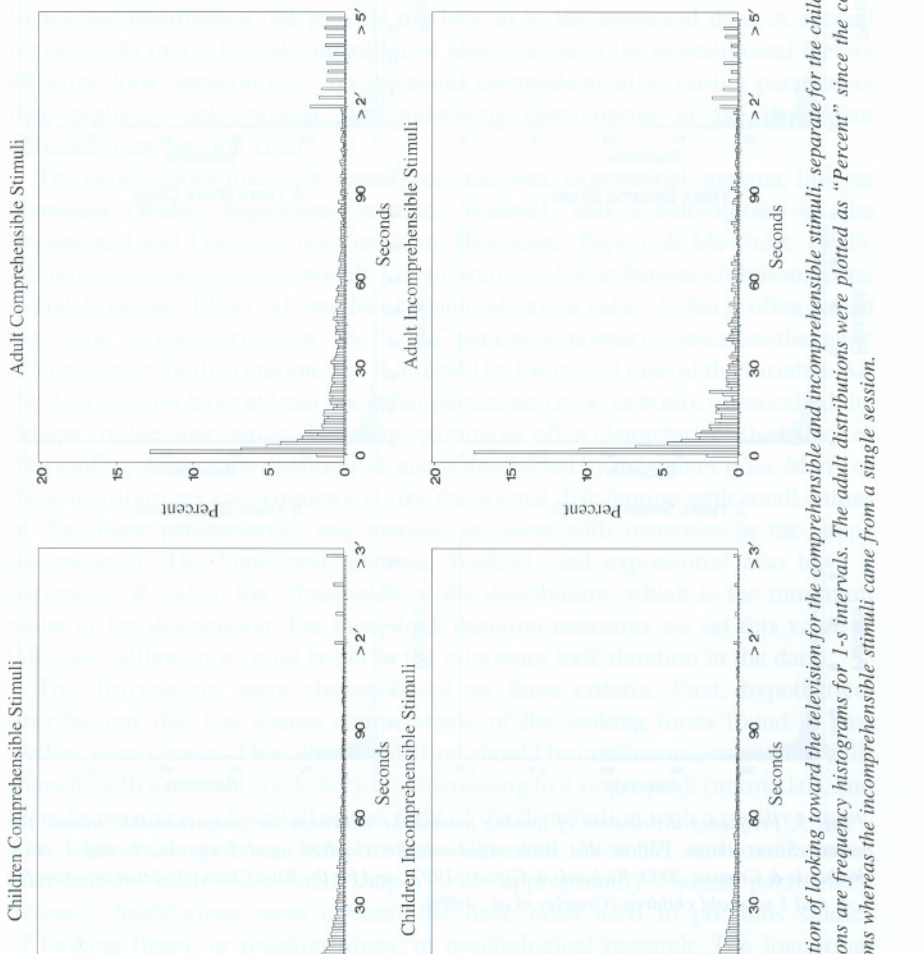

Fig. 4. Frequency distribution of looking toward the television for the comprehensible and incomprehensible stimuli, separate for the children and adult participants. These distributions are frequency histograms for 1-s intervals. The adult distributions were plotted as "Percent" since the comprehensible stimuli came from four sessions whereas the incomprehensible stimuli came from a single session.

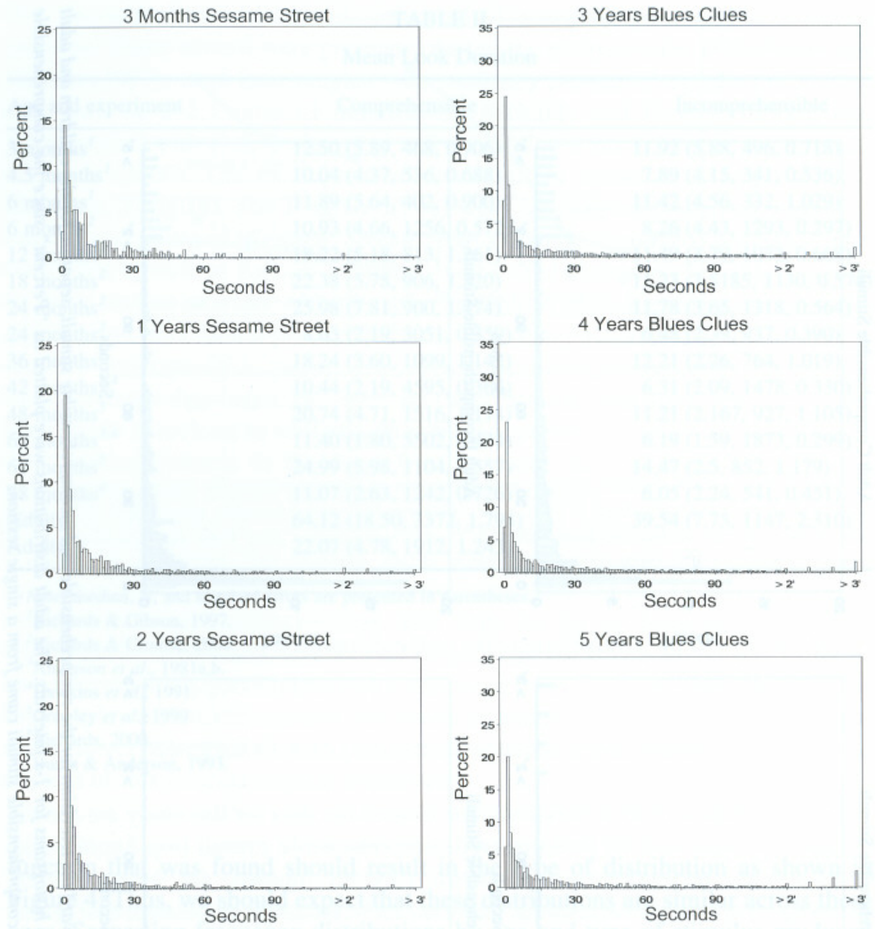

Fig. 5. Frequency distribution of looking toward the television for comprehensible stimuli, the Sesame Street *movie,* Follow that Bird, *separately for children aged 3 months, 1, and 2 years (Richards & Cronise, 2000; Richards & Gibson, 1997), and for the* Blue Clues *television program for 3, 4, and 5 year old children (Crawley et al., 1999).*

D. HYPOTHETICAL DISTRIBUTIONS

The empirical data were compared against hypothetical distributions to determine the best fitting probability distribution type. There were several reasons to do this. First, the lognormal distribution has been reported to describe look durations (Anderson *et al.*, 1981a,b; Burns & Anderson, 1993; Choi & Anderson, 1991; Hawkins, Yong-Ho, & Pingree, 1991, 1995; Richards, 2000; Richards & Cronise, 2000; Richards & Gibson, 1997) but only some studies

(Burns & Anderson, 1993; Richards, 2000; Richards, 2002; Richards & Anderson, 1999; Richards & Casey, 1992; Richards & Cronise, 2000; Richards & Gibson, 1997; Richards & Turner, 2001) have provided a quantitative comparison of distributions. Thus we wanted to confirm for all the studies that the lognormal distribution did provide the best fit to the empirical data. A second reason to do this is to make quantitative assessments of the experimental factors affecting look duration (i.e., age, stimulus comprehensibility) using parameters that explicitly acknowledge the underlying distributions of the dependent variables (see Section II.E).

The distributions that were tested were the beta, exponential, gamma, inverse Gaussian (Wald), lognormal, normal, Weibull, and a convolution of the exponential and Gaussian (ex-Gaussian; Heathcote, Popiel, & Mewhort, 1991). All but the ex-Gaussian are widely known statistical distributions (Johnson, Kotz, & Balakrishnan, 1994). All but the exponential have a value, ξ, that is often called the "scale" of the distribution. The "scale" parameter primarily describes the range of numbers in the distribution, and is affected by the unit of time of the variable. All the distributions have at least one other parameter (σ, λ, or both), often called the "shape" of the distribution. The shape parameter often characterizes the extent of the positive skew of the distribution, and is unaffected by the unit of time. Many of these distributions are symmetrical like the normal distribution with small values of the shape parameter(s), and increase in skew with increases in the shape parameter(s). The lognormal, gamma, Weibull, and exponential also have a parameter, θ, called the "threshold" of the distribution, which is the minimum value of the distribution. For these look duration measures we set this value at 0.0 msec, although it could be set to the minimum look duration in the data.

