Eye Movements of Children and Adults While Reading Television Subtitles

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Abstract. Eye movements of children (Grade 5–6) and adults were monitored while they were watching a foreign language movie with either standard (foreign language soundtrack and native language subtitling) or reversed (foreign language subtitles and native language soundtrack) subtitling. With standard subtitling, reading behavior in the subtitle was observed, but there was a difference between one- and two-line subtitles. As two lines of text contain verbal information that cannot easily be inferred from the pictures on the screen, more regular reading occurred; a single text line is often redundant to the information in the picture, and accordingly less reading of one-line text was apparent. Reversed subtitling showed even more irregular reading patterns (e.g., more subtitles skipped, fewer fixations, longer latencies). No substantial age differences emerged, except that children took longer to shift attention to the subtitle at its onset, and showed longer fixations and shorter saccades in the text. On the whole, the results demonstrated the flexibility of the attentional system and its tuning to the several information sources available (image, soundtrack, and subtitles).

Keywords: eye movements, reading, attention, children, fixation

Many countries import a large number of television programs from abroad. The imported programs are generally either dubbed or subtitled in the local language. Most countries with a small language community typically apply subtitling because of its lower cost. Wherever in the world subtitling is being applied (and as far as we know), the following rules of thumb are used for timing the subtitles. Up to two lines of text, each with a maximum of 32 characters and spaces, are used at a time. If there are two lines of 32 characters and spaces each, the subtitle is displayed for 6 s. Shorter subtitles are time-scheduled proportionally.

With a subtitled television program, there are three different but overlapping sources of information: the visual image, the soundtrack in a foreign language; and the subtitles in the native language. The information in the subtitles should, ideally, be completely overlapping with the translated information of the soundtrack. Since most imported programs in small countries are in English, a language that often is fairly well known by the adult observers, the foreign language soundtrack is likely also processed to a certain extent. Also, the pictorial image and the sequence of events in the movie often provide sufficient context, which makes either understanding the spoken language or reading the subtitle less compelling. Finally, people unconsciously speech-read to a certain extent (Campbell, 1999).

Previous studies (for an overview, see d'Ydewalle & Gielen, 1992) have examined the dynamics of attention in the context of subtitled television. Since most film and television research have not addressed attention and processing issues, the main question is how an observer is able to divide and shift attention in such a complex situation. Therefore, observers' eye-movement patterns between image and subtitles were monitored. From the findings, d'Ydewalle and Gielen concluded that paying attention to the subtitle at its presentation onset is more or less obligatory and is unaffected by major contextual factors such as the availability of the soundtrack, knowledge of the foreign language in the soundtrack, and important episodic characteristics of actions in the movie: Switching attention from the visual image to "reading" the subtitles happens effortlessly and almost automatically.

Not much research has addressed the characteristics of eye movements when text and pictures have to be integrated. However, the obligatory nature of processing the subtitle, as observed in our research, is consistent with a few studies examining eye movements when the two sources of information are available. For example, Carroll, Young, and Guertin (1992) reported a study with single-frame cartoons, with no dialog balloons but with a single text caption. Typically, the picture was not given full inspection until the caption had been read. Hegarty (1992a, 1992b) found students looked at diagrams only after reading the supporting text. Rayner, Rotello, Stewart, Keir, and Duffy (2001) found that observers' eyes went very quickly to the text in advertisements, which they then read (though not exhaustively) before looking at the picture of the advertisement. Finally, in a sentence-picture verification task, Underwood, Jebbett, and Roberts (2004) confirmed the pattern of scan-paths reported by Carroll et al. (1992), Hegarty (1992a,b), and Rayner et al. (2001), who found an exten-

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sive inspection of the text followed then by an examination of the picture.

Our previous eye movement studies on television subtitling focused mainly on attention and processing issues, and consequently only looked globally at the latency time to shift from the visual image to the subtitle at its presentation onset, and the percentage of time the observers spent in the subtitles (i.e., time in subtitle as a function of its presentation time). The goal of the present study was to establish whether there is regular word-by-word reading behavior in the subtitles. We, therefore, calculated the number of fixations in the subtitle, the fixation duration, the saccade amplitude, the number of regressive eye movements in the subtitle as well as how often the subtitles were completely skipped. Finally, we also examined the number of back and forth shifts between the visual scene and the subtitle area.

d'Ydewalle and Van Rensbergen (1989) showed that the automaticity of paying attention to subtitles is already apparent with children in Grades 4 and 6. With children in Grade 2, however, the time spent in the subtitles depended heavily on the nature of the movie: With a movie involving numerous actions (e.g., Popeye), less time was spent in the subtitle; with more verbal interactions in the movie (e.g., Garfield), the typical adult pattern of findings was obtained. Apparently, paying attention to the subtitles is not as compulsory for young children as it is for older children and adults. Therefore, reading behavior in the present study was investigated in both children and adults. Given that the movie fragment in the present study contained large portions of verbal conversation, we expected no major differences in eye movement patterns between the age groups.

