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Extended Visual Fixation and Distractibility in Children from Six to Twenty-Four Months of Age

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Distractibility during extended visual fixations in children 6 months to 2 years of age was examined. A children's *Sesame Street* movie (*Follow That Bird*) was presented to children ($N = 40$) for a minimum of 20 min while fixation was videotaped and heart rate was recorded. Distractors (computer-generated patterns or another *Sesame Street* movie) were presented on an adjacent television screen. Consistent with prior research with older preschool-age children, the latency to turn toward the distractor was a function of the length of the look occurring before distractor onset. For the period immediately before distractor onset, children had a greater sustained lowered heart rate for the trials on which they continued looking at the center television monitor than for the trials on which they looked toward the distractor. This pattern of distractibility suggests attention increases over the course of a look toward the television, and that heart rate changes reflect this increase in attention.

INTRODUCTION

To understand the nature of attention in young children, extended looks during television viewing have been studied in infants (Richards & Gibson, 1997), preschool-age children (Anderson, Lorch, Field, & Sanders, 1981; Hawkins, Yong-Ho, & Pingree, 1991; Richards & Cronise, 2000), and college-age students (Burns & Anderson, 1993; Hawkins, Tapper, Bruce, & Pingree, 1995; Richards, 2000). These studies found a lognormal distribution of looks toward a television and have interpreted this distribution as supporting an increasing engagement of attention over the course of a look. At least two studies (Anderson, Choi, & Lorch, 1987; Lorch & Castle, 1997) found that preschool-age children become increasingly less distractible by peripheral distractors over the course of a look toward a television. This article reports a study showing that children in the early preschool years, 6 months to 2 years of age, become increasingly less distractible during extended looks during television viewing and that heart rate changes reflect this increasing attention engagement over the course of a look.

The distribution of look duration during extended television viewing has been shown to be positively skewed. That is, looks of relatively short duration (5–10 s) make up the largest proportion of looks, with a decreasing probability of occurrence of longer-duration looks. This distribution has been found in a number of studies of television viewing across a wide range of ages (Anderson, Alwitt, Lorch, & Levin, 1979; Burns & Anderson, 1993; Hawkins et al., 1991, 1995; Richards, 2000; Richards & Cronise, 2000; Richards & Gibson, 1997), and has been interpreted as being consistent with a model of *attentional inertia* for television viewing (Anderson & Lorch, 1983; Burns & Anderson, 1993; Richards & Anderson, 2000). The attentional inertia model hypothesizes that attention is relatively unengaged at the beginning of a look and becomes progressively more engaged as a look continues. Attentional inertia holds fixation toward a television in the face of changes in viewing content (new programs, commercials), structural changes in the program (cuts, edits, pans, scenes), and environmental distractors.

One implication of the attentional inertia model is that distractibility should change over the course of a look. At the beginning of a look, when attention is relatively unengaged, there should be a high level of distractibility. If the look survives beyond the first few seconds, as attention engagement increases, the probability of being distracted should progressively decrease as the look duration increases. This change in distractibility over the course of a look has been shown in studies of preschool-age children. Anderson et al. (1987) tested distractibility in 3- and 5-year-old children who were viewing a *Sesame Street* program. They found that peripheral distractors were relatively effective in eliciting localization at the beginning of a look, and less effective in interrupting looks if presented after at least 15 s of looking toward the program. The attentional inertia model and look distractibility may apply to other children's activities as well. Choi and Anderson (1991) tested distractibility in 5-year-old children while engaging in toy play. They found that length of time in the toy play episode was positively correlated with longer distractor localization latencies and lower distractor localization probabilities. Finally, Lorch and Castle (1997) found that 5-year-old children's performance on a secondary reaction time task demonstrated longer reaction latencies after a

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look had been in progress for 15 s than for shorter lengths of time. These two studies suggest that attention becomes increasingly engaged over the course of cognitive activity and is not limited to viewing behavior.

One goal of the current study was to determine if a particular distractibility procedure would be useful in evaluating attention engagement during television viewing in younger children. Studies of infants through age 12 months have shown that infants are relatively indistractible from central stimulus viewing (Richards, 1987, 1997) or toy play (Doolittle & Ruff, 1998; Lansink & Richards, 1997; Oakes & Tellinghuisen, 1994; Ruff, Capozzoli, & Saltarelli, 1996; Tellinghuisen & Oakes, 1997) while their attention is actively engaged. Alternatively, when attention becomes disengaged, infants are easily distracted from the stimulus they are viewing to look toward a peripheral stimulus. These studies have been interpreted as showing that during attention engagement the infant attends to objects in one part of the visual field and ignores others, whereas when attention is disengaged the infant is responsive to the total visual field (Richards & Lansink, 1998).