The distributions were chosen based on three criteria. First, hypothetical distributions that had shapes characteristic of the looking times found in past studies were chosen. Thus, the distribution should be continuous, somewhat bell-shaped, with a probability density first increasing to a single peak (unimodal), and then decreasing to a long tail on the right of the distribution with a positive skew. The lognormal, gamma, beta, inverse Gaussian, Weibull, and ex-Gaussian distributions each have such shapes with appropriately chosen parameters. Second, distributions were chosen that have been used in previous studies of looking times, or reaction times, in psychological research. The lognormal (Bree, 1975; Hockley, 1984; Ratcliff & Murdock, 1976; Richards, 2000; Richards & Cronise, 2000; Richards & Gibson, 1997; Ulrich & Miller, 1993), ex-Gaussian (Ashby, 1982; Heathcote, Popiel, & Mewhort, 1991; Hockley, 1984; Hockley & Corballis, 1982; Hohle, 1965; Ratcliff, 1978, 1979; Ratcliff & Murdock, 1976; Ulrich & Miller, 1994; Van Zandt & Ratcliff, 1995), Weibull (Logan, 1988, 1992, 1995; Van Zandt & Ratcliff, 1995), and gamma (McGill & Gibbon, 1965; Ratcliff & Murdock, 1976; Van Zandt & Ratcliff, 1995) have been used to characterize fixation data and reaction time data. The normal and exponential distributions do not have the characteristic shape for the looking times, but have been used widely in psychological research. Third, we chose the gamma and beta distributions because they are the "parent" distribution of several distributions used widely in psychological research (e.g., exponential, χ^2, t and F) and as such may successfully model this data. Several of these distributions are related (e.g., the exponential distribution is a special case of the gamma distribution, and a special case of the Weibull distribution; ex-Gaussian is the convolution of the exponential and normal distributions). Because of this, the comparisons of the hypothetical distributions with the empirical data should overlap. For example, the fit of the gamma distribution or the Weibull distribution should be better than the exponential distribution. The underlying hypothesis of the exponential distribution, as applied to duration data, is that the process that causes the duration to conclude is constant over time. That is, the hazard of termination is constant from one interval of time to the next. Attentional inertia, in contrast, implies that the hazard decreases with time. Nevertheless, the exponential distribution was included because it has been commonly used in other psychological research and represents a form of null hypothesis for a theory of attentional inertia.

E. COMPARISON OF EMPIRICAL AND HYPOTHETICAL DISTRIBUTIONS

The frequency distributions of look durations from the empirical data were compared to the hypothetical distributions. The details for estimating the parameters of these distributions from the empirical data are presented elsewhere (Richards, 2000; Richards & Anderson, 1999).[1] First, the data from all children's

[1]The details for estimating the parameters of these distributions from the empirical data are presented elsewhere (Richards, 2000; Richards & Anderson, 1999). We used iterative minimization techniques based on maximum likelihood parameter estimates. A "quasi-Newton" technique known as the Broyden-Fletcher-Goldfarb-Shanno algorithm (Press *et al.*, 1992) was used for the minimization. A by-product of this minimization method is the "inverse Hessian matrix," which represents the covariance matrix of the fitted estimates. The inverse Hessian matrix also contains the standard error (SE) of each estimate for quantitative comparison of the parameter values (Press *et al.*, 1992). The standard errors of the parameter estimates may be used to compare parameters obtained from different groups (i.e., ages, comprehensible, and incomprehensible stimuli). The fit of the hypothetical distribution and the empirical data was assessed with methods based on χ^2. The null hypothesis in each case was that the hypothetical and empirical distributions did not differ. With large N the null hypothesis of no difference between the hypothetical and observed distribution is easily rejected, so that very few comparisons would be "nonsignificant," indicating a fit of the hypothetical and empirical distributions. Therefore, a measure of the closeness of the fit of the hypothetical distribution and the empirical distribution, the "root-mean-squared error of approximation" (RMSEA) was calculated for each of the tests. The RMSEA ranges from 0.0 to 1.0, with small values indicating a good fit of the data and the hypothetical distribution, and takes into account the N of data used to estimate the χ^2. A specific value for a "close fit" has been recommended as 0.05 (Browne & Cudeck, 1993; MacCallum, Browne, & Sugawara, 1996).

looks from the unrestricted presentation studies (Crawley *et al.*, 1999; Richards & Cronise, 2000; Richards & Gibson, 1997) were compared separately for the comprehensible and incomprehensible stimuli (Figure 4). The comparison was made by estimating parameters of the hypothetical distribution with maximum likelihood techniques and comparing the empirical and hypothetical distribution's χ^2. The null hypothesis that the hypothetical distribution was not different from the empirical distribution of the looks toward the stimulus was rejected for all hypothetical distributions. However, this is typical of distributional analyses in which there is a great deal of statistical power. The frequency distribution of the look durations toward the comprehensible stimuli had the closest fit to the lognormal distribution, $\chi^2(146, N = 9000) = 475.76$, followed by the inverse Gaussian, $\chi^2(146, N = 9000) = 839.93$, Weibull, $\chi^2(146, N = 9000) = 1404.33$, and the gamma, $\chi^2(146, N = 9000) = 4612.31$. We also tested the beta, exponential, normal, and ex-Gaussian distributions. These latter distributions were extremely poor fits to the data. The frequency distributions for the looks toward the incomprehensible stimuli followed the same pattern as the comprehensible stimuli. The frequency distribution and the lognormal hypothetical distribution had the closest fit, $\chi^2(97, N = 8485) = 273.94$, followed by the inverse Gaussian, $\chi^2(97, N = 8485) = 362.07$, Weibull, $\chi^2(97, N = 8485) = 1113.96$, and the gamma, $\chi^2(97, N = 8485) = 15518.78$. In this case the gamma distribution, as well as the beta, exponential, normal, and ex-Gaussian distributions, were very poor fit to the empirical data.

A measure of fit of the hypothetical distribution and the empirical distribution, the RMSEA, was calculated for each of the tests. The RMSEAs for the comprehensible stimuli were 0.01584, 0.02298, 0.03094, and 0.05830 for the lognormal, inverse Gaussian, Weibull, and gamma distributions, respectively. Because of the large number of observations ($N = 9000$) the confidence intervals around these estimates were very small, and each was significantly different from the closest one. An RMSEA of 0.05 has been suggested as indicating a close fit of two distributions (Browne & Cudeck, 1993; MacCallum, Browne, & Sugawara, 1996). This would lead to the conclusion that the lognormal, inverse Gaussian and Weibull distributions were a close fit with the empirical distribution. The RMSEAs for all the other distributions were greater than 0.05, indicating a poor fit of those distributions and the empirical frequency histograms. The RMSEAs for the incomprehensible stimuli followed the same pattern. Richards (2000), using adult data, reported that the lognormal distribution fit the best, followed by the Weibull, gamma, and inverse Gaussian distributions.

The probability density functions for the lognormal, inverse Gaussian, Weibull, and gamma are shown in Figure 6 separately for the comprehensible and incomprehensible stimuli, and only for the children's data. The lognormal and inverse Gaussian show the nonmonotonic peak near 1 sec and the decrease over the next 20 sec. The Weibull and gamma show a typical

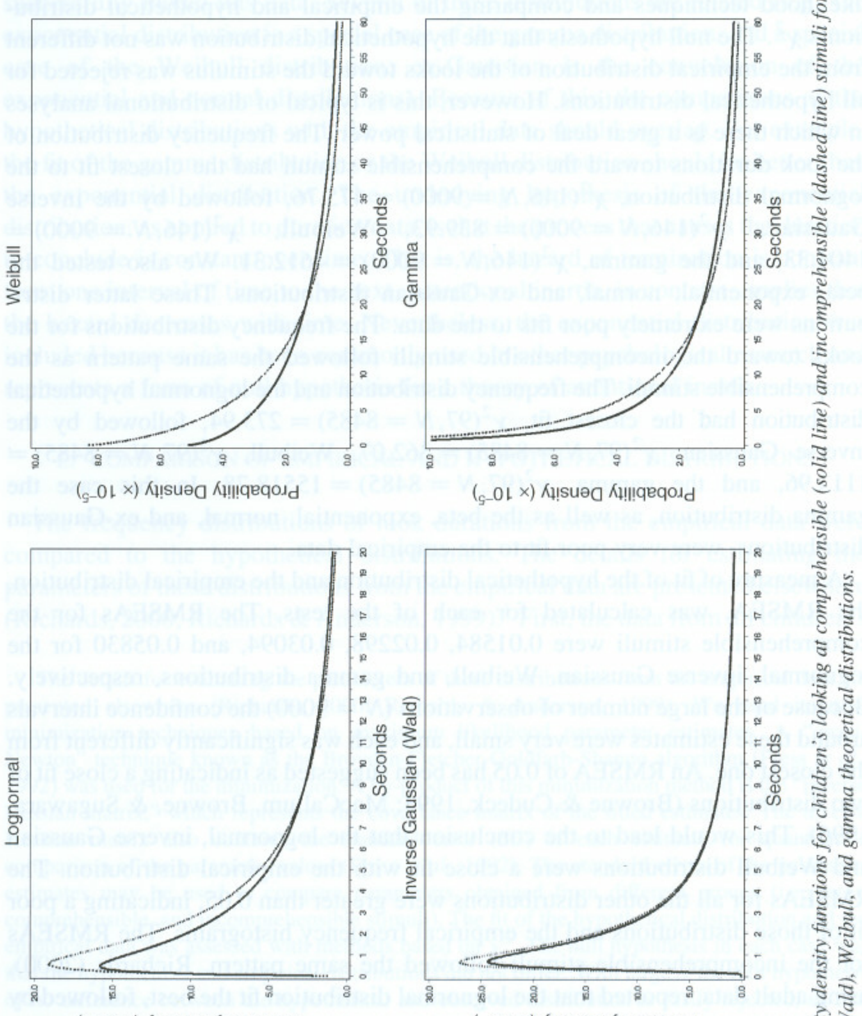

Fig. 6. Probability density function for children looking at comprehensible (solid line) and incomprehensible (dashed line) stimuli for the lognormal, inverse Gaussian (Wald), Weibull, and gamma theoretical distributions.

