Video storybooks as a bridge to literacy

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Visual attention: a key to learning from book exposure

A study of preliterate children's visual attention to illustrations in picture storybooks

Abstract

The major purpose of this study was to test how preliterate children use illustrations in storybooks to understand a story. Subjects were 23 5-year old low-SES children, learning Dutch as a second language. Each child was exposed four times to a digital picture storybook. Five books were used and counterbalanced over children and repetitions. During book exposure, eye movements were registered using the Tobii 1750 eye-tracking system. To test whether eye fixations match the text we scored how often and how long children fixated visual elements in the illustrations that the story text highlights. We also scored how often human and non-human objects were fixated. In line with the hypothesis that eye fixations are time locked to referential expressions in the text, visual elements that the text highlights were fixated more often and longer than elements in illustrations not highlighted in the story text. We also found evidence that inspection of illustrations at times follows an autonomous pattern. We discuss how both types of visual behavior can add to vocabulary development and story comprehension.

Introduction

In picture storybooks, children have illustrations at their disposal as an additional source of information but we hardly know how children use information from illustrations. Studies of story comprehension have demonstrated that real or made up images of story events facilitate story understanding and the memory of story events (Guttman, Levin, & Pressley, 1977). More recently Paivio's experiments (Paivio, 1986; Sadoski & Paivio, 1994) showed that recall of story language can be improved by concretizing words and phrases. Do eye fixations while listening to the oral text enable the emergence of associations between the verbal and nonverbal information (Paivio, 1986; Sadoski & Paivio, 1994)? The study presented hereafter is unique in that we applied an eye-gaze methodology as a means for online, direct examination of details in illustrations that attract children's attention and how the eye-gaze patterns relate to the orally presented text (e.g., Evans & Saint-Aubin, 2005; Justice, Skibbe, Canning, & Lankford, 2005).

Are children's eye fixations on illustrations time locked to referential expressions in the text as is suggested by psycholinguistic experiments (Allopenna, Magnuson, & Tanenhaus, 1998; Cooper, 1974; Spivey, Tanenhaus, Eberhard, & Sedivy, 2002; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Tanenhaus, 2007)? A typical feature of those experiments is that oral language is presented to subjects while they have an array in front of them consisting of a selection of objects that occur in the discourse. Viewers listening to the spoken language, quickly move their eyes to fixate objects even during pronunciation or immediately after hearing relevant words. When the language is ambiguous and children misinterpret the meaning of a sentence, eye movements include fixations on incorrect representations thus making misunderstandings visible (Eberhard, Spivey-Knowlton, Sedivy, & Tanenhaus, 1995).

It is most unlikely that eye fixations on illustrations in picture storybooks are controlled to the same extent by the summoning power of semantic information in the story text as the above-described experiments suggest because not all elements that the text highlights are depicted in illustrations. Illustrations mostly represent only part of the story text and it is rare to be able to precisely follow the complete text in the illustration. For instance if one takes a closer look at one of the illustration in the *Rummage Dragon*, one of the stimulus stories, the text says that the dragon's cave is becoming more and more comfortable due to all the furniture thrown by the king and queen in an attempt to try to chase away the dragon. The dragon is sitting comfortably in an easy chair blowing smoke from his nose. Around the dragon we see all the furniture that was thrown at him by the

king and queen: a teapot, a floor lamp, an umbrella, pots and pans, a stove and many other objects. The story text tells that the dragon thinks of the king and queen who are probably buying a new floor lamp at that very moment. On the one hand the illustration goes beyond the content of the text – it suggests, for instance, that this thought makes the dragon smile. On the other hand, the illustration is incomplete in that there is no image of the action – the king and queen buying a new floor lamp.

In so far that details highlighted by the accompanying text are depicted, verbal information processing may affect nonverbal information processing and eye-fixations may thus be controlled by text. In this line of argumentation, Sipe (1998) presented attention during book exposure as a complex process of switching between words and pictures. The resulting process is a type of oscillation whereby the interpretation of pictures is adjusted in terms of the words and, vice versa, the interpretation of the words in terms of the pictures. In addition, because the meanings of the signs are always shifting, this oscillation is a potentially never-ending sequence in which text is interpreted in terms of pictures and pictures in terms of text. Building on Sipe's premise that the interpretation of pictures is adjusted in terms of the words, we expect that children pay more visual attention to elements that the story text highlights than to other elements, and probably more so when children have become more familiar with the text after a few repetitions of the same story.