In some former studies, attention allocation to the various information sources in reversed subtitling (i.e., native language soundtrack and foreign language subtitles) was also studied (for an overview, see De Bruycker & d'Ydewalle, 2003). Interest in reversed subtitling stemmed from research on foreign language acquisition through watching subtitled television programs. Several studies suggested that the most promising results for language acquisition are found when using reversed instead of standard subtitling (Holobow, Lambert, & Sayegh, 1984; Lambert, Boehler, & Sidoti, 1981; Lambert & Holobow, 1984). This is a rather surprising finding, given that in the reversed subtitling condition the participants need to process the foreign language subtitles in order to allow for any acquisition. Why would they pay attention to written script in a language they do not know, instead of listening to the native language soundtrack or processing the pictorial information? Pavakanun (1992) registered eye movements of adults watching movies with either standard or reversed subtitling. As expected, she found that more time was spent looking at the subtitles with standard than with reversed subtitling. Still, in the reversed condition at least 40% of the presentation time of the subtitles was spent looking at the foreign language subtitles. Yet, the fact that attention is allocated to the subtitles does not necessarily imply that there is true word-by-word reading. Moreover, if such reading occurs, are subtitles read in the same way in standard and reversed subtitling? Although the present study did not deal with foreign language acquisition, a reversed subtitling condition was included in order to explore the reading pattern in foreign language subtitles. Finally, in several former studies (see d'Ydewalle & Gielen, 1992), the time spent in the subtitle area was proportionally higher with two lines of text than with one line; accordingly, a more regular reading pattern (e.g., fewer subtitles skipped, relatively more time spent in subtitle, higher word fixation probability, etc.) was expected with two-line subtitles than with one-line subtitles.

In short, the present study investigated to what extent there is regular word-by-word reading behavior in television subtitles among both children and adults. This was done for a standard subtitling situation (i.e., foreign-language soundtrack and native-language subtitles), as well as for a reversed subtitling situation, in which the languages in the soundtrack and subtitles were switched (native language in soundtrack and foreign language in subtitles). In the analysis, a distinction was made between one-line and two-line subtitles. To establish reading behavior several dependent variables were calculated, including measures of attention allocation (percentage of skipped subtitles, latency time, percentage time spent in the subtitle area), characteristics of fixations (fixation duration, word-fixation probability) and characteristics of saccades (saccade amplitude, percentage of regressive eye movements, number of back and forth shifts between visual image and subtitle).

Method

Participants

Twelve adults (age 19–26) and eight Grade 5–6 children (age 10–12) volunteered to participate in the experiment. Adults were students selected in the entrance hall of the Department of Psychology in Leuven, by simply asking if they wanted to participate in an eye-monitoring experiment. The children were the sons and daughters of faculty staff members. In both age groups, there was an equal number of male and female participants, who were randomly assigned to one of the two subtitling conditions (standard or reversed). All participants were native Dutch speakers and did not have any knowledge of the foreign language in the movie (Swedish). All participants had normal or corrected-to-normal vision (contact lenses or eyeglasses). They were all naive about the purpose of the experiment, that is, they did not know that the study concerned subtitles.

Material

Excerpts of a Swedish cartoon movie, "Pelle Svänslös", were chosen. The excerpts contained a fair amount of con-

versation while maintaining the story line of the movie. The total time of the movie fragment was about 15 min. Two versions of the movie were constructed: one with standard subtitling (Swedish soundtrack and Dutch subtitles) and the other with reversed subtitling (Dutch soundtrack and Swedish subtitles). In both versions, the presentation time of the subtitles followed as closely as possible the 6-second rule used by television stations almost everywhere in the world and which has been demonstrated to be optimal (Warlop, Van Rensbergen, & d'Ydewalle, 1986). The rule states that a full-length two-line subtitle of 64 characters (including spaces and punctuation marks) is displayed for 6 s. Shorter subtitles are timed proportionally. The one-line subtitles were at the position of the first line of the two-line subtitles. Presentation onset of the subtitle and voice onset in the soundtrack corresponded as closely as possible. All assembling was done using a miroVIDEO DC20 system.