descending exponential-like function. The lognormal, inverse Gaussian, and Weibull have a higher peak for the incomprehensible stimuli, and the gamma function shows a slightly larger probability for looks from about 3 to 15 sec. This difference between the comprehensible and incomprehensible stimuli reflects the predominance of short duration looks for the incomprehensible stimuli (Figure 4). The lognormal, Weibull, and gamma also show a larger probability density at the long duration looks for the comprehensible stimuli.

In addition to comparing the fit of the empirical and hypothetical functions separately for the comprehensible and incomprehensible stimuli, we compared the fit only for the comprehensible data, but separately for each testing age. In this case the lognormal, inverse Gaussian, Weibull, and gamma distributions were compared to the frequency distributions at each age for the participant's look duration toward the comprehensible stimulus. Approximately, the same pattern of results was obtained for the four hypothetical distributions (i.e., the lognormal was the best fit to the empirical data, followed by the inverse Gaussian, Weibull, and gamma.) However, in this comparison there were differences across the testing ages in the fit of the empirical and hypothetical distributions. Across all ages the lognormal distribution was a good fit to the data. However, in the preschool years (years 1–5) the lognormal and inverse Gaussian distributions fit the empirical distributions equally well, and for the 5-year-olds and adults the inverse Gaussian became a relatively poor fit to the empirical data. Conversely, throughout the childhood years the Weibull and gamma functions fit the empirical data poorly. However, at 5 years (Weibull) and for the adult data (Weibull, gamma) these two distributions were a very good fit for the empirical data.

The probability density functions of the theoretical distributions were examined by sequentially eliminating long duration looks (i.e., all looks, all looks <120 sec, all looks <60 sec, all looks <30 sec, all looks <15 sec). This was done to determine if the distributions would "scale down" from a session with extended viewing (e.g., studies with extended viewing sessions; Crawley *et al.*, 1999; Richards & Cronise, 2000; Richards & Gibson, 1997) to one in which long duration looks were restricted because the video segments were relatively brief (e.g., studies that interspersed comprehensible and incomprehensible *Sesame Street* segments in a single viewing session, Anderson *et al.*, 1981a; Hawkins, Yong-Ho, & Pingree, 1991). The probability density function for the lognormal distribution for the children's looks toward comprehensible stimuli is shown in Figure 7. The basic shape of the function was retained over the five duration restrictions. This pattern of results was true for the inverse Gaussian, Weibull, and gamma functions as well (*cf.* hypothetical distributions in Figure 6). The four functions retained their relative order in the fit between the theoretical distribution and the empirical

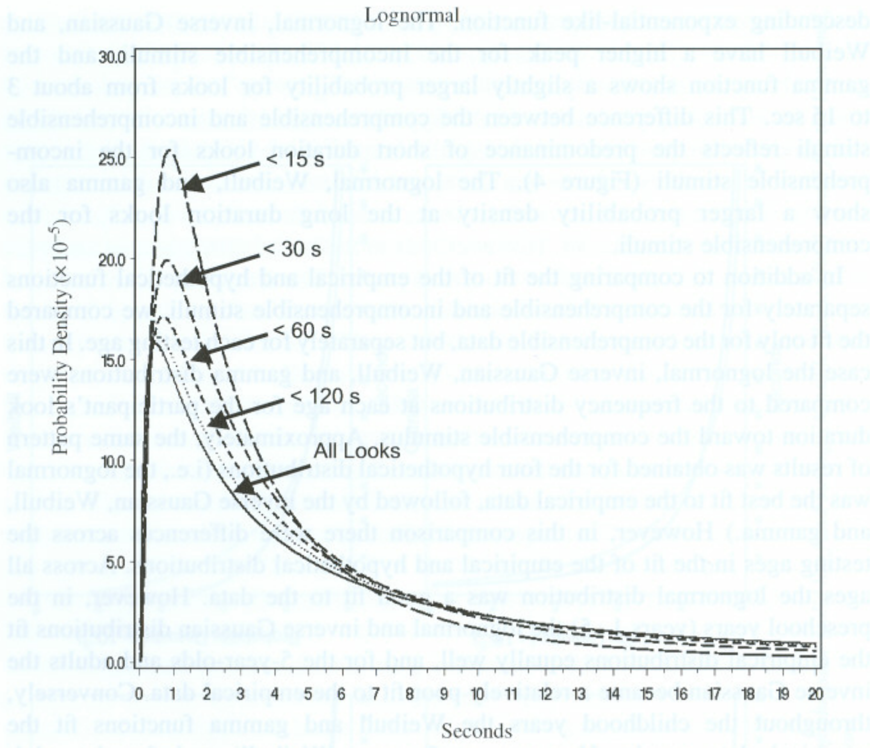

Fig. 7. Probability density function for the lognormal distribution, for children's looks toward comprehensible stimuli, separately for all looks, looks <120, looks <60, looks <30, and looks <15 sec. The solid line is for the data from all looks, and the other lines show an increasing peak density as look duration becomes more restricted.

data (i.e., lognormal, inverse Gaussian, Weibull, and gamma, in order of increasing RMSEAs).

Several conclusions may be drawn regarding the fits of the empirical distribution of look durations and the hypothetical distributions. First, the probability density function of the lognormal distribution was the best fit of the empirical data for all stimulus types and ages. This was true for infant, children, and adult participants, for comprehensible and incomprehensible stimuli in extended viewing situations, and for the restricted duration distributions (either restricted through sampling, as shown in Figure 7, or for the restricted duration data in Anderson *et al.*, 1981a,b; Hawkins *et al.*, 1991). This is the first time that a quantitative test of this distribution has been applied to all these studies. We are confident that the lognormal distribution is the best fit of these data.

The second conclusion we make from this analysis is an inference about the theoretical mechanism underlying look durations during television viewing. Previously, we described the hazard function analysis as applied to television viewing (Section II.B). This function increases from 0 sec to a peak at a short interval (i.e., 1–2 sec) followed by a decrease in the hazard over time (Figure 1). This hazard function implies two things. First, a lognormal distribution will characterize the distribution of looking durations. That was the case in the analyses in this section. Second, this hazard function implies the probability relations among look times and the probability of continuing a look or looking away. Looks in progress for a short time have a high probability of ending. As looks at the television become longer, the probability of the look terminating becomes progressively less likely. The attentional inertia phenomenon implies this relation between look length and looking away. The viewer becomes progressively engaged in the television program over the course of a look and thus should be less likely to look away voluntarily or be distracted by events occurring in the environment. We also should note that the lognormal distribution forms the basis for the quantitative models developed later in this chapter (Section III).

Finally, our conclusion from the similarity of these distributions over the various testing ages is that the same cognitive process affects look duration at the different ages. The empirical properties of the look distributions imply that attentional inertia is controlling looking toward television. The similarity of the look duration distributions suggests that the processes controlling looking are similar for young infants, preschool aged children, and adults. By characterizing this distribution, we are in a better position to describe what changes in television viewing occur in young children. A theoretical understanding of the mechanisms generating these distributions (Section III) should lead to a better characterization of the developmental processes affecting television viewing in infants and young children.

F. PARAMETER COMPARISONS

A final goal for this section is to use the distributional properties of the look durations during television viewing to assess what changes in television viewing in young children. Almost all the studies of television viewing made quantitative assessments of their experimental factors using log-transformed variables with ANOVA-based methods. Alternatively, using the parameters that describe the lognormal distribution rather than parameters of the normal distribution (i.e., mean, standard deviation) would have the advantage of specifically acknowledging the underlying distributions. This should result in more appropriately sensitive and discriminative analyses for experimental factors than methods based on transformations (Heathcote, Popiel, & Mewhort, 1991; Levine & Dunlap, 1982, 1983; Ratcliff, 1993) or truncation of outliers that do not seem to fit the normal distribution (Miller, 1991; Ratcliff, 1993;

Van Selst & Jolicoeur, 1994; Ulrich & Miller, 1994). A distributional analysis of the look durations done previously (Section II.D) should not be regarded as a technique only to verify the distributional properties of looks. Rather, we choose the best distribution(s) that fit the data, and based on that distribution, should compare the parameter estimates for children at different ages, or for comprehensible and incomprehensible stimuli.