It is difficult to apply the same experimental procedures ordinarily used for studying attention in older children (e.g., 3–5 years of age; Anderson et al., 1987) to "toddlers" (e.g., 12–24 months) or "infants" (6–12 months). The distractibility procedure used during extended television viewing may be a useful experimental tool for studying attention in children in these two age ranges. According to the attentional inertia model, attention is relatively unengaged at the beginning of a look toward a television and therefore distractibility is greatest. This relatively disengaged attention could be similar to the "casual attention" state exhibited by infants and children who are engaged in object manipulation or play with toys during which attention is not actively engaged (Ruff, 1986; Ruff, Capozzoli, & Weissberg, 1998; Ruff & Lawson, 1990). Additionally, the attentional inertia model states that as a look progresses, attention becomes more engaged. This increased attention engagement could be similar to the "focused attention" state exhibited by infants and children who are engaged in toy play and object manipulation while attention is actively engaged (Ruff, 1986; Ruff et al., 1998; Ruff & Lawson, 1990). The study of attentional inertia during extended television viewing provides a technique that bridges the gap between studies of attention in young infants (Richards & Gibson, 1997), early preschool-age children (Richards & Cronise, 2000), and children older than 2 years (Anderson et al., 1981; Hawkins et al., 1991). Similarly, it was expected that the changes in distractibility during extended looks that are found in older preschool-age-children (Anderson et al., 1987; Lorch & Castle, 1997) and young infants (Richards & Lansink, 1998) would also be found in children in the age range of 6 to 24 months.

A second goal of the present study was to determine if there were changes in the level of distractibility over the 6-to-24-month age range. The lower distractibility found while children are engaged in extended television viewing (Anderson et al., 1987) or extended toy play (Choi & Anderson, 1991) has been attributed to an increased attention engagement, which may increase over this age range. For example, the time that children spend in focused attention and on-task time increases over this age range (Ruff & Lawson, 1990) and throughout the later preschool years (Ruff et al., 1998; see also Ruff & Rothbart, 1996, pp. 42–54). Similarly, there is an increase in television viewing over this age range (Anderson & Levin, 1976) and children become more responsive to comprehensible television program content (Richards & Cronise, 2000). These changes would be consistent with an increase in the amount, duration, or quality of engaged attention from 6 to 24 months of age. If this is the case, then the older children in the present study might be less distractible than the younger children during extended looking.

The third goal of this study was to examine the relation between heart rate changes and distractibility during extended visual fixation. Several studies with young infants have found that distractibility is related to heart rate changes elicited to a central stimulus. During periods of attention engagement in infants there is a sudden deceleration of heart rate that continues as long as the infant is attending to the stimulus (Richards & Casey, 1992). When the infant becomes disinterested in the stimulus, heart rate returns to its prestimulus level. Infants are less distractible from viewing a central stimulus (Casey & Richards, 1988; Richards, 1987, 1997) or playing with toys (Lansink & Richards, 1997) when their heart rate has decelerated than when it has returned to its prestimulus level. Thus, focused attention, which may change over this age range (Ruff & Lawson, 1990), and attention disengagement may be defined by heart rate changes in young infants and children (Lansink & Richards, 1997; Richards & Lansink, 1998). It was hypothesized that distractibility during extended television viewing would be related to the level of heart rate change occurring at the time of distractor presentation.

Two recent studies found changes in heart rate of children in the early preschool years over the course of an extended look (Richards & Cronise, 2000; Richards & Gibson, 1997). These studies showed a large, tonic, and progressive decrease in heart rate over the course, of extended looks during television viewing.

This progressive decrease was interpreted as reflecting increasing attention engagement consistent with the attentional inertia model. Conversely, children's heart rate returned to its prestimulus level immediately preceding a look away from the television, which was interpreted as a disengagement of attention preceding the look away from the television. The period of extended heart rate slowing would be analogous to "sustained attention" (Richards, 1987; Richards & Casey, 1992) or "focused attention" (Ruff, 1986), during which infants are relatively indistractible by peripheral stimuli (Lansink & Richards, 1997; Richards & Lansink, 1998). Alternatively, the period during which heart rate returned to its prestimulus level would be analogous to "attention termination" (Richards & Casey, 1992) or "casual attention" (Ruff, 1986), during which infants are more easily distracted by peripheral stimuli (Lansink & Richards, 1997; Richards & Lansink, 1998). The pattern of heart rate change during extended looks implies that children in this age range (6 months to 2 years) would be less distractible during the extended looks while heart rate was progressively decreasing, and would be more distractible when heart rate was returning to its prestimulus level. Thus, in the current study the heart rate level at the onset of a peripheral distractor was examined in relation to whether a look occurred toward the distractor stimulus.