Design

There were three independent variables, each with two levels, producing a $2 \times 2 \times 2$ factorial design. One independent variable was the age group of the participants (children vs. adults). The second independent variable involved the subtitling mode: In one condition, participants saw the movie with standard subtitles, while in the other condition reversed subtitles were used. Since significant differences between one-line and two-line subtitles have repeatedly been observed (see d'Ydewalle & Gielen, 1992, for an overview), the third independent variable, a within-subjects variable, was the number of lines in the subtitle (one line vs. two lines).

Procedure

Participants' eye movements were registered with the Eyelink eye-tracking system. The Eyelink system is based on video technology and has a sampling rate of 250 Hz. This means that every 4 ms the Eyelink system determines pupil position (and pupil size) of the registered eye and the relative head position. The data were processed in real time to compute almost instantaneously true gaze position (with an average error of 0.5 to 1.0°). True gaze-position data reported the actual (x, y) display coordinates (pixels) of the participant's gaze on the display.

The system parses online the participant's eye movements into saccades, fixations, and blinks. Therefore, velocity and acceleration are computed for each data sample. If either one is above a saccadic threshold, a saccade signal is generated. Thresholds were fixed at 30°/s for velocity and 8000°/s² for acceleration, a conservative configuration that maximizes fixation duration and increases the threshold for microsaccades to appear. A saccade was then defined as a period where the saccade detector was active for two or more samples in sequence, and continued until the start of a period of saccade-detector inactivity of at least five samples. A blink was defined as a period of saccade-detector activity with the pupil missing for three or more samples in sequence. A fixation was any period that was not a blink or a saccade.

The saccades, fixations, and blinks were recorded in an EDF file (Eyelink Data File). The EDF file was then converted to a regular text file for further analysis. For fixations, there was a time stamp for the first and the last sample in the fixation, next to the duration of the fixation (in ms), the average x and y coordinates, and the average pupil size (pupil area). For saccades, there were the time of the first and last sample in the saccade, the duration of the saccade, the x and y position at the start and at the end of the saccade, the total visual angle covered by the saccade, and the peak velocity. Time stamps in the text files, in combination with the video output that mapped the momentary true gaze-position onto the originally displayed movie and that also contained a time indicator, made it possible to narrow down the data files to only the relevant portions: the eye movement data during subtitle presentation.

All participants were tested individually in a sufficiently lightened room. They were seated in a comfortable, stable chair, with the eyes at a distance of about 110 cm from the television screen (i.e., the prescribed ideal distance for a screen with a display size of 55 cm width). In order to minimize head movements, adults' heads were fixed in a specially constructed headrest. As children had problems with sitting still (leading to more eye-movement registration problems), their heads were only fixed with a chin rest; a set of four infrared markers measured their head position relative to the television screen. This was the only procedural difference between the adults and the children.

After the calibration procedure (consisting of fixating a 9-point grid with randomized target order, followed by a calibration-accuracy validation), participants were asked to watch a movie fragment in the way they would do when watching television at home. The movie was divided into 10 parts of 90 s, each separated by a drift correction to adjust for possible inaccuracies in the eye movement registration. Thereafter, participants were asked whether they could identify the foreign language in the movie and whether they had any knowledge of the language. None of the participants could tell with certainty which foreign language was used nor had any knowledge of Swedish. However, when encouraged to guess, most adults correctly stated that it was likely to be one of the Scandinavian languages.

Results

First, a database was created for each participant, containing a number of variables for each subtitle. The first five variables indicated whether the subtitle was either fixated at least once or completely skipped, the latency time (i.e.,

Table 1. Average percentage skipping, latency, percentage time in subtitles, fixation time, word fixation, saccade amplitude regressive eye movements and shifts as a function of condition lines and age