Even when pictures function as an autonomous source of information it is not very plausible that eye-catching properties like density, contrast, and intensity determine nonverbal information processing; informativeness may play a more crucial role (Henderson, Brockmole, Castelhano, & Mack, 2007). Eye-gaze patterns of images demonstrate that viewers show a strong preference for the human figure in the illustrations (Buswell, 1935; Fletcher-Watson, Findlay, Leekam, & Benson, 2007; Yarbus, 1967). This finding is replicated in studies with normally developing children as well as children diagnosed with autism (van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2002). Images encompassing quite a number of neutral objects in addition to one cartoon-like or nondescript human figure, without accompanying text, elicited a clear preference for the human figure. This preference for human beings, who can be people but also anthropomorphic figures, as often happens in children's books may be driven by the ability to derive intentional, goal-directed actions from the depiction of human figures. There is evidence that from an early age on children possess a sophisticated ability to interpret and draw inferences about people's goal-directed actions (Gergely & Csibra, 2003). If this eye-

gaze pattern also applies to visual information processing when children look at illustrations in picture storybooks we might expect that children demonstrate a strong preference for the human or anthropomorphic figures within the set of elements that the story text highlights.

Prior studies using eye-gaze methodology to monitor visual attention during picture storybook reading (Evans & Saint-Aubin, 2005; Justice, Skibbe, Canning, & Lankford, 2005; Justice, Pullen, & Pence, 2008) mainly studied how much attention is paid to text in comparison with illustrations. In so far the studies tested the connection between the accompanying text and eye fixations to details in illustrations - the main question of the present study - it appeared that fixations are to some extent controlled by the summoning power of the story text. A study by Evans and Saint-Aubin (2005) provides evidence that fixations on details in illustrations can be alternated by altering the content of the text. Eye fixations on small details in the illustrations (a fish, a boat, or two stars) increased if the text highlighted those details thus demonstrating that the children's visual attention was, to some extent, dependent on the accompanying text in line with the premise that eye fixations are adjusted in terms of the words. In the same vein, this research group showed that it takes longer for children to fixate on low-frequency words than on high-frequency words (Evans, Saint-Aubin, Roy-Charland, & Allen, 2006). So far the findings seem in line with the assumption that eye-fixation patterns are controlled by the summoning power of text. What kind of autonomous processes apply is unknown. To date there have been no studies that tested a preference for human or anthropomorphic figures among the elements in illustrations that the text highlights.

Using an eye-gaze system we tested where in illustrations and how long children fixate while they listen to the story text. We studied non-interactive book reading sessions to exclude other factors than text and illustrations as decisive elements for eye-gaze patterns. To increase the chance that visual processing plays a crucial role in comprehending a story, we chose second-language learners as subjects in the current study. We argued that visual processing may become more superficial when pupils do not experience problems in understanding the story language and drawing inferences about the story.

Exploring eye-gaze patterns during book reading we tried to answer the following questions:

1. Are eye-gaze patterns influenced by the summoning power of oral text processing and do children thus demonstrate a preference for visual elements that the text highlights?
2. Do human or anthropomorphic figures attract most attention among all visual elements that the accompanying story text highlights?
3. Does visual attention for elements that are referred to in the accompanying story text increase as the story is repeated several times?

Method

Sample

A total of 25 five-year old children participated in this study, recruited from four different schools in the city of The Hague; data from 23 children were available for processing. The data of one child were lost because of technical problems caused by the Tobii software in the first session and the other child was an outlier on all visual processing measures. Mean age of the 23 children (10 boys, 13 girls) ranged from 61 to 72 months (M = 66.26 months, SD = 3.63). All children had attended school for more than a year and during this year they were taught Dutch as a second language. They were from low-educated and low-income immigrant families originating from nine different countries. They scored among the 50% lower scoring peers on a standardized language test for Dutch kindergarten children but in the normal range on a test for nonverbal intelligence (RCPM). None of the children were familiar with the stimulus books.