The current study involved the presentation of audiovisual stimuli and distractors to children at 6, 12, 18, and 24 months of age. These ages bridge studies of distractibility in younger infants (e.g., 3–6 months; Richards, 1987, 1997), older infants (e.g., 6–12 months; Lansink & Richards, 1997), and older preschool-age children (e.g., 3–5 years; Anderson et al., 1987). These ages also were chosen to see if the heart rate changes of children in this age range that had been noted during extended television viewing (Richards & Cronise, 2000) were related to distractibility.

METHOD

Participants. Participants were recruited from birth notices published in a Columbia, SC, newspaper. They were all term, defined as having birthweight greater than 2,500 g and gestational age of 38 weeks or greater based on the mother's report of her last menstrual cycle. Forty children participated in the study (5 female and 5 male at each testing age). Participants' age were 6 months (M = 185.4 days, SD = 2.22), 12 months (M = 360.5 days, SD = 5.48), 18 months (M = 545.8 days, SD = 6.14), and 24 months (M = 727.5 days, SD = 4.66). Data from seven children were not included in any analyses: one 6-month-old child looked only briefly at the center television; and three 12-month-old children and one 18-month-old child became fussy during the testing. Data from two children were not included because of equipment problems.

Apparatus. A 33-cm television monitor was positioned on each side of a center monitor (a 49-cm television monitor that subtended a 34° visual angle), such that the center of each outside monitor was 42 mm (32° visual angle) from the center of the middle monitor, and each outside television monitor subtended a 13° visual angle. A Radio Shack Power Amplifier amplified the sound that was played through two Radio Shack Realistic audio speakers, which were placed above the center monitor. A neutral-colored material covered the surrounding area. A video camera placed above the television monitor recorded the session on videotape with a time code to synchronize fixation changes, heart rate, and stimulus information. The time codes for the videotape recording, heart rate times, and stimulus information (e.g., distractor onset time) were stored on a computer with a common time base.

The stimuli for the sessions were the *Sesame Street* movie *Follow that Bird*, computer-generated visual stimuli, and the *Sesame Street* movie, *The Muppet Movie.* The *Follow That Bird* movie played continuously on the center monitor with audio throughout the session. The computer-generated visual stimuli consisted of 16 different dynamically changing visual patterns (for further description, see Richards & Cronise, 2000; Richards & Gibson, 1997). The computer-generated visual stimuli and the *The Muppet Movie* were the distractors; these were presented on one of the two peripheral monitors without audio.

Procedure. Parents sat in a chair in the viewing area with the child on their lap approximately 72 cm from and facing the center television monitor. If the child became fussy, a short break was taken and the presentations were paused. The duration of each session was a minimum of 20 min, but the session could continue for up to 45 min. The *Follow that Bird* movie was continuously presented on the center monitor. One of the 16 computer-generated patterns was presented during one distractor presentation, alternating with *The Muppet Movie* on the next presentation. Each of the computer-generated patterns was presented in 16-distractor blocks by randomly choosing a pattern without replacement. The peripheral monitor on which the distractor was presented (right or left) was randomly chosen on each presentation. The distractor remained on for 5 s and then was turned off. The duration between distractors was 5, 10, 15, 20, 25, 30, or 35 s. Each interdistractor interval was used in seven-distractor blocks by randomly choosing each interval without replacement.

Measurement and quantification of heart rate changes. The infant's electrocardiogram (ECG) was recorded and heart rate was computed for the entire session, although only heart rate changes near the distractor onset were analyzed in the results. The interbeat interval (IBI) was identified from the ECG and calculated for each .5-s interval. The IBI is the reciprocal of heart rate, so that a lengthened IBI corresponds to heart rate deceleration and a shortened IBI corresponds to heart rate acceleration or the return of heart rate to its prestimulus level. The ECG was recorded with Ag-AgCl electrodes on the child's chest and was digitized at 1000 Hz (each ms) with a microcomputer. A computer algorithm identified the QRS complex in the ECG, and IBI was defined as the duration between successive R waves in the ECG. Artifact correction was accomplished using the Berntson, Quigley, Jang, and Boysen (1990) and Cheung (1981) algorithms, as well as visual inspection of suspect beats. The IBI was assigned to .5-s intervals by averaging the IBIs in each interval weighted by the proportion of the interval occupied by that beat.