	Children		Adults		Overall	
Subtitling	Standard	Reversed	Standard	Reversed	Standard	Reversed
Percentage skipped subtitles						
One Line	11	28	2	21	6	24
Two Line	3	20	0	16	2	18
Latency time (ms)						
One Line	391	461	275	372	333	416
Two Line	490	628	293	592	391	610
Percentage time in subtitles						
One Line	42	29	31	27	37	28
Two Line	52	26	37	23	45	24
Fixation time (ms)						
One Line	243	239	178	185	210	212
Two Line	252	284	179	201	215	242
Word fixation probability						
One line	0.84	0.62	0.85	0.75	0.85	0.69
Two line	1.00	0.46	0.94	0.51	0.97	0.48
Saccade amplitude in degrees (in characters) (forward)						
One line	5.07° (7.6)	4.63° (7.0)	6.51° (9.8)	5.03° (7.5)	5.79° (8.7)	4.83° (7.2)
Two line	4.35° (6.5)	4.52° (6.8)	6.38° (9.6)	5.40° (8.1)	5.36° (8.0)	4.96° (7.4)
(backward)						
One line	3.17° (4.8)	3.00° (4.5)	4.29° (6.4)	3.02° (4.5)	3.73° (5.6)	3.01° (4.5)
Two line	3.02° (4.5)	2.54° (3.8)	3.84° (5.8)	3.30° (4.9)	3.43° (5.1)	2.92° (4.4)
Percentage regressive eye movements						
One line	43	48	45	46	44	47
Two line	33	36	32	34	32	35
Number of back and forth shifts						
One line	0.26	0.15	0.24	0.13	0.25	0.14
Two line	0.83	0.37	0.63	0.33	0.73	0.35

the time between the subtitle presentation onset and the first fixation in the subtitle), the percentage of time spent in the subtitle (i.e., the total duration of all fixations and saccades in the subtitle, divided by the total presentation time of the subtitle), the average fixation duration as well as the word-fixation probability. The word-fixation probability was obtained by dividing the total number of fixations by the number of words in the subtitle. This weighting was done because the average length of the subtitles in the analyses was not the same for each participant. The value of this variable was obviously influenced by the number of words that were either skipped or refixated, and is only an approximate measure. Accordingly, different populations of fixations (e.g., single fixations on a word vs. refixations) are mixed together, and a measure of gaze duration instead of average fixation-duration would be more informative. However, a measure of gaze could not be computed, since eye-movement data could not be mapped onto the individual words, but only onto the subtitle area as a whole.

Saccade amplitude was measured, separately for forward and backward saccades, in visual degrees (as the usual proportional lettering was used, 1° covered 1.5 characters or spaces, on average). The next variable gave the percentage of regressive eye-movements, relative to the total number of saccades in the subtitle; that is, the number of successive saccades between two fixations on the same line (thus, excluding return sweeps), where the x-coordinate of the second fixation had a smaller value than the x-coordinate of the first fixation, divided by the total number of saccades in the subtitle. Since the eye-movement data could not be related to individual words, interword as well as intraword regressions are included in this measure. The final variable involved the number of shifts from the visual image to the subtitle (i.e., number of saccades from a fixation in the visual image to a fixation in the subtitle area; the first image-to-subtitle shift after subtitle presentation onset was not included).

Not all subtitles were used in the analysis. First of all, the first 3 min of the movie fragment were considered as an adaptation to the situation and, hence, were not taken

into account. A further selection was made on the basis of the following criteria: meaningful content, comprehensible soundtrack, sentences not spread over two subtitles, at most one speaker in the subtitle, and no two subtitles the same. After the first 3 min, there were 181 subtitles in the standard subtitling condition, of which 114 remained after the selection; in the reversed subtitling condition 138 of the 192 subtitles remained. We also removed from the individual database the parts of the movie fragments (about 30%) for which an off-line screening showed too large an inaccuracy in eye-movement registration. Accordingly, analyses were made on a different set of subtitles for each participant. An analysis of variance on the percentage of missing data with subtitling condition and age group of the participants as independent variables revealed no significant effects, suggesting that the missing cases were randomly distributed.

The means of all dependent variables for each participant were calculated, separately for one- and two-line subtitles. The analyses of variance were carried out on those means. In the analyses, subtitles that participants did not fixate were excluded (12% of the remaining subtitles). The exclusion was obviously not done for the first dependent variable where an analysis was made on the percentage of subtitles being skipped, and for calculating the means of percentage of time spent in the subtitle and number of fixations in the subtitle. Finally, since the percentage of regressive eye-movements was calculated relative to the total number of saccades in the subtitle, only subtitles with at least two fixations were included in calculating the means of this measure (80% of the remaining subtitles).

All analyses included the subtitling condition (standard vs. reversed) and age as between-subjects variables, and number of text lines as a within-subjects variable. In the analysis of the saccade amplitude, the direction of the saccade (forward vs. backward) was an additional within-subjects variable. Table 1 gives all the means that were involved in the several analyses.