Design

When processing visual information, we continually make eye movements, called saccades whereas the eyes remain relatively still during the fixations between eye movements (Rayner, 1998). Since persons respond an average of 250 ms after the end of a word (Tanenhaus et al., 1995) we may assume that only longer fixations of 200 ms or more imply language processing. To explore possible book effects we included five different picture storybooks. The five books were randomly assigned to the 23 children that eventually were included in data analysis. One book was read by five children, one book by six and three by four. Children heard the assigned book four times. To enable monitoring of eye movements, the book illustrations were displayed on the computer screen with a built-in, high-resolution camera. Unlike a new generation of digital picture storybooks with animated pictures (Verhallen, Bus, & De Jong, 2006), the illustrations in

this series of books were "still". Like in print books the complete illustration could be viewed all at once. Because this study's aim was to explore how children use illustrations while listening to the story text, print was not displayed on screen but orally presented by a prerecorded voice. Each child watched the storybook four times on different days spread over a two-week period. We compared visual attention during the first and fourth session to demonstrate any differences due to familiarity with the book. All children were tested preceding the intervention.

Procedure

The four book exposure sessions were spread over a two-week-period. The sessions took place in a spare room at school. The experimenter collected children individually from their classroom during school hours and returned them after the reading session. Book exposure took 5 minutes on average. Pre-testing was done in two sessions. During the book exposure sessions, two experimenters were present, one controlling the eye-tracking device and the other putting the child at ease, starting the computer program, and instructing the child as per protocol. As visual attention in the form of eye fixations is sensitive to task demands (Yarbus, 1967), children were invited to look and listen to the story on the computer thereby encouraging linguistic as well as visual information processing. Children could not control the rate of page display or of the oral text presentation. No interaction between the child and the experimenter took place while the book was being read to the children. During the sessions, children were seated in a chair heightened with cushions to the level of the computer monitor thereby restricting their action radius. The experimenter suggested to the children that they should place their hands in their laps or by their sides but they were free to move their hands. After children were seated, the eye-gaze system was calibrated following a procedure of approximately 10 ms. The child looked at five consecutive dots that appeared in different positions on the screen.

Selection Tests

The *Raven Coloured Progressive Matrices* with Dutch standards (Van Bon, 1986) was used to measure children's nonverbal intelligence.

The children's second language proficiency was assessed using the *Cito Language Test for Senior Kindergarten Children* (Centraal Instituut voor Testontwikkeling [Dutch Institute for Test Development], 1996).

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Familiarity with target books. Five cover pictures from the picture storybooks used in this study alternated with 36 covers of other well known picture storybooks were presented to the children. Per picture children indicated whether they were familiar with the story's name or story characters. When children were familiar with one or more target books they were excluded from further participation.

Materials

Five Dutch picture storybooks similar in length, characterization, story line, linguistic complexity, and illustrations were used: 'Rokko Krokodil'[Rokko Crocodile] (de Wijs, 2001), 'Beer en Varkentje'[Bear and Piglet] (Velthuijs, 2003), 'Met Opa op de Fiets' [A Bicycle Ride with Grandpa] (Boonen, 2004), 'De Rommeldraak' [The Rummage Dragon] (de Wijs, 2004) and 'Beer in de Speeltuin' [Bear in the Playground] (Verroen, 1998). All books are prize-winning picture storybooks for children in the preschool age designed by different authors and illustrators. The relationship between text and pictures is harmonious as in most picture storybooks. The pictures show what the text tells but the pictures also include many details that are not mentioned in the text (Sipe, 1998). For instance, one picture in the *Rummage Dragon* shows the king and queen standing on the roof of their castle throwing furniture at the dragon. The text names some of the furniture falling down but not all. Vice versa, text may describe events that are not concretized in the illustrations. Piglet is talking about the coming winter while the illustration displays the height of summer. As Table 1 demonstrates there was some variety in length of text, length of sentences, number of sentences, number of words per picture and number of pictures.

Table 1 *Characteristics of Focal Books*

Book	Number of words	Number of pictures[1]	Mean number of words per picture (*SD*)	Number of sentences	Mean length of sentences (*SD*)
The Rummage Dragon	557	14	39.79(14.16)	66	8.32(4.74)
Bear and Piglet	732	22	33.27(11.58)	74	9.89(5.43)
Bicycle Ride with Grandpa	556	12	46.33(12.31)	94	5.64(2.36)
Bear in the Playground	668	12	55.67(25.56)	75	8.91(4.37)
Rokko Crocodile	449	20	22.45(5.61)	51	8.80(3.44)

Note[1] except title page.