Fixation judgments. A single observer judged each session off-line. A time code recorded on the videotapes allowed for ms accuracy in judgment, although resolution was limited to a single video scan (.5 · total frame length = ~16 ms). The observer judged the videotapes in two passes. First, for the recording of the entire session, the observer judged the child as either looking toward the center television monitor or looking away from the television monitor, or noted that judgment could not be made. Second, the observer forwarded the videotape recording to the time code stored in the computer representing the distractor onset. The observer judged whether the child was looking at the center television monitor at its onset, and then advanced frame by frame (~16 ms) and judged the first frame in which the child looked away from the center monitor to a peripheral monitor. A localization was defined as a look from the center monitor to the monitor with the distractor ($n = 624$), and a nonlocalization was defined as continued looking at the center monitor while the distractor was present ($n = 453$). Distractor presentations were eliminated from subsequent analyses ($n = 784$) if the child was not looking at the center television monitor when the distractor came on, or if the child looked from the center monitor to anywhere other than the distractor.

The fixation judgments were used to categorize the duration of the ongoing look at the center television monitor at the time of each distractor presentation. The length of the look at the time of distractor onset was divided into four categories: 0 to 5 s before distractor onset, 5 to 10 s, 10 to 20 s, and greater than 20 s. These categories were chosen to allow sufficient detail in changes in latency or distraction probability over ages, and to be consistent with studies of television viewing using heart rate changes (Richards & Cronise, 2000; Richards & Gibson, 1997). Table 1 shows the distribution of the number of usable distractor presentations for these look-length categories as well as those across the look-length categories for the four testing ages. The distribution of look durations in this study was not analyzed (cf. Anderson et al., 1981; Hawkins et al., 1991, 1995; Richards & Cronise, 2000; Richards & Gibson, 1997). This distribution would not reflect the duration of undisrupted looking because the looks were interrupted by the presentation of the distractors. Interobserver agreement for the overall looking duration and look onset and offset toward the center television monitor was not performed in this study. The agreement for overall look duration and look onset and offset was high in previous studies (Richards & Cronise, 2000; Richards & Gibson, 1997). The resolution for judging the onset of the looks was not critical given the four look duration categories used in the analyses. The interrater agreement of looks toward peripheral stimuli was assessed for 2 participants at each age. The agreement of a look toward the peripheral monitor was 97%, and the look onsets were judged as occurring within two frames (~33 ms) for 90% of the judgments and between two and four frames (~133 ms) for 7% of the judgments.

Table 1 Number of Usable Distractor Presentations for the Categories of Look Duration before Distractor Onset

Testing Age (Months)	Look Duration before Distractor Onset (s)			
	0–5	5–10	10–20	>20
6	95	64	50	51
12	83	38	51	67
18	73	50	65	101
24	97	55	63	74
All ages	348	207	229	293

RESULTS

Extended looks and localizations. The duration of the ongoing look at the center television monitor at the time of each distractor presentation was used as a measure of extended look at distractor onset. This study tested the hypothesis that attention engagement increased over the course of a look by categorizing distractor presentations based on the length of the look in progress at the time of distractor onset. Progressive attention engagement would be demonstrated by an increasing latency to localize the distractor or a decreasing probability of localizing the distractor. The ANOVAs for many of the analyses were performed with a general linear models approach using a nonorthogonal design because of the unequal distribution of distractor presentations across factors, and because of the different epoch numbers for the look duration categories (see Hocking, 1985; Searle, 1971, 1987). The sums of squares (hypothesis and error) for the nested effects in the design were estimated using participants as a class and nesting repeated measures (e.g., distractor type, extended look length) within this class variable. The "PROC GLM" of SAS was used for the computations. The localization latency was logtransformed before analysis to obtain a variable consistent with a normal distribution.

Look-length category was used in an ANOVA to analyze localization latency using an Age (4: 6, 12, 18, and 24 months) × Gender (2) × Distractor Type (2: computer generated and *The Muppet Movie*) × Look Length (4: 0–5 s, 5–10 s, 10–20 s, >20 s) factorial design. There were no significant effects for any of the experimental factors on localization latency. There was a tendency for the localization latency to increase as look length progressed (*M*s = 1,220.16, 1,240.32, 1,542.64, and 1,462.31 ms for 0–5 s, 5–10 s, 10–20 s, and >20 s, respectively). The localization latencies were approximately 1,200 ms for each of the testing ages (*M* = 1,342.11, *SE* = 82.34; *M* = 1,197.60, *SE* = 109.05; *M* = 1,477.57, *SE* = 87.27; and *M* = 1,356.46, *SE* = 93.78, for 6, 12, 18, and 24 months, respectively). The average localization latency for the computer-generated stimuli was 1,338.34 ms (*SE* = 69.61), and for *The Muppet Movie*, 1,357.86 ms (*SE* = 62.85).