Percentage Skipped Subtitles

In the analysis on the percentage of subtitles that were not fixated at least once, the main effects of subtitling mode, $F(1, 16) = 22.85$, $MSE = 122.59$, $p < .001$, and the number of lines in the subtitle, $F(1, 16) = 17.94$, $MSE = 16.41$, $p < .001$, were significant. With standard subtitling only 4% of the subtitles were skipped while with reversed subtitling 21% of the subtitles were skipped. With the one-line presentation, 15% of the subtitles were skipped, while this was 10% in the two-line presentation.

Latency Time

For latency time, there were significant main effects of subtitling condition, $F(1, 16) = 10.46$, $MSE = 20933.85$, $p < .01$, age, $F(1, 16) = 5.52$, $MSE = 20933.85$, $p < .04$, and number of text lines, $F(1, 16) = 27.10$, $MSE = 5621.60$, $p < .001$. With standard subtitling participants, on average, waited 362 ms before shifting to the subtitle, while with reversed subtitling the average latency time was 513 ms. Children were slower than adults to shift ($M = 493$ vs. 383 ms). When reading one-line subtitles the average latency time was 375 ms, while this was 501 ms with two-line subtitles. The main effects of subtitling condition and number of text lines were, however, involved in a significant two-way interaction, $F(1, 16) = 7.82$, $MSE = 5621.60$, $p < .02$. There was a significant effect of the number of text lines with reversed subtitling, $F(1, 16) = 32.02$, $MSE = 180026$, $p < .001$: Participants, on average, waited 416 ms before shifting to a one-line reversed subtitle, while an extremely long latency ($M = 610$ ms) was found for two-line reversed subtitles. With standard subtitling the difference was much smaller and not significant ($M = 333$ vs. 391 ms).

Percentage Time in Subtitles

Participants with standard subtitling, on average, spent 41% of the presentation time in the subtitle area, while this was only 26% with reversed subtitling, $F(1, 16) = 23.28$, $MSE = 85.98$, $p < .001$. Children spent proportionally more time in the subtitles than adults did ($M = 37\%$ vs. 30%), $F(1, 16) = 6.27$, $MSE = 85.98$, $p < .03$. Furthermore, there was a significant interaction between subtitling condition and number of text lines in the subtitle, $F(1, 16) = 18.98$, $MSE = 17.60$, $p < .001$: With standard subtitling participants spent significantly more time in a two-line subtitle ($M = 45\%$) than in a one-line subtitle ($M = 37\%$), $F(1, 16) = 16.96$, $MSE = 17.60$, $p < .001$; with reversed subtitling the difference was in the opposite direction, and only marginally significant ($M = 24\%$ vs. 28%), $F(1, 16) = 4.11$, $MSE = 17.60$, $p < .06$.

Fixation Duration

In the analysis of the fixation duration, there were significant main effects of the number of text lines in the subtitle, $F(1, 16) = 16.44$, $MSE = 182.63$, $p < .001$, and age, $F(1, 16) = 25.40$, $MSE = 1764.11$, $p < .001$. Fixations in one-line subtitles were shorter than in two-line subtitles ($M = 212$ vs. 228 ms), and children made longer fixations than adults ($M = 254$ vs. 186 ms). However, both main effects were significantly involved in two first-order interactions.

There was a significant interaction between subtitling condition and the number of text lines, $F(1, 16) = 8.65$, $MSE = 182.63$, $p < .01$. Fixation duration in one-line subtitles was about the same in the standard and reversed subtitling conditions ($M = 210$ vs. 212 ms), $F < 1$; however, in two-line subtitles, fixation duration was longer with reversed subtitling than with standard subtitling ($M = 242$ vs. 215 ms), $F(1, 16) = 24.47$, $MSE = 4469.42$, $p < .001$. While there was a considerable increase in fixation duration in

two-line reversed subtitles as compared to one-line reversed subtitles (M = 212 vs. 242 ms), $F(1, 16) = 24.47$, $MSE = 182.63$, $p < .001$, the difference was not significant with the standard subtitles (M = 210 vs. 215 ms), $F < 1$.

The second significant interaction involved the number of text lines and age, $F(1, 16) = 4.51$, $MSE = 182.63$, $p < .05$. While there was no significant difference between one and two lines of text among adults (M = 182 vs. 190 ms), fixation durations of children were longer with two lines of text than with one line of text (M = 241 vs. 268 ms), $F(1, 16) = 15.91$, $MSE = 182.63$, $p < .002$.