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Eye-gaze system

The Tobii 1750 is a distant eye tracker that allows eye movements of subjects to be measured without cumbersome headgear, thus making the session a more natural book reading event on the computer. While sitting in front of the screen, the Tobii 1750 eye-gaze system determines a child's gaze direction by registering the reflection of infra red lights on the cornea with a high-resolution camera and measuring the relative positions of the pupil centre (Klingner, Kumar, & Hanrahan, 2008). These reflection patterns together with other visual information are collected with a camera and gaze points are computed. The system compensates for head motion. The average accuracy over a set of individuals has been tested and found to be 0.5 degrees using standard accuracy measurement principles for eye trackers. Half a degree of accuracy corresponds to an average error of about 0.5 cm between the measured and the intended gaze point from the user. The Tobii 1750 eye tracker identifies fixations at a sampling rate of 50 Hz. We were only interested in longer fixations (gaze durations of 200 ms or longer) because processing of verbal information takes time; it takes on average about 250 ms before subjects respond to a spoken word (Tanenhaus et al., 1995). The Tobii 1750 is capable of tracking virtually everyone, whatever ethnic origin, age or glasses/contacts (Tobii Technology, 2006). Eye-tracking data were analyzed using the Clearview program 2.5 (Tobii Technology, 2006).

Coding

We first made lists of all visual elements in the illustrations including facial expressions of states (thinking, laughing), spatial information like propositions (next to), states (frozen, surprised), and more abstract concepts like spring, winter, morning, evening. In coding we followed a two-step procedure. After agreeing on the number of visible elements per illustration, two coders independently scored whether or not elements from the list were referred to in the story text. Two independent coders agreed on 96% of all visual information units. Disagreements were resolved through discussion.

Next for each illustration in all five books we defined visual elements that the text highlights. In Figure 1, for instance, we marked 'bear', 'sun', and 'apples'. Some visual elements referred to more than one word in the text. The illustration of bear in the sun shows a "lazy" bear that "dozes" in the sun. The two qualifications of bear, *lazy* and *doze* could not be marked separately from bear and separately from one another. Per book there were between 38 and 69 demarcated zones, representing 5.7% to 11.8% of the content words in the texts (see Table 2). Figure 1 also shows a hedgehog, bees, a dandelion, stones,

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plants, and grass, none of which were referred to by the story text. Fixations on those elements were defined as fixations outside the demarcated zones. Two independent coders agreed on 96% of all elements. Disagreements were resolved in discussion.

Figure 1 Scene from Bear and piglet. Central elements representing the story text are demarcated by blue lines. Note that the bear needed more than one central element to demarcate as only a maximum of 50 points or coordinates can be used to define elements. The rest was coded as other elements.' The verbal text with the accompanying picture runs as follows: "Once upon a time there was a lazy bear. Most of all he preferred to doze in the sun. Whenever he was hungry he ate what he could find. Apples, berries and nuts from the forest. He was contented with life and did not worry about the future." From *Bear and piglet*, 2003, illustration by M. Velthuijs, Amsterdam: Leopold.

Table 2 *Elements in Illustrations Mentioned in the Story Texts*

Story	Number of Elements in Illustrations	Elements in Illustrations Highlighted by the Story Text	% Elements in Illustrations Highlighted by the Story Text
The Rummage Dragon	161	95	59
Bear and Piglet	196	92	47
Bicycle Ride with Grandpa	210	102	49
Bear in the Playground	135	92	68
Rokko Crocodile	152	64	42
Total	854	445	52

To test differences in number of fixations and fixation duration between human or anthropomorphic figures and neutral elements we coded all elements that referred to the story text as human or neutral. Two independent coders agreed on 100% of all elements.

Using the Clearview program 2.5 (Tobii Technology, 2006), we coded per child the number of longer fixations (> 200 ms) and their exact duration. We scored both dependent measures for inside and outside demarcated zones and for human versus neutral elements. Scores were calculated for sessions 1 and 4.