The probability of localizing the distractor as a function of the look length at the time of distractor onset was analyzed with linear categorical modeling. The marginal probabilities for localizing the distractor differed for the four look-length categories, $\chi^2(3, N = 1{,}077) = 23.24$, $p < .001$. The two-way interactions of the look-length categories and age, gender, and distractor type also were analyzed; none of these interactions were significant. Figure 1 (top) shows the localization probabilities as a function of the look-length categories for the four testing ages. A high localization probability was evident for the looks that were in progress from 0 to 5 s before distractor onset, and a gradual and statistically significant decrease in look probability occurred as the look length before the distractor onset increased. Figure 1 (bottom) shows the conditional probability for localizing the distractor stimulus (e.g., probability of localization · probability of look length), or the probability of localizing the distractor as a function of the occurrence of the look-length category. The conditional probability modifies the raw probability on the basis of the actual occurrence of the look categories in the study. Therefore, the conditional probability controls for the different probabilities of the look-length categories (Table 1) and is similar to the hazard function. The conditional probabilities in Figure 1 show a steep drop in the probability of localizing the distractor stimulus from when looks were in progress a short time (0–5 s) to looks that were in progress for longer lengths (e.g., 5–10 s). This drop was similar to the hazard function for extended television viewing (e.g., Burns & Anderson, 1993).

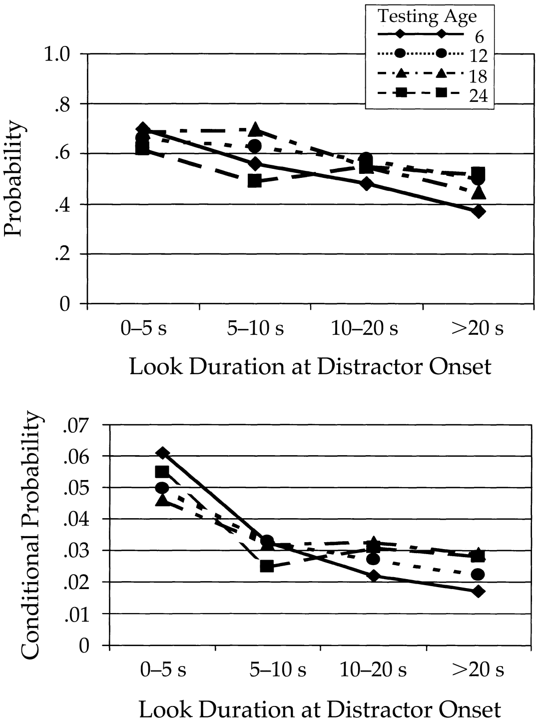

Figure 1 **The probability of localizing the distractor stimulus as a function of look duration at distractor onset for each testing age (given in months). The conditional probability represents the probability of turning toward the distractor given the probability of looks for this interval.**

Interbeat interval changes, extended looks, and distractor localization. The hypothesis that heart rate changes would accompany the lengthening periods of fixation and mediate distractor localization was examined. The IBI level that occurred immediately prior to the onset of the distractor was examined for trials in which a localization occurred or did not occur. Figure 2 shows the IBI levels before distractor onset as differ-