The parameters describing the theoretical distributions that fit the observed distributions were estimated with maximum likelihood techniques. The scale and shape parameters that were estimated for the lognormal probability density function were also analyzed by testing age and stimulus condition (comprehensible, incomprehensible).[2] The data for this analysis were taken from the children that had the unrestricted viewing times (Crawley *et al.*, 1999; Richards & Cronise, 2000; Richards & Gibson, 1997). The scale for the comprehensible stimuli was significantly larger (scale = 8.62, $SE = 0.0165$) than the scale for the incomprehensible stimuli (scale = 8.29, $SE = 0.0151$), $t(243) = 1.83, p < 0.05$, whereas shape parameters did not differ significantly for the two stimulus types (shape = 1.57, $SE = .0116$, and 1.40, $SE = .0108$, for the comprehensible and incomprehensible stimuli, respectively). The "scale" parameter primarily describes the range of numbers in the distribution and is related to the positive skew of the distribution, whereas the "shape" parameter represents the shape of the dispersion of the distribution. This suggests that the primary difference between the comprehensible and incomprehensible stimuli in these studies was the extended viewing durations found for the comprehensible stimuli and the preponderance of short viewing durations for the incomprehensible stimulus (Figures 4 and 5).

The scale and shape parameters were compared across the different ages, separately for the comprehensible and incomprehensible stimuli. As shown in Figure 8, the scale parameter did not change as a function of age for the incomprehensible stimuli but did change for the comprehensible stimuli $F(8, 610) = 2.33, p < 0.02$. (Table III includes more detailed information of the change in scale across age in these studies.) The parameter did not change from age 3 to 6 months, and then increased from 6 to 24 months. Due to methodological differences between studies, there were differences in the absolute value of the scale parameter between the Richards and Cronise (2000), Crawley *et al.* (1999), and Anderson *et al.* (1981a,b; see Table III) or Hawkins *et al.* (1991; see Table III) studies, as was found with the mean look duration

[2] The ANOVAs for the parameter comparison were determined by calculating the between-groups mean square from the parameters and the within-subject variance from the standard errors of the estimates obtained in the maximum likelihood optimization. The within-subject variance was obtained by transforming the standard errors into variance and calculating the pooled variance and mean squares from the variance obtained with the standard errors.

TABLE III

Scale and Shape Parameters for the Lognormal Probability Density Functions

	Comprehensible			Incomprehensible		
Age and experiment	Scale parameter	Shape parameter	df	Scale parameter	Shape parameter	df
3 months[1]	8.68 (0.059)	1.29 (0.041)	42	8.63 (0.057)	1.28 (0.040)	43
4.5 months[1]	8.41 (0.054)	1.26 (0.038)	21	8.34 (0.062)	1.15 (0.044)	28
6 months[1,2]	8.49 (0.031)	1.28 (0.022)	73	8.40 (0.030)	1.19 (0.021)	64
12 months[2]	8.70 (0.050)	1.45 (0.035)	60	8.42 (0.041)	1.33 (0.029)	60
18 months[2]	8.80 (0.052)	1.58 (0.037)	74	8.31 (0.042)	1.42 (0.030)	65
24 months[2]	9.02 (0.054)	1.57 (0.037)	81	8.38 (0.038)	1.39 (0.026)	72
24 months[3,4]	7.73 (0.030)	1.66 (0.021)	81	7.71 (0.050)	1.54 (0.035)	44
36 months[5]	8.37 (0.052)	1.74 (0.037)	75	8.05 (0.056)	1.56 (0.039)	48
42 months[3,4]	7.78 (0.025)	1.76 (0.018)	119	7.74 (0.037)	1.45 (0.026)	56
48 months[5]	8.54 (0.044)	1.73 (0.031)	99	8.23 (0.049)	1/50 (0.034)	48
60 months[3,4]	7.66 (0.025)	1.87 (0.017)	133	7.41 (0.039)	1.69 (0.027)	59
60 months[5]	8.70 (0.053)	1.79 (0.047)	85	8.15 (0.054)	1.62 (0.039)	
78 months[3,4]	8.13 (0.040)	1.97 (0.028)	60	7.87 (0.052)	1.61 (0.036)	30
Adults[6]	9.67 (0.032)	1.90 (0.023)	64	9.10 (0.038)	1.79 (0.027)	76
Adults[7]	8.58 (0.038)	1.68 (0.027)	79	–	–	–

Note: Standard errors are in parentheses.
[1] Richards & Gibson, 1997.
[2] Richards & Cronise, 2000.
[3] Anderson *et al.*, 1981a,b.
[4] Hawkins *et al.*, 1991.
[5] Crawley *et al.*, 1999.
[6] Richards, 2000.
[7] Burns & Anderson, 1993.

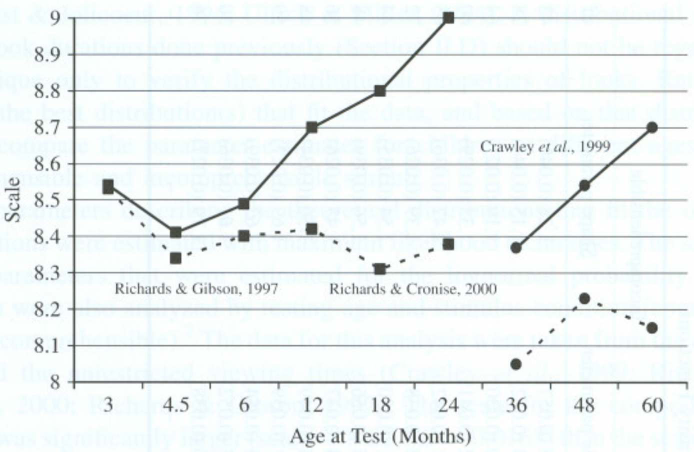

Fig. 8. The scale parameter of the lognormal distribution, shown separately for the comprehensible and incomprehensible stimuli and for each testing age. The solid lines in each case represent the comprehensible stimuli and the dashed lines represent the incomprehensible stimuli. Included in this graph were the experiments in which the participants had an unlimited exposure to the stimulus.

(Figure 3). Overall, however, there was a systematic increase in the scale over the ages used in these studies.

The shape parameter for both the comprehensible and the incomprehensible stimuli did not change over the three youngest ages (3, $4\frac{1}{2}$, 6 months; Figure 9). However, it increased steadily from 6 to 78 months for the comprehensible stimuli (Figure 9), $F(8, 610) = 2.83$, $p < 0.01$, but not for the incomprehensible stimuli. Although the overall age effect was not significant for the incomprehensible stimuli, Figure 9 illustrates some differences. *Post hoc* tests revealed that the shape parameter for the three youngest ages (3, $4\frac{1}{2}$, 6 months), the three middle ages (12, 18, 24 months), and the oldest ages (3, 4, 5 years) were significantly different ($p < 0.05$). The shape parameter represents the shape of the dispersion of the distribution. The finding that the shape changed significantly over the testing ages for both the comprehensible and incomprehensible stimuli implies that there was a developmental process affecting shape dispersion that applied to both the comprehensible and incomprehensible stimuli.

The data from the studies in which the comprehensible and incomprehensible *Sesame Street* segments were interspersed within a single testing session were also analyzed (Anderson *et al.*, 1981a,b; Hawkins *et al.*, 1991). The results from this study differed in several respects from those with the stimuli presented in an extended viewing session. The scale and shape parameters did not differ significantly despite the fact that the children paid more

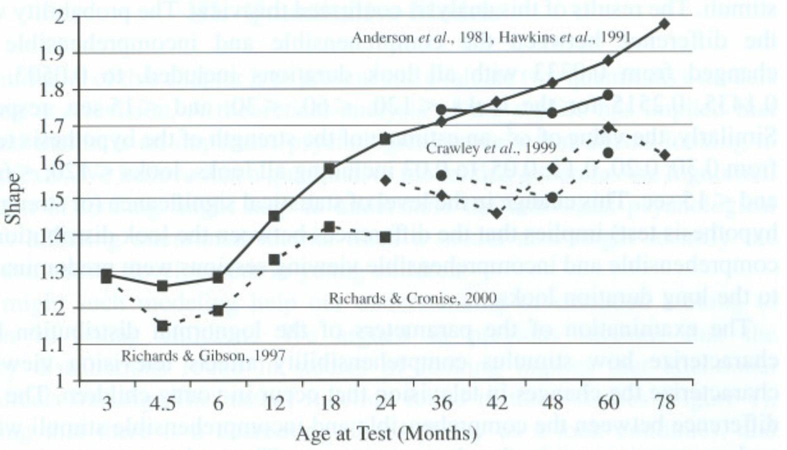

Fig. 9. The shape parameter of the lognormal distribution, shown separately for the comprehensible and incomprehensible stimuli and for each testing age (cf. Figure 4). This figure illustrates the experiments with the unlimited stimulus exposure and the experiments with the comprehensible and incomprehensible stimuli interspersed within a viewing session.

attention overall to the comprehensible stimuli. The scale parameters from the four testing ages differed significantly, $F(3, 438) = 8.61, p < 0.001$, such that the scale parameter for the oldest age group ($6\frac{1}{2}$ years) differed from the scale parameters for the three youngest ages (2, $3\frac{1}{2}$, 5 years, see parameters in Table III).