Table 3: *Percentage of Human and non Human Central Elements per Book*

Story	Number of human central elements (%)	Number of neutral central elements (%)
The Rummage Dragon	62 (60)	53 (40)
Bear and Piglet	50 (45)	69 (55)
Bicycle Ride with Grandpa	94 (62)	73 (38)
Bear in the Playground	87 (59)	44 (41)
Rokko Crocodile	106 (71)	33 (28)

Results

We examined the following questions:

a. Do illustrations in each of the five picture storybooks include visual elements that the text does not highlight?

b. Do children fixate more and longer on visual elements that the text highlights?

c. Do fixation patterns differ for human and neutral story elements?

d. Do fixation patterns change after a few repetitions of the same story?

Percentage of central elements.

About half of all visualizations in the illustrations (52%) were highlighted by the text ranging from 42 to 68% for the five stimulus books (see Table 2). This indicates that there are numerous potential visual distracters in all five books. Note also in Table 2 that some books included a higher percentage of visual elements that are not highlighted by the story text. For instance, 'A Bicycle Ride with Grandpa' included a lower amount of representational information (49%) than 'Bear in the Playground' (68%).

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Longer fixations (> 200 ms).

In the visual presentation of eye movement data, circles superimposed on the pictures represent fixations of more than 200 ms (see the circles in Figure 2). The diameter of the circles is proportional to fixation durations. By calculating the sum of all fixation durations divided by the total duration of the computer book, we determined which percentage of the total time of the first session was spent on longer fixations. On average longer fixations took 69.83% (SD = 8.29) of the time it took to read a book, meaning that a smaller amount of time was spent on saccades (the stripes in Figure 2) and short fixations (< 200 ms). Books were similar in percentages of longer fixations as was indicated by a nonsignificant effect of storybook. In sum, longer fixations made up most of the time that children spent on looking at illustrations in picture storybooks. Results for the fourth session calculated and analyzed the same way, were exactly like the first session.

Number of fixations inside and outside demarcated zones.

Here is an example of how one of the subjects looked at the screen in the experiment: Farouk's eye movements while he explores the illustration in Figure 2 show that he mainly fixates elements that the text highlights: in addition to 'dragon' he fixates 'tea pot' ("the dragon made tea in the royal tea pot"), 'easy chair' ("he sat in the royal chair"), 'floor lamp' ("he thought about the king and queen: they might need to buy a new floor lamp") and 'smoke' ("content he blew out smoke pff pff"). Only a few of Farouk's fixations target elements outside the demarcated zones like the cooking pot with utensils and the umbrella. To test whether a similar fixation pattern dominated in the scores of the group and fixation patterns changed after repeated exposures to a book, we determined the number of fixations inside and outside the demarcated zones for each child, in the first as well as fourth session. An ANOVA with target (inside vs. outside the demarcated zone) and storybook as factors, applied to the data from session 1, revealed a main effect for target, Wilks' = .13, F (1, 18) = 111.63, p < .000, η^2 = .86, meaning that most visual attention was inside the demarcated zones. The interaction book x target was significant (Wilks' = .41, F (4, 18) = 6.37, p < .002, η^2 = .59) but not storybook, meaning that inside and outside did not differ to the same extent for all storybooks. Post hoc *t*-tests carried out per book contrasting inside and outside revealed significant contrasts for all books except *Bear and Piglet*. Outcomes for session 4 were similar but when we compared session 1 with session 4 (see Table 4) we noticed a decrease in number of fixations from an average
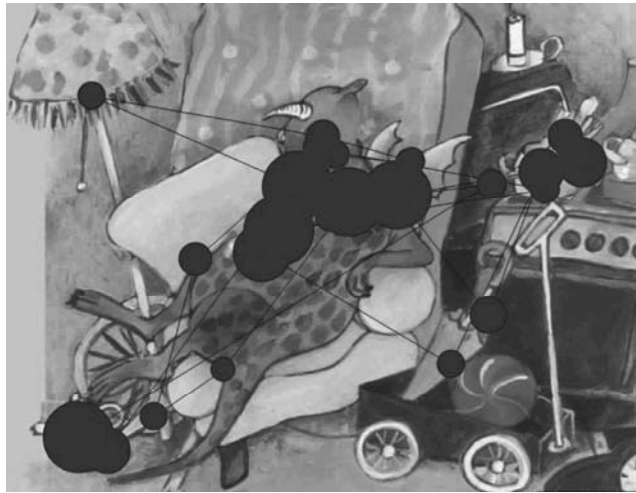
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Figure 2