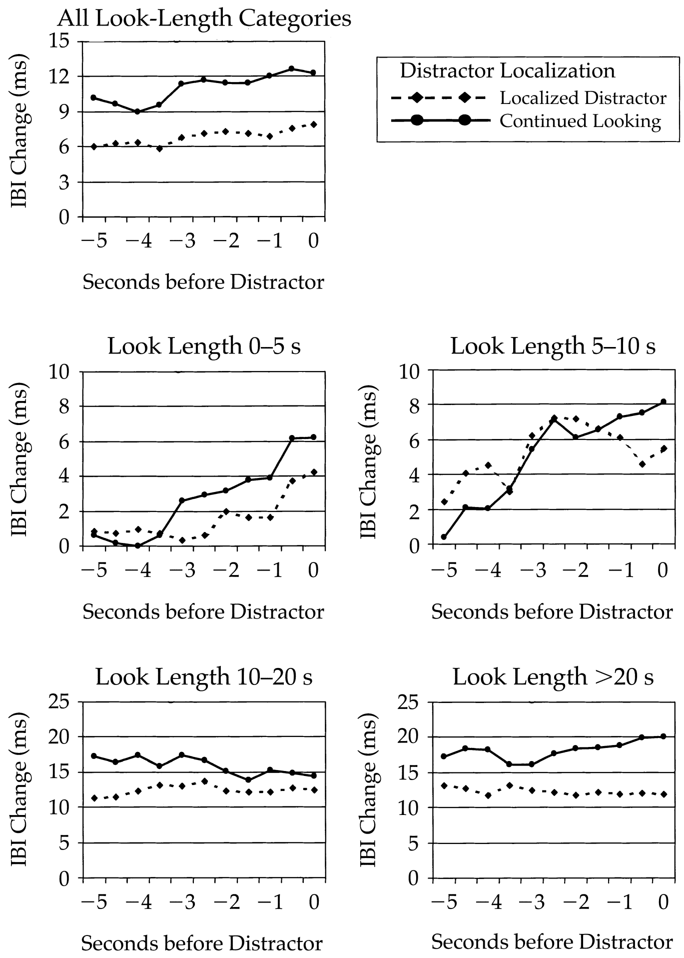

Figure 2 **The interbeat interval (IBI) change before distractor onset, calculated as the difference between the IBI level and the average IBI level 2.5 s before look onset. The solid line on each graph represents distractor presentations on which the child continued looking at the center television; the dashed line on each graph represents presentations on which the child turned toward the distractor stimulus.**

ences from the average IBI level 2.5 s before the look onset to the center monitor. These IBI changes before distractor onset were larger on the distractor presentations when the child continued looking in the direction of the center monitor than when the child looked toward the distractor monitor (see All Look-Length Categories, top left, Figure 2). This larger IBI change occurred for the look lengths from 0 to 5 s, 10 to 20 s, and greater than 20 s. Figure 2 also shows the initial heart rate deceleration (IBI lengthening) that occurred at look onset (look lengths 0–5 s and 5–10 s) and the increasingly sustained IBI change that occurred as look length progressed (10–20 s and >20 s).

The IBI levels before distractor onset were analyzed. The average IBI level 2.5 s before look onset to the center television was used as the baseline IBI level, and the difference between this value and that at 5 s before distractor onset was analyzed. This IBI change was analyzed using an Age (4) × Gender × Distractor Type (2) × Look Length (4) × Distractor Localization (2: look toward distractor and continue looking at center monitor) ANOVA. There were main effects for look length, $F(3, 97) = 4.92$, $p = .0032$, and distractor localization, $F(1, 34) = 4.93$, $p = .0331$. The look-length effect reflects the increasingly sustained IBI change that occurred as look length progressed. The distractor-localization effect reflects the larger IBI difference for the distractor presentations during which the child continued looking at the center monitor. This occurred in the IBI changes summed over all look-length categories (Figure 2, top left panel), when the child had been looking from 10 to 20 s or greater than 20 s before distractor onset (Figure 2, bottom panels), and to a lesser degree when the child had been looking for only a short period of time (Figure 2, middle left panel). The interaction between look length and distractor localization was not significant.

The IBI changes were analyzed as an independent variable affecting localization latency or probability. In Richards and Cronise (2000) and Richards and Gibson (1997), the heart rate changes during extended visual fixation included a heart rate deceleration at look onset, a progressive heart rate decrease over the course of a look, and a rapid return of heart rate to its prestimulus level immediately preceding a look away from the television monitor. For the current study, the IBI values at distractor onset for the short look-length categories (0–5 s, 5–10 s) were classified as those that showed a rapid deceleration, or not, by identifying those distractor onsets with a positive linear trend in the last 3 s before distractor onset. Thus, this classification distinguished trials on which there was a rapid deceleration of heart rate at look onset ("attentive") and those on which heart rate did not decelerate at look onset ("inattentive"). The IBI values at distractor onset for the long look-length categories (10–20 s, >20 s) were classified as those showing a return of heart rate to its prestimulus level by determining a negative linear trend over 3-s intervals anywhere in the 10 s before distractor onset; the others were classified as a continuing lowered heart rate. Thus, this classification distinguished between those trials on which there was a continuing lowered heart rate (attentive) and those on which heart rate returned to its prestimulus level before distractor onset (inattentive).

The latency to localize the distractor and the probability of localizing the distractor were examined as a function of the post hoc IBI pattern categories. (Localization latency and probability were not statistically analyzed as a function of the heart rate change pattern categories. These categories were derived post hoc and were not crossed sufficiently with the look-length, age, distractor type, and gender factors for an ANOVA analysis.) Figure 3 shows the latency to localize the distractor; there was no difference in localization latency on the distractor trials during which a deceleration had occurred or had not occurred for looks less than 10 s in duration (0–5 s, 5–10 s, 10–20 s). Only a slightly longer latency to turn toward the distractor was evidenced for the presentations on which the heart rate change was sustained than when heart rate had returned to its prestimulus level (>20 s). Figure 4 shows the probability and conditional probability of localizing the distractor for the post hoc IBI change categories; a lower conditional probability for localizing the distractor stimulus was observed for the presentations with a rapid heart rate deceleration (5–10 s), as well as for those during which the heart rate change was sustained (10–20 s, >20 s).