The shape parameter for the comprehensible stimuli increased with age from $1.66(SE = 0.021), 1.76(SE = 0.018), 1.87(SE = 0.017)$, to 1.97 $(\mathrm{SE} = 0.028)$, $F(3, 438) = 4.14, p < 0.01$, but did not change significantly for the incomprehensible stimuli, $F < 1.0$. The values of the shape parameter and their increase over the three testing ages for the comprehensible stimuli were very similar to the results for the stimuli presented in an extended viewing session (Figure 9). This suggests that the age differences in the shape parameter were relatively uninfluenced by stimulus type or the experimental procedure, whereas the scale parameter was highly sensitive to interactions between the age changes and the stimulus parameters.

The effect of the stimulus type on the scale parameter was further examined by sequentially eliminating long duration looks (i.e., all looks, all looks < 120 sec, all looks < 60 sec, all looks < 30 sec, all looks < 15 sec) from the studies with extended viewing sessions (Crawley *et al.*, 1999; Richards & Cronise, 2000; Richards & Gibson, 1997). This was done to determine whether the difference between the comprehensible and incomprehensible stimuli found with restricting the look duration length was primarily due to long looks during comprehensible stimuli. The results of this analysis confirmed this view. The probability value for the difference between the comprehensible and incomprehensible stimuli changed from 0.0333 with all look durations included, to 0.0503, 0.0782, 0.1435, 0.2515 for the looks < 120, < 60, < 30, and < 15 sec, respectively. Similarly, the value of ω^2, an estimate of the strength of the hypothesis test, went from 0.30, 0.20, 0.13, 0.05, to 0.03 including all looks, looks < 120, < 60, < 30, and < 15 sec. This change in the level of statistical significance (or strength of the hypothesis test) implies that the differences between the look distributions in the comprehensible and incomprehensible viewing sessions were predominantly due to the long duration looks.

The examination of the parameters of the lognormal distribution helps to characterize how stimulus comprehensibility affects television viewing and characterize the changes in television that occur in young children. The primary difference between the comprehensible and incomprehensible stimuli was in the scale parameter, not in the shape parameter. The scale parameter is related to the positive skew of the distribution. The primary difference, therefore, between the comprehensible and incomprehensible stimuli in these studies is the extended look durations for the comprehensible stimuli and the preponderance of short duration looks for the incomprehensible stimuli. This is consistent with ideas presented earlier (Section I.A) that comprehensible stimuli are more likely to elicit the phase of viewing in which active and engaged processing of television program content occurs. Attentional inertia is more effective for such stimuli precisely because the comprehensible content allows the increasing engagement of attentiveness over the course of a look. This also implies that the large difference in scale between the studies using extended viewing sessions (Crawley *et al.*, 1999; Richards & Cronise, 2000; Richards & Gibson, 1997) and those that interspersed comprehensible and incomprehensible *Sesame Street* segments in a single viewing session (Anderson *et al.*, 1981a; Hawkins *et al.*, 1991; see Table III) was primarily due to the truncation of the extended looks in the restricted duration studies.

The change in look durations over testing ages is more complex. There is a tendency to show more extended duration looks over the preschool ages (Figure 5), and the change in the scale parameter reflects this age change. The shape parameter also changed significantly over the testing ages for both the comprehensible and incomprehensible stimuli. This implies that some developmental process affects the overall shape of the frequency distribution in addition to the increasing preponderance of extended looks. Perhaps, some aspect of the shape parameter may be inferred from the quantitative models presented in the next section. The analysis of the parameters of the lognormal distribution gives a more fine-detailed description of the effect that comprehensibility plays in looks toward television, and the age changes in look duration, than did the simple changes in average look duration (Figure 3).

III. Quantitative Models

The third goal of this chapter is to present and evaluate two quantitative models of looking at television. A theoretical analysis of the studies has implied that attentional inertia is an important psychological process that affects looking in these contexts. We believe that a quantitative model that generates the lognormal distribution of looking might help to understand the individual psychological processes affecting attentional inertia. Such a model also might identify the process that shows development in young children.

Why might such modeling help our understanding of extended looking to television in young children? We argued in previous sections that the frequency distributions found in studies of looking implies that attentional inertia affects looking. The hazard function found in these studies (Figure 1), the finding that there is a decreasing distractibility as a look continues, and empirical studies showing better memory or less distractibility were taken to support the idea that there was an increasing attentional engagement over the course of a look. However, a process or mechanism that accounts for this increasing attentional engagement is not implied by these studies. The quantitative modeling of this phenomenon may provide a mechanism to account for attentional inertia.

A chief constraint in quantitative modeling of looks at television is that the model must generate data that conform at least approximately to the lognormal distribution. We know from the previous section and from several individual studies of looking that the lognormal distribution of looks occurs over a wide variety of testing ages and in several contexts in which extended looking occurs. Thus models that generate data that conform to the lognormal distribution are examined. These models were developed by Anderson in his studies of looking at television and play with toys (Burns & Anderson, 1993; Choi & Anderson, 1991), and by Richards in his studies of infant looking at audiovisual displays (Richards, 2000; Richards & Cronise, 2000).

A. ATTENTIONAL STRENGTH MODEL

Anderson developed a model based on a theory of attentional inertia that was fully described by Burns and Anderson (1993). The theory consists of seven principles (Burns & Anderson, 1993, pp. 779–780):

1. discourse processing occurs in a series of discrete cognitive units, each unit taking a discrete amount of time;
2. while processing a unit the person is highly resistant to distraction;
3. vulnerability to distraction occurs between processing unit boundaries because there is momentarily no focus of information processing;

4. inertial engagement is the strength of sustaining looking from one unit to the next, which is weak at the beginning of a look and strengthens over the course of a look;
5. increased inertial engagement results in decreased *distractibility*;
6. the increased inertial engagement also intensifies cognitive processing of the material to which processing is directed; and
7. inertial engagement is reset to an initial weak value at the end of a look, and does not carry over from one look to another.

For purposes of this chapter the quantitative model described by Anderson (Burns & Anderson, 1993; Choi & Anderson, 1991) will be referred to as the "attentional strength model." The model assumes that the "attentional glue" that sustains looking across successive units of processing strengthens as more units are processed.

The attentional strength model contains five parameters, including the length of a comprehension act, which is assumed to come from a normally distributed set of possible lengths with a mean and standard deviation, and the initial probability of looking away following the first comprehension act. The most theoretically important is the inertia parameter, *i*. The probabilities of looking away at the completion of successive units of cognitive processing are described as $p_t = ip_{t-1}, 0.0 < i < 1.0$. The degree to which the inertia value is less than 1.0 represents how quickly the tendency to continue looking at the television becomes strengthened over time; that is, the probability of looking away, between comprehension units, is driven down over time.

Burns and Anderson (1993) estimated parameters from the adult participants in their study. The length of a comprehension unit was estimated to be approximately 1 sec, the inertia parameter, *i*, was about .9, and the initial probability of looking away following the first comprehension unit was about 0.3. Simulations of the model produced data that matched the observed data quite well.