Eye movement data of one child for The Rummage Dragon. The blue circles represent fixations of more than 200 ms. The diameter of the circles is proportional to fixation durations. Visual elements in the illustration that were mentioned in the text were: Dragon, smoke, easy chair, floor lamp and teapot. From *De Rommeldraak*, 2004, illustration by N. van den Hurk, Amsterdam: Leopold.

Table 4 *Mean Number of longer fixations (> 200 ms) inside and outside the demarcated zones for sessions 1 and 4*

Story	Session 1		Session 4	
	Inside zone	Outside zone	Inside zone	Outside zone
Rummage Dragon	241.75(33.24)[1]	124.00(12.73)	199.75(40.05)	133.75(12.84)
Bear and Piglet	223.25(36.53)	213.75(24.68)	161.00(8.29)	193.00(21.46)
Bicycle Ride with Grandpa	228.67(43.55)	167.67(29.13)	207.33(49.23)	139.83(28.31)
Bear in Playground	252.75(19.19)	163.75(18.88)	211.25(28.79)	152.75(2.63)
Rokko Crocodile	203.20(16.18)	121.60(27.39)	184.80(15.02)	127.20(21.62)
Total	228.65(33.92)	157.39(39.88)	193.74(35.48)	147.52(29.65)

Note[1] Standard Deviations between parentheses

194.04 at session 1 (SD = 36.34) to an average 171.07 at session 4 (SD = 33.42). Furthermore, it looked like the number of fixations inside the demarcated zones decreased more (by 15%) than fixations outside (by 6%). A 2 x 2 x 5 repeated measures analysis of

variance (ANOVA) with session (1 vs. 4), target (inside vs. outside) and storybook as factors confirmed those observations. There were effects of time, Wilks' = .62, F (1, 18) = 11.13, $p < .004$, $\eta^2 = .38$, and of target, Wilks' =. 13, F (1, 18) = 118.75, $p < .000$, $\eta^2 = .87$, as well as a significant interaction between time and target, Wilks' = .56, F (1, 18) = 14.22, $p < .001$, $\eta^2 = .44$.

Mean durations of fixations inside and outside the demarcated zones.

Inspecting the visual presentation of Farouk's eye movements, we had the impression that circles superimposed on the dragon were larger than circles on other elements that the text did not highlight, meaning that fixations on the dragon lasted longer. In line with this impression, Table 5 demonstrates that fixations inside the demarcated zones lasted on average longer than fixations outside. In session 1, children fixated on average for 468.96 ms (SD = 45.22) inside and for 440.57 ms (SD = 39.51) outside. An ANOVA with target (inside vs. outside) and storybook as factors confirmed that fixations inside lasted longer than fixations outside, Wilks' = .64, F (1, 18) = 10.17, $p < .005$, $\eta^2 = .36$. There was no book effect or interaction target x book meaning that outcomes were similar for all five storybooks. The pattern of outcomes of session 4 duplicated the pattern of session 1 though the mean fixation durations had expanded in session 4 for inside as well as outside fixations. A 2 x 2 x 5 repeated measures analysis of variance (ANOVA) with session (1 vs. 4), target (inside vs. outside) and storybook as factors confirmed the effect of time, Wilks'= .50, F (1, 18) = 18.22, $p < .000$, $\eta^2 = .50$, and of target, Wilks'= .50, F (1, 18) = 18.32, $p < .000$, $\eta^2 = .50$, but not of an interaction.