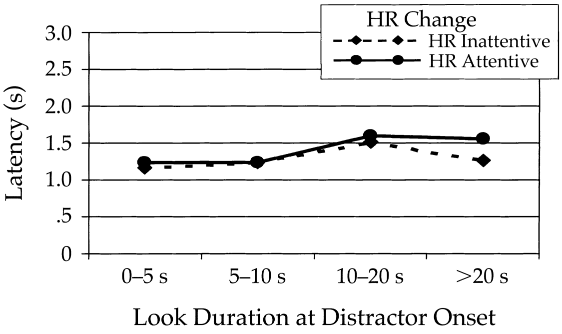

Figure 3 Latency to localize the distractor stimulus as a function of look duration at distractor onset for attentive and inattentive distractor presentations. HR = heart rate.

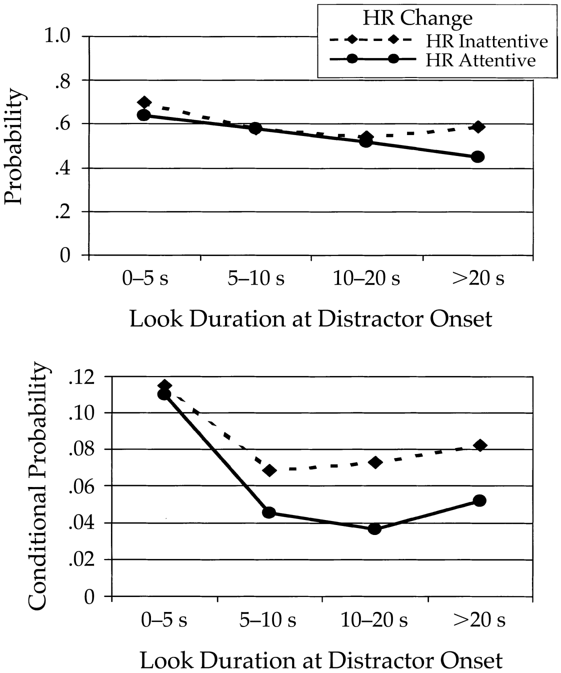

Figure 4 The probability and conditional probability of localizing the distractor stimulus as a function of look duration at distractor onset for attentive and inattentive distractor presentations. HR = heart rate.

DISCUSSION

The first goal of the present study was to determine if the distraction procedure employed would be useful for studying attention engagement during television viewing in early preschool-age children. This study found that children were relatively distractible from viewing television when a look had been in progress only a short time. As look duration increased the probability of looking from the central television monitor toward the peripheral monitor decreased. This pattern of distractibility as a function of look length replicates that found with older children (Anderson et al., 1987; Lorch & Castle, 1997). The attentional inertia theory, which posits an increasing engagement of attention over the course of extended looks, is consistent with these findings. At the beginning of a look, attention is presumed to be relatively unengaged and children are easily distracted by a peripheral stimulus. As the look progresses, attention toward a television is presumed to be increasingly engaged and distractibility therefore decreases. This interpretation is consistent with the pattern of distraction probability (Figure 1) found in the current study. It also is consistent with studies showing that infants through age 12 months are relatively indistractible while engaged in active attention and easily distracted when attention becomes disengaged (Casey & Richards, 1988; Doolittle & Ruff, 1998; Lansink & Richards, 1997; Oakes & Tellinghuisen, 1994; Richards, 1987, 1997; Richards & Lansink, 1998; Ruff et al., 1996; Tellinghuisen & Oakes, 1997).

The pattern of the changes in probability for distraction across the look lengths was consistent with the attentional inertia model for television viewing. This model is based on the hypothesis that each look consists of the aggregation of brief comprehension units of approximately 1 to 2 s in duration (Burns & Anderson, 1993; Choi & Anderson, 1991). According to the model, at the end of the first comprehension unit (~1 s) attention engagement is relatively weak, resulting in a high level of looking away and toward the distractor. In the current study, the largest probability of looking away occurred for looks that had been in progress from 0 to 5 s before the distractor onset (Figure 1). The pattern of changes in distractor localization probability over the course of extended looks replicates the pattern found with older preschool-age children (Anderson et al., 1987; Lorch & Castle, 1997; see especially Figures 5 and 6 in Choi & Anderson, 1991). The conditional probability of looking away in the current study appears remarkably similar to the hazard function in unrestricted television viewing for infants (Richards & Gibson, 1997), older preschool-age children (Hawkins et al., 1991), and adults (Burns & Anderson, 1993), as well as toy play in older preschool-age children (Choi & Anderson, 1991).