For the present chapter, this model was tested with quantitative techniques that allowed us to determine the model's fit to a number of data sets. A model was developed according to the parameters outlined by Burns and Anderson (1993). We used quantitative techniques for estimating the fit of the model similar to techniques used in previous sections (i.e., Section II.E and II.F; see Footnotes 1 and 2, and more details in Richards, 2000; Richards & Anderson, 1999). These techniques provided a measure of fit of the quantitative model and the empirical data, separate fits for comprehensible and incomprehensible stimuli and for the testing ages, and parameters that could be compared across these factors. Modeling of the observed look durations was moderately successful. First, the studies with unrestricted viewing sessions were modeled (Crawley *et al.*, 1999; Richards & Cronise, 2000; Richards & Gibson, 1997). The look durations from all testing ages were combined and the model parameters were estimated separately for the

comprehensible and incomprehensible stimuli. The fit between simulations and the observed look duration data was satisfactory for the comprehensible stimuli, $\chi^2\,(185, N = 9000) = 2728.40, RMSEA = 0.0390$, and for the incomprehensible stimuli, $\chi^2\,(131, N = 8485) = 2460.24, RMSEA = 0.0457$, indicating adequate fits. The inertia parameter was 0.981 ($SE = 6.606 \times 10^{-5}$) for the comprehensible stimuli and 0.968 ($SE = 2.869 \times 10^{-5}$) for the incomprehensible stimuli. These inertia parameters did not differ significantly, $t(303) = 1.31$, $p < 0.10$. It is not clear whether one would expect attentional inertia to change with type of content or whether it represents a parameter of the individual viewer, changing with age, perhaps. In terms of the model, one might expect the attractiveness of content to be captured in the initial probability of maintaining attention across the first content boundary, p_0.

The parameters of the attentional strength model were also estimated separately for each of the testing ages and the stimulus types. These parameters were estimated on the data including all look durations. The RMSEA fit index was often larger than 0.05 for these analyses indicating unsatisfactory fits. This was true for the data from the children aged 12 months to 5 years, in which the RMSEA was larger than 0.05 for each analysis (0.054–0.102). Further explorations indicated that although the attentional inertia model fit the overall observed data satisfactorily it did not account for developmental differences well and was not particularly sensitive to the experimental manipulations.

We suspect that this model did not fit the data well for two reasons (Richards, 2000). First, the underlying model does not explicitly generate output that is distributed lognormally. It is able to fit the data satisfactorily, but may not be intrinsically matched to the lognormal distributions of the look duration data. Second, the model fares poorly with truncated datasets (Figure 7). Thus for subsets of data for individual ages, some of which have shortened looking times compared to others, the model may be inadequate to provide satisfactory fits (Richards, 2000). A model that explicitly generates the lognormal distribution may therefore be a better quantitative approximation of attention inertia.

B. ATTENTION ENGAGEMENT GROWTH MODEL

Several models in biology, economics, and the social sciences produce outcome variables with lognormal frequency distributions (Crow & Shimizu, 1988). An attractive metaphor for present purposes is a model of active biological growth (Koch, 1966, 1969; Mosimann & Campbell, 1988; also see "partial-output model" of Ulrich & Miller, 1993). This model posits that growth at a previous stage actively contributes to production of new growth at the next stage. For example, the production of tissue at time 1 depends on the tissue existing at time 0; the production of tissue at time 2 depends on the production of tissue at time 1, and therefore also on the production of tissue at time 0. The processes combine in a multiplicative manner before a response (e.g., reaction time, look duration, tissue mass, body weight, brain size) is output or measured. The multiplicative relation between growth at the various stages leads to a lognormal distribution of measurements. Note that if a model posited a simple accretion of tissue at various stages, independent of previous stages, the model would be additive, producing a normal distribution.

A model consistent with the growth model and with the idea of attentional inertia might posit that viewing of complex audiovisual stimuli consists of a chain of discrete cognitive activities (e.g., "comprehension units") such as sequentially understanding the parts of a story. The initial cognitive activity is some brief comprehension unit such as initial recognition of the characters or setting currently presented on the screen (similar to the attention strength model described above). Unlike the strength model, the result of this comprehension affects the following comprehension unit by increasing its length, such as following an action or dialogue as it unfolds in time. Subsequently, the viewer may see that the action or dialogue is part of an unfolding narrative that can be considered at a higher level of abstraction, but which takes even more time to process. These discrete cognitive activities affect each other in a multiplicative growth relation, resulting in an expanding activation of attention, ultimately leading to the lognormal distribution of look durations. Alternatively, the expanding activation can be thought of as simply produced by prior engagement with a medium and not necessarily due to processing of larger and larger blocks of content. Rather, attention is engaged for increasingly longer periods of time in a multiplicative manner. In other words, even though the viewer may or may not be processing larger units of content, the progressive increase in attention activation will cause the viewer to maintain attention even when the content changes, as has been found by Anderson and Lorch (1983) and Burns and Anderson (1993).

Several variables must be estimated in the attention engagement growth model (for derivations of this class of model see: Koch, 1966; Mosimann & Campbell, 1988; Richards & Anderson, 1999; Ulrich & Miller, 1993). The level of activation at any given time is a multiplicative function of the level of activation at previous times. Therefore, the most important parameter of this model for this paper is the multiplicative parameter. For example, the level of activity after the first comprehension activity is $A_1(t) = k_1$, after the second comprehension activity, $A_2(t) = k_2A_1(t)$, or $A_2(t) = k_2k_1$, and finally the level of activation at any point in time is therefore, $A_n(t) = \prod_{i=1}^{n} k_i$. Although the model specification allows values of k_t to vary randomly from a normal distribution with a mean and variance, these multiplication constants may be modeled with a single value, as was done in the present analyses, reducing the number of parameters to be estimated. The looks away from the television occur when the activation level of the environment outside of the television (the viewing room and its associated distractions) exceeds the activation level to the television. The activation produced by the nontelevision environment is assumed to vary randomly according to a normal distribution with a mean and variance. Because the look begins with a low level of activation, there is a much larger chance that the look will terminate early than when the look has already survived to become a longer look and consequently has a much greater level of activation. Details of the model are presented in Richards (2000) and Richards and Anderson (1999).

An advantage of the attention growth model is that it explicitly generates look durations that are distributed lognormally. Consequently, the modeling of the observed look durations with the attention engagement growth model was successful. First, the data from the studies with unrestricted viewing sessions were examined (Crawley *et al.*, 1999; Richards & Cronise, 2000; Richards & Gibson, 1997). The look durations from all testing ages were combined and the model parameters were estimated separately for the comprehensible and incomprehensible stimuli. The simulated look durations fit the data well for the comprehensible stimuli, $\chi^2(199, N = 9000) = 633.17, \mathrm{RMSEA} = 0.0155$, and for the incomprehensible stimuli, $\chi^2(139, N = 8485) = 496.02, \mathrm{RMSEA} = 0.0173$. The RMSEA for both types of stimuli was substantially (and significantly) less than 0.05, indicating a very close fit of the data and the model. These RMSEA values, not surprisingly, were similar in magnitude to the fit of the lognormal distribution and the empirical data (0.01584). The multiplicative constant that related successive comprehension activities was 2.91 ($SE = 0.0019$) for the comprehensible stimuli and 2.53 ($SE = 0.0033$) for the incomprehensible activities, and these values differed significantly, $t(348) = 5.21, p < 0.001$. One interpretation of this value is that each comprehension act nearly tripled (increased by a factor of 2.91) in duration over the course of attention engagement growth within a look for the comprehensible stimuli. An alternative way to express this is that as a look is maintained, attention activation grows such that the look is likely to continue through time according to a logarithmic metric (base 2.91). The growth of attention engagement for the incomprehensible stimuli was not as large, suggesting that the activation parameter captures the attentional value of the stimulus as well as the tendency of the individual viewer to sustain attention.

The parameters of the attention engagement growth model were also estimated separately for the testing ages and the stimulus types. The attention activation parameter, k, is shown in Figure 10 for the different stimulus conditions (detailed information is presented in Table IV). The parameter for the comprehensible stimuli did not change from age 3–6 months (Richards & Cronise, 2000; Richards & Gibson, 1997), but increased from 6–24 months, $F(8, 549) = 23.18, p < 0.001$. The parameter for the incomprehensible stimuli did not change significantly from 6–24 months of age (data from Richards & Cronise, 2000). The RMSEA value for the ages and stimulus types ranged from 0.007 to 0.038,

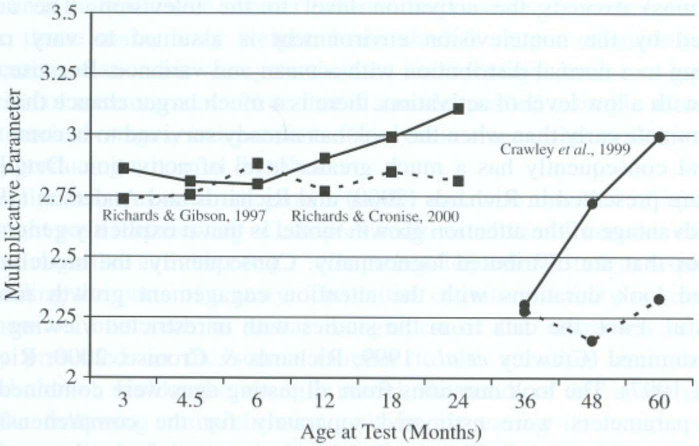

Fig. 10. The multiplicative parameter of the attention engagement growth model, separately for the comprehensible and incomprehensible stimuli and for each testing age, for the experiments with unrestricted viewing exposures.