Table 5: *Mean Fixation Durations in ms Inside and Outside the Demarcated Zones for Sessions 1 and 4*

Story	Session 1		Session 4	
	Inside zone	Outside zone	Inside zone	Outside zone
Rummage Dragon	434.98(26.27)[1]	406.19(18.03)	484.31(47.79)	435.87(35.39)
Bear and Piglet	482.03(85.55)	438.60(34.58)	582.88(65.50)	548.68(85.47)
Bicycle Ride Grandpa	484.16(27.64)	452.85(37.05)	516.98(15.31)	490.79(54.86)
Bear in Playground	476.32(21.13)	459.79(28.71)	512.61(52.54)	461.14(33.38)
Rokko Crocodile	461.55(46.42)	439.52(57.70)	543.54(115.01)	466.01(55.05)
Total	468.96(45.22)	440.57(39.51)	527.77(68.97)	480.76(62.50)

Note[1] Standard Deviations between parentheses

Preference for human or anthropomorphic elements within the demarcated zones.

Among the elements that the text highlights, Farouk shows most interest in the dragon and in particular in his self-contented face. Comparisons of human with neutral elements in the whole group were in the same line; average numbers of fixations were 176.74 (SD = 33.22) and 51.91 (SD = 13.97), respectively. According to a 2 x 5 repeated measures analysis (ANOVA) with target (human vs. neutral) and storybook as factors, target caused a significant effect, Wilks' = .06, F (1, 18) = 285.92, p < .000, η^2 = .94. Outcomes were similar for all five books. The pattern of outcomes for session 4 was almost identical, except that the overall number of fixations in session 1 (M = 114.96) outnumbered the overall number in session 4 (M = 96.41). A 2 x 2 x 5 repeated measures analysis of variance (ANOVA) with session (1 vs. 4), target (human vs. neutral) and storybook as factors confirmed this observation. There was an effect of time, Wilks' = .50, F (1, 18) = 18.24, p < .000, η^2 = .50, and of target, Wilks'= .05, F (1, 18) = 337.69, p < .000, η^2 = .95, but no significant interaction.

On average children fixated on human or anthropomorphic elements for 493.98 ms (SD = 65.79) and neutral elements for 443.84 ms (SD = 48.31) in session 1. According to a 2 x 5 repeated measures analysis (ANOVA) with target (human vs. neutral elements) and storybook as factors, there was a main effect for target, Wilks' = .63, F (1, 18) = 10.48, p < .005, η^2 = .37, but no book effect. Outcomes for session 4 were almost identical, except that the mean duration of fixations had increased in session 4. Fixation duration on neutral elements increased from 443.94 (SD = 48.31) to 513.81 (SD = 110.52) and on human elements from 493.98 (SD = 65.79) to 541.74 (SD = 59.21). A 2 x 2 x 5 repeated measures analysis of variance (ANOVA) with session (1 vs. 4), target (human vs. neutral elements) and storybook as factors confirmed that there was an effect of time, Wilks' = .61, F (1, 18) = 11.33, p < .003, η^2 = .39, and of target, Wilks' = .75, F (1, 18) = 5.86, p < .026, η^2 = .25, but no significant interaction.

Discussion

So far there is barely any research reporting how children proceed in processing illustrations in picture storybooks. This study applied the technology of eye tracking to study how children use pictures while listening to the story text. A unique result is that the text limits where children fixate. They fixate more often and longer inside the demarcated zones than outside. Outcomes were similar for all five books with one exception: in *Bear and Piglet* the number of fixations inside and outside demarcated zones was equal but

fixation duration revealed similar differences as the other books. By totalling fixation duration of all fixations inside and outside the demarcated zones we estimate that children spent on average 43% of the total time on longer fixations of visual elements that the text highlights and 27% on other elements. The findings thus indicate that children's visual attention is controlled to some extent by the summoning power of the meaning of the text. A logical consequence is that text is partially coordinated with visualisations. By thus concretizing text, children may be more successful in storing and retaining the story language (Paivio, 1986; Sadoski & Paivio, 1994) and the story meaning (Guttman et al., 1977).

Another main result is the preference for human beings, who can be people but also anthropomorphic figures, as often happens in children's books. This preference, which has been demonstrated several times for static pictures without text (Buswell, 1935; Fletcher-Watson et al., 2007; van der Geest et al., 2002; Yarbus, 1967), is also present when children are exposed to picture storybooks accompanied by oral text. Children fixate human figures more frequently and longer. The preference for human or anthropomorphic figures may be the outcome of an autonomous pattern of visual processing. Children may be more prone to fixate on humans or anthropomorphic figures because figures' actions and reactions are perceived as a main source for interpreting and drawing inferences about story events (Gergely & Csibra, 2003). This would also explain why faces, which are most instructive about the characters' emotions and intentions, seem to attract more attention than other body parts. On the other hand, the interest of children may well be drawn to humans or anthropomorphic figures because they are agential in the story, rather than because of their human characteristics. Further research is warranted for excluding this interpretation.