A notable finding in the present study was the lack of age differences in the analyses involving the distractor. Several changes take place over this age range (such as changes in television viewing) that may indicate an increase in attention engagement. Television viewing in general increases (Alwitt, Anderson, Lorch, & Levin, 1980; Anderson & Levin, 1976), as does the amount of time viewing a comprehensible television program (Anderson et al., 1981; Richards & Cronise, 2000). These changes would be consistent with a change in the effectiveness of television programs in eliciting attention. In the present study, however, these age changes in television viewing did not interact with the potency of the distractor to elicit localizations. Given the interpretation that the pattern of distractibility reflects the attentional inertia mechanism, the lack of age differences implies that the attentional mechanism works similarly in young infants, children, and adults. The amount of time that children spend in focused attention and on-task time increases over the age range of infants in the current study (Ruff & Lawson, 1990). Similarly, there are changes in the amount of sustained heart rate response during extended looks in this age range (Richards & Cronise, 2000). Apparently, however, when a fixed heart rate level (see Figure 2) or specific heart rate patterns is identified (see Figures 3 and 4), any interactions among heart rate level, attention engagement, and age are obscured. This suggests that the attention–distractibility relation, or the heart rate engagement–distractibility relation, has been well established by the youngest children in this study. Similarly, one study of distractibility during extended looking with older preschool-age children (Anderson et al., 1987) also reported no age differences in distractibility.

The third goal of this study was to examine the relation between distractibility and heart rate changes that occur during extended television viewing. First, it was found that heart rate change was greater before distractor presentations in which fixation continued on the center television monitor than before distractor presentations that elicited a look toward the distractor (Figure 2). This difference occurred primarily on the distractor presentations for looks greater than 10 s in length. Second, a lower conditional probability for turning toward the distractor was found when a significant heart rate deceleration occurred or when the heart rate change was sustained through long look lengths (Figure 4). A previous study revealed a progressive decrease in heart rate over the course of extended looks in children in the age range of infants in the current study (Richards & Cronise, 2000). The results in the current study suggest that those looks that were associated with such a progressive decrease in heart rate were not interrupted by the distractor presentation. Looks for which heart rate did not remain as far below prestimulus level or were associated with a return of heart rate to its prestimulus level were more easily interrupted.

The progressive decrease in heart rate over the course of an extended look in preschool-age children (Richards & Cronise, 2000; Richards & Gibson, 1997) has been interpreted as reflecting increasing attention engagement consistent with the attentional inertia model. The findings from the present study affirm this interpretation. Research with infants has shown that a sustained lowering of heart rate during fixation toward a visual stimulus correlates with sustained attention (Richards & Casey, 1992; Richards & Lansink, 1998). This sustained attention (indexed by heart rate change) is similar to focused attention measured in behavioral changes (Lansink, Mintz, & Richards, 2000; Lansink & Richards, 1997). The return of heart rate to its prestimulus level indicates that attention is no longer engaged. The relative indistractibility during such sustained heart rate lowering in the current study supports the validity of using heart rate during extended viewing as an index of attention engagement with a television program. When heart rate returned to its prestimulus level the children in the current study were more distractible, indicating that attention had been disengaged. The return of heart rate to its prestimulus level may reflect a mechanism for attention disengagement that ends the attentional inertia that had been keeping fixation on the television, that is, attention termination (Casey & Richards, 1988; Lansink, Mintz, & Richards, 2000; Richards & Casey, 1992; see discussion in Richards & Gibson, 1997).

The successful application of the distraction methodology used in the present study to children in this age range suggests that this method is useful for examining attention over a wide range of ages. This distraction method has been used previously with 3- to 6-month-old infants (Casey & Richards, 1988; Richards, 1987, 1997), 6- to 12-month-old infants (Doolittle & Ruff, 1998; Lansink & Richards, 1997; Oakes & Tellinghuisen, 1994; Ruff et al., 1996; Tellinghuisen & Oakes, 1997), and 3- to 5-year-old preschool children (Anderson et al., 1987; Choi & Anderson, 1991; Lorch & Castle, 1997). The current study shows that this method may be applied across a wide range of ages in the extended television viewing paradigm. Additional experimental control in this method could be achieved by defining a priori patterns of heart rate change (deceleration, progressive heart rate decrease, return of heart rate to prestimulus level) and then presenting the distractor based on the existence of specific heart rate change patterns and extended look durations. This a priori method has been used successfully with younger infants (e.g., 6–12 months; Lansink & Richards, 1997; Richards & Lansink, 1998). The present study and others of extended television viewing (Richards & Cronise, 2000; Richards & Gibson, 1997) show that attention in infancy and in the early preschool-age years, as well as in older preschool-age children and adults, is affected by similar processes. The distraction methodology used in the present study may be helpful in providing a common metric for evaluating other developmental changes that could affect extended television viewing in the early years of life.

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