and in each case the RMSEA value was significantly less than 0.05, indicating a close fit of the model for each of the tests. As with the mean look duration (Figure 3) and other indices from these studies, the absolute value of this parameter decreased between the Richards and Cronise (2000) and the Crawley *et al.* (1999) studies. However, in the Crawley *et al.* (1999) *Blues Clues* study, the parameter increased with age between 3 and 5 years. Analyzing look duration at

TABLE IV

Multiplicative Parameter for the Attention Engagement Growth Model

Age and experiment	Comprehensible	Incomprehensible
3 months[1]	2.951 (0.0254, 38)	2.915 (0.0031, 38)
4.5 months[1]	2.750 (0.0019, 36)	2.803 (0.0098, 26)
6 months[1,2]	2.851 (0.0116, 69)	2.781 (0.0018, 59)
12 months[2]	2.962 (0.0040, 55)	2.808 (0.0087, 53)
18 months[2]	3.076 (0.0086, 64)	2.696 (0.0064, 56)
24 months[2]	3.139 (0.0061, 66)	2.703 (0.0047, 63)
36 months[3]	2.583 (0.0038, 65)	2.201 (0.0211, 45)
48 months[3]	2.791 (0.0083, 82)	2.185 (0.0215, 42)
60 months[3]	2.923 (0.0001, 74)	2.379 (0.0119, 42)
Adults[4]	3.437 (0.0219, 61)	3.093 (0.0094, 78)

Note: Standard error and df are in parentheses.
[1]Richards & Gibson, 1997.
[2]Richards & Cronise, 2000.
[3]Crawley *et al.*, 1999, *Busy Town.*
[4]Richards, 2000.

the relatively low attention stimulus *Busy World* from Crawley *et al.* (1999), however, there was no increase from 3–5 years of age.

The attention engagement growth model parameters were examined by sequentially eliminating long duration looks (i.e., all looks, all looks <120, all looks <60, all looks <30, all looks <15 sec) from the studies with extended viewing sessions (Crawley *et al.*, 1999; Richards & Cronise, 2000; Richards & Gibson, 1997). This was done to determine if the model parameters and fit needed the extended viewing session or would be affected by restricting the range of looks to those that could occur in studies that used brief video segments. The fit for all models restricting looks up to 30 sec was excellent (i.e., RMSEAs <0.031, significantly <0.05), and the model for all looks less than 15 sec was only satisfactory (RMSEA $= 0.052$ and 0.046 for the comprehensible and incomprehensible stimuli). The multiplicative parameter changed little for the models (comprehensible stimuli, 2.91, 2.85, 2.86, 2.78, 2.62 for all looks, <120, <60, <30, <15 sec, respectively; incomprehensible stimuli, 2.53, 2.64, 2.71, 2.67, 2.50, respectively), dropping off primarily for the looks less than 15 sec. The difference in the multiplicative value between the comprehensible and incomprehensible stimuli was statistically significant for all looks, looks less than 120 sec, and looks less than 60 sec, but was not significant for looks less than 30 sec and looks less than 15 sec. These results imply that the attention engagement growth model fit the data of all durations well, and that the model parameters were sensitive to the experimental manipulations for the moderate and extended duration data.

Having established that the growth model accurately characterizes data based on short video segments, parameters were estimated from the studies in which the comprehensible and incomprehensible *Sesame Street* segments were interspersed (Anderson *et al.*, 1981a,b; Hawkins *et al.*, 1991). This was done to determine if the distributions would "scale down" from a session with extended viewing to one in which long duration looks were restricted because the video segments were relatively brief. The fit of the model and the observed data was excellent for each model that was tested (RMSEA values range from 0.0071 to 0.0363, all significantly less than 0.05). However, the results differed in several respects from the results with the stimuli presented in an unrestricted viewing session. The multiplicative attention engagement parameter for these data was larger for the incomprehensible stimuli (1.75, $SE = 0.0074$) than the comprehensible stimuli (1.66, $SE = 0.0019$) but this difference was not statistically significant, $t < 1.0$. These values were substantially less than the values estimated for the sessions with unrestricted viewing times (e.g., 2.91, 2.53). There was a significant effect of testing age on the multiplicative parameter for the comprehensible stimuli sessions, $F(3, 336) = 58.96$, $p < 0.001$, as well as for the incomprehensible stimuli sessions, $F(3, 167) = 19.55$, $p < 0.001$. Unlike the age effects on the parameter for the data from the unrestricted viewing session studies, there was no clear increase over age, and the distinction in the parameter between comprehensible and incomprehensible stimuli found for the 2- and $3\frac{1}{2}$-year-old children was not found at 5 and $6\frac{1}{2}$ years of age. This lack of change is likely due to the restriction of the extended looks in the procedure due to the interspersing of the comprehensible and incomprehensible stimuli. It suggests that an important factor changing over age is the presence of these very long duration looks during extended television viewing.

One reason the attention growth model fits the data so well is that the underlying multiplicative model explicitly generates look durations that are lognormally distributed. Figure 11 presents the best lognormal distribution for the modeled data and the observed data, separately for the comprehensible and incomprehensible stimuli. The model produced a probability density function that was similar in shape and size to the observed distributions for looks to both

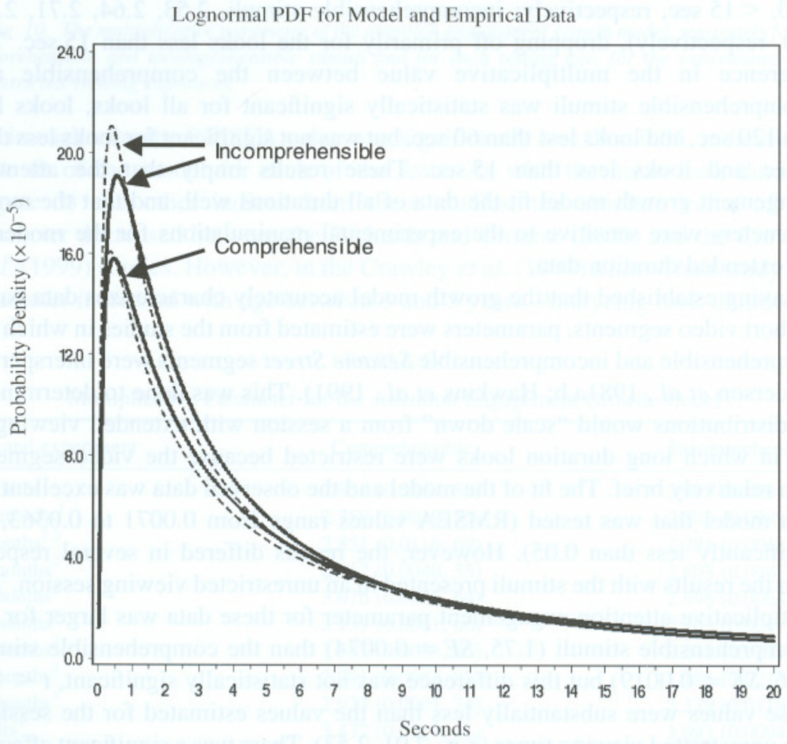

Fig. 11. The hypothetical probability density functions for the best-fitting lognormal function for the data generated by the attention engagement growth model (dashed lines) and for the observed data (solid lines). The data are shown combined across all testing ages. The comprehensible stimuli for the model and the data had the lowest density at the short durations and higher density at the long durations.

comprehensible and incomprehensible stimuli. The relative differences in the probability distribution function between the comprehensible and incomprehensible stimuli sessions for the observed data were preserved in the best fitting distribution for the model-generated data. This fit between the distribution of the simulated data from the modeling and the observed data from the experiments reflects the small RMSEAs for the attention growth model.

C. SUMMARY OF MODELING RESULTS

What is the significance of this modeling for our understanding of attentional inertia, and the development of extended looking to television in young children? The inertia parameter of the attentional strength model (Burns & Anderson, 1993) represents how quickly the tendency to continue looking at the television becomes strengthened over time. The implication of this model is that the primary process driving attentional inertia is related to resistance to distraction and continued looking. This model fits the overall data but did poorly for smaller datasets. There also was no significant age change in the inertia parameter. If we accept this model as an adequate description of the processes underlying attentional inertia, it would imply that the distractibility/continued looking process does not change significantly in infants and preschool aged children.

The attention growth model (Richards, 2000; Richards & Anderson, 1999; Richards & Cronise, 2000) fits the data more closely than the attentional strength model. This likely was due to the fact that the underlying mechanics of the model (Koch, 1966; Mosimann & Campbell, 1988; Richards & Anderson, 1999; Ulrich & Miller, 1993) uses a multiplicative relation between successive comprehension units, thereby explicitly generating lognormally distributed output data. This model posits that the comprehension occurring at a specific time affects subsequent comprehension activities by increasing their length. That is, the viewer might make an initial recognition of something in the program, and subsequent action or dialog is comprehended more fully and for a longer period of time. The engagement with comprehensible material in the program leads to a progressive increase in attention activation and the viewer maintains attention even when the content changes.