As children are more familiar with the story after three encounters they are less inclined to jump from one visual detail to another. The changes that have taken place in the fourth session – the number of fixations has decreased while fixations last longer – indicate that each separate fixation induces more information processing. To explain this change in fixation pattern, we may assume that after hearing the story three times children have built up more verbal and nonverbal associations at images (Sadoski & Paivio, 2004), thus increasing processing time.

There is no evidence that text, to an increasing degree, limits the fixations by telling the readers what visual details of a great array of possibilities they should pay attention to. In the fourth session, children continue to fixate occasionally on small and

incidental objects in the illustrations like a bird in a tree or a hare on a hill. In fact, the number of fixations on such objects that the text does not highlight remains relatively stable while the number of fixations on objects that the text highlights decreases with story repetition. This observation makes Cooper's (1974) theory - attention is directed by the story text unless the text is incomprehensible or unrelated to the illustration – less plausible. It seems more plausible that fixations are not only inspired by text but by intriguing details in illustrations as well thereby supporting Sipe's (1998) oscillation model.

Limitations

Some methodological choices imply discrepancies with book reading thus causing limitations in the ability to generalize to book reading. One possible objection could be that, due to the way in which information was presented to the children – it was a screen-based task with no book used during the process, and no written text – the present research has minimal application to book reading. However, it is indisputable that the screen-based task in this research and book reading have common grounds in visual and oral information sources and how visual and oral processing relate to each other. Outcomes thus are likely to apply to book reading.

Eye tracking seems to be a good method for measuring visual attention and seeing the selection process of attention at work. However, pixel precision in eye tracking systems is somewhat limited. The Tobii 1750 used in this study has an average of 0.5 degrees of inaccuracy (Tobii Technology, 2006). This means that there is an average error of about 0.5 cm between the measured and the intended gaze point. We also have to take into account some other limitations of the eye-tracking system when interpreting the results. In their book, Itti, Rees, and Tsotsos (2005) described the concept of covert attention. This concept involves the fact that one can attend to an object without making an eye movement to it. Objects that are attended to by this so-called covert attention cannot be measured by an eye-tracking system. So although eye movement systems make it possible to get an insight into formerly hidden processes, there are still processes that remain covert.

Subjects were second-language learners of Dutch. Due to serious problems in understanding the Dutch story texts, we expected them to be more prone than Dutch pupils to use illustrations as a relevant information source. Further research is needed to test whether outcomes for second-language learners differ from those for Dutch children. The

latter mostly experience fewer problems in understanding the story text and due to this, their eye fixations may show a less distinct preference for elements that the text highlights.

Another so far unanswered question is how elements, such as adult support during book reading, influence children's attention to pictures. Pointing at details in illustrations accompanied with questions and comments may enhance learning from book reading by guiding children's visual attention to the right spots. However, this hypothesis waits further testing.

Practical Implications and Future Directions

In the light of current efforts by researchers, educators, and policymakers to identify ways to heighten the effects of book reading, this research offers some guidance to these efforts. Specifically, it lends support to the assumption that language is only one source of information used by children to construct meaning about the story (Rowe, 1994). In a group that has problems understanding the story text, children concretize what the text highlights by fixating on those elements more than elements not highlighted in the text. According to previous research, this can be a strong incentive for story understanding (Guttman et al., 1977) and language acquisition (Paivio, 1986; Sadoski & Paivio, 1994). In so far as visual information processing is autonomous, it seems to be controlled by the intention to find cues for interpreting and drawing inferences about the story figures' actions and reactions. Children may gain an insight into the actions that take place as well as the internal responses of main characters to the actions, especially by paying attention to human or anthropomorphic figures (and especially their faces). Further research may highlight features of picture storybooks that support children in matching visual details with the accompanying text. New studies may also test the hypothesis that books with animated illustrations can be more supportive than 'still' books in concretizing language and can foster readers' understanding of the main characters' behaviour and responses.

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