This model implies that the change in looking duration in the preschool children tested in this study is directly linked to a growing effect of comprehension on looking. The multiplicative parameter relating successive comprehension units increased significantly for the comprehensible stimuli but not for the incomprehensible stimuli. This suggests that what develops over this age is the viewer's ability to use the initial recognition of program content to control the subsequent engagement with the program. The maintenance of looking toward the stimuli is progressively strengthened over this age period.

The results of this model fitting also point to two developmental invariants. One, the success of the model for accounting for looking durations over all testing ages implies that the mechanism controlling this progressive attention growth is similar at all testing ages. Developmental changes occur in processes other than look duration control, perhaps increases in language, familiarity with television, or general cognitive advancement. Second, the response to incomprehensible stimuli does not vary significantly over ages. The response to the incomprehensible stimuli is similar to comprehensible stimuli in the earliest ages (Figure 3), but the response to the incomprehensible stimuli remains the same at the same time that the response to comprehensible stimuli is growing.

IV. Questions for Future Research

Although theorists have argued for the existence of something like attentional inertia since James (1890), its discovery in a research context is relatively recent (Anderson *et al.*, 1979). Prior to the mid-1970s, recording and quantifying the stream of behavior, including the onset and offset of a child's look at television, was very difficult. With the advent of affordable video technology interfaced to microcomputers, the quantitative study of the vicissitudes of looking became practical. Consequently, the statistical properties of large numbers of episodes of attention (looks at TV, toy play episodes) could be determined. Those statistical properties, in the form of hazard of look termination functions, led to the hypothesis that attention becomes increasingly engaged as a look or toy play episode is sustained. Despite early skepticism (Mendelson, 1983), that hypothesis has been affirmed by experiments showing sustained heart rate deceleration, decreased vulnerability to distraction, increased reaction times to secondary tasks, and increased information processing. A quantitative model that is based on the idea of a progressive growth in attentional activation fits the observed data well. All these findings are consistent with the hypothesis of increased attentional engagement over time.

Complex comprehension activities are not necessary for the existence of attentional inertia. This comes from the fact that very young infants show attentional inertia and that attentional inertia is found with incomprehensible audiovisual stimuli. This helps explain the observation that attentional inertia serves to drive attention across content boundaries in television such as from programs to commercials. The cognitive processes that are involved in comprehending the program (e.g., the contents of short-term memory, the functioning of the ongoing narrative schema) surely have to be reset as the viewer attends to the entirely different commercial.

Does this mean that attentional inertia is an automatic "dumb" attentional process only indirectly related cognition? Apparently not, insofar as the analyses

presented in this chapter show that attentional inertia increases with age, but only for comprehensible audiovisual content from about 6 months of age and older. Kaleidoscopic computer-generated images or fragmented incomprehensible TV programs produce attentional inertia, but not as much as programs that can engage higher cognitive processes. Attentional inertia seems to be a primitive attentional process that appears early on but with development comes to work in the service of higher cognition. We have a hint from the work with ADHD children (e.g., Lorch *et al.*, 2004) that attentional inertia may also be a significant factor in individual differences in attentional abilities as well as in narrative comprehension abilities.

Although attentional inertia appears to be a real phenomenon, we have much to learn about it. What causes attentional inertia? In what situations is it minimized, and in what situations is it maximized? Is it an automatic consequence of maintaining a look at a dynamic audiovisual stimulus or of maintaining a toy play episode? Is attentional inertia found in other domains of behavior such as reading, writing, and computer game playing? After a person becomes deeply engaged, what causes attention episodes (or play episodes) to end? That is, what factors ultimately negate attentional inertia? Richards (e.g., Richards & Casey, 1992) has observed that heart rate shows clear evidence of attention termination 3 or 4 sec before a look actually ends. Sometimes the termination response occurs without a look termination, and a reengagement process occurs (Lansink *et al.*, 2000). How do we reconcile these observations with the apparently inexorable increase in engagement as a look is sustained?

What is the relation of attentional inertia to habituation? For example, if an infant has been engaged in a long look at television, and if a static image is then displayed on the TV screen, would habituation to that image be slowed? Are attentional inertia and habituation opponent processes?

Answering these questions requires a great deal of more experimental and descriptive research. For example, because attentional inertia appears to occur in toy play, dynamic audiovisual stimulation apparently is not a necessary condition for its presence. Are there behavioral domains other than TV viewing and toy play in which attentional inertia might occur? Consider reading. When people read, they may continuously read for several minutes and then pause, looking away from the page briefly or for a more extended period of time, and then resume reading. Analysis of reading episode lengths by Imai *et al.* (1992) revealed hazard functions that are remarkably similar in form to those found for television viewing. If the same experimental procedures were applied to reading episodes as we have applied to TV viewing and toy play, would we find evidence for increased attentional engagement the longer a reading episode was in progress? That is, as a reading episode continued, would the reader become progressively less distractible, slower to respond to a secondary task, show progressively decelerated heart rate, be more likely to keep reading into a new and different unit of content, and show better memory and comprehension?

Even within the domain of television viewing where we know attentional inertia occurs there is a great deal to learn. For example, must TV viewers be freely in control of looking patterns for attentional inertia to emerge? Imagine that we could put look onsets under experimental control. This could happen, for example, if we gave a viewer some task that required attention to a computer screen, and then at some experimentally determined time point required the viewer to turn to another screen to watch an audiovisual stimulus, manipulating the length of time that stimulus was on before the stimulus was turned off, signaling the viewer to turn back to the computer screen. Would attentional inertia still be found as the look was sustained, as indexed by decreased distractibility, relatively slow reaction time to a secondary task, progressively improved memory for the audiovisual content, and so on?

If we could thus put attentional inertia somewhat under experimental control, we could begin to ask questions about changes in the brain as a look is sustained. Both electrophysiological and functional imaging techniques could reasonably be applied to answer such questions. Tucker and Williamson (1984) suggested that through dopaminergic prefrontal activation, a person is able to sustain an activity even as the momentary focus of attention changes. They argued that the activation is predominantly located in the right hemisphere in dorsolateral prefrontal areas. They contrasted this to the system that activates momentary foci of attention to specific stimuli, which they associated with a norepinephrine-based activation system located predominantly in the left hemisphere. If such patterns of activation could be confirmed, it would be interesting to see if the dopamine-based system followed the time course of attentional inertia.

What kinds of video stimuli do or do not produce attentional inertia? We are fairly certain that single static images would not, and would instead produce habituation. Would sequences of still images produce attentional inertia? If so, how frequently would they have to change? These questions can be multiplied and it is clear that parametric experimental research on the issue is possible.

Attentional inertia did not evolve so that people could watch TV commercials. It is obviously functional in ordinary human (and perhaps animal) perception and cognition. It may be an important bootstrap mechanism of cognitive development, insofar as it may keep a child attending to a source of discourse or other temporally structured information even when comprehension temporarily fails. For example, consider a young child listening to her parents talk. Other things being equal, the child will not pay much attention if the conversation concerns topics, such as politics, that are incomprehensible. If, instead, the parents are talking about an upcoming birthday party, the topic is both interesting and understandable and the child will pay extended attention. If the parents shift topics, they may use vocabulary that is unfamiliar to the child, and because

the conversation is difficult to comprehend, would ordinarily lose the child's attention. But having paid extended attention for some time, attentional inertia causes the child to continue to pay attention and devote more cognitive resources to trying to understand the conversation. In this way, the child may expand her lexicon as she hears words used in context, and may expand her general understanding as she processes discourse she might otherwise ignore. In this way, attentional inertia may be an essential enhancer of learning in formal as well as informal settings. In our view, it is quite worthy of future research and theory.

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UNDERSTANDING CLASSROOM COMPETENCE: THE ROLE OF SOCIAL-MOTIVATIONAL AND SELF-PROCESSES

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Being successful at school requires children to perform a range of social as well as academic competencies. In addition to mastering subject matter, developing effective learning strategies, and performing well on tests, children also must work to maintain and establish interpersonal relationships, strive to develop social identities and a sense of belongingness, observe and model standards for performance displayed by others, and behave in ways that are valued by teachers and peers (Wentzel, 2003). Research on children's school-related competence typically is focused on three sets of general outcomes: academic skills, displays of social competencies (e.g., cooperative or compliant behavior, positive relationships with peers), and the absence of negative or maladaptive behavior (e.g., aggressive, inattentive, or disruptive actions). Educators and policy makers also endorse these outcomes; the development of social competencies as well as scholastic achievements has been stated as an

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