Word Fixation Probability

The analysis of the word fixation probability showed a significant main effect of subtitling condition, $F(1, 16) = 26.81$, $MSE = .04$, $p < .001$: There were more fixations with standard than with reversed subtitling (M = .91 vs. .59). However, the interaction between subtitling mode and number of text lines was also significant, $F(1, 16) = 31.77$, $MSE = .008$, $p < .001$: Two-line reversed subtitles showed significantly fewer fixations (M = .48) than one-line reversed (M = .69), one-line standard (M = .85), and two-line standard (M = .97) subtitles; on the other hand, the differences between one-line reversed, one-line standard, and two-line standard subtitles were not significant.

Saccade Amplitude

In the analysis of the saccade amplitude, only two significant main effects emerged. Adults showed larger saccades than children (M = 4.72° vs. 3.79°; corresponding to approximately 7.1 vs. 5.7 characters or spaces), $F(1, 16) = 4.53$, $MSE = 3.69$, $p < .05$, and forward saccades were larger than backward saccades (M = 5.24° vs. 3.27°; 7.9 vs. 4.9 characters or spaces), $F(1, 16) = 45.30$, $MSE = 1.63$, $p < .001$.

Percentage of Regressive Eye-Movements

In the analysis of the percentage of regressive eye-movements, only the main effect of the number of text lines was significant, $F(1, 16) = 28.35$, $MSE = 46.19$, $p < .001$: There were proportionally more regressive eye-movements with one-line than with two-line subtitles (M = 46% vs. 34%).

Number of Back and Forth Shifts

For the number of back and forth shifts between the visual scene and the subtitle area, the main effects of subtitling mode, $F(1, 16) = 12.93$, $MSE = 0.044$, $p < .003$, and number of text lines, $F(1, 16) = 57.88$, $MSE = 0.020$, $p < .001$, were significant. Participants viewing standard subtitling showed more back and forth shifts than participants viewing reversed subtitling (M = 0.49 vs. 0.24). When reading two-line subtitles participants made more shifts than when reading one-line subtitles (M = 0.54 vs. 0.19). From the significant interaction between these two variables, $F(1, 16) = 8.66$, $MSE = 0.020$, $p < .01$, it appears that the effect of number of lines in the subtitle was stronger in the standard than in the reversed subtitling mode, because of the much larger number of shifts with the two-line standard subtitles (all averages from the interaction differ significantly from each other).

Discussion

The present study investigated the eye-movement patterns of adults and children watching a subtitled movie fragment. Subtitling was either in the native language (standard subtitling) or in a foreign language (reversed subtitling, with the soundtrack in the native language), and was either with one or two simultaneously presented lines of text. An analysis of the eye-movement behavior revealed, first, that although saccade amplitude and percentage regressions were similar between reading reversed and standard subtitles, reversed subtitles were more often skipped, were fixated less frequently (resulting in less time spent in the subtitle), showed longer latencies, longer fixations (in two-line subtitles only), and a smaller number of shifts between the visual scene and the subtitle than standard subtitles.

Second, there were several interactions between subtitling condition and number of text lines in the subtitle: In general, standard subtitling showed a more regular reading pattern with two lines of text than with one line (e.g., less skipping of the subtitles, larger proportion of time spent in the subtitle, and a smaller percentage of regressive eye-movements), while with reversed subtitling less regular reading was found with two-line than with one-line subtitles (longer latency time to jump to the subtitle, smaller percentage of time spent in the subtitle, longer fixation durations, and lower word-fixation probability).

Finally, children did not show a radically different pattern of eye-movements than that of the adults. Overall, children did not skip the subtitles more frequently, did not make more fixations, did not show more regressive eye-movements, and did not switch back to the visual image more or less frequently than the adults. Exceptions were the children's longer fixation durations (resulting in more time spent in the subtitle), their smaller saccade amplitude, and their longer latency to jump to the subtitle. However, these results were to be expected. Older studies have already convincingly showed that children make longer fixations while reading than adults do (see, e.g., Lefton, Nagle, Johnson, & Fisher, 1979; Spragins, Lefton, & Fisher, 1976; Taylor, 1965). Moreover, studies on general saccade characteristics have demonstrated that the latency of a saccade to a visual target is longer for children than for adults

(e.g., Miller, 1969). Finally, it is also typical for children to make shorter saccades when reading text (Rayner, 1998). Moreover, in the comparison of standard versus reversed subtitling, not many age differences emerged: In the several analyses no significant interactions were found between age group and subtitling mode.

These results are consistent with d'Ydewalle and Van Rensbergen (1989), who also investigated eye movements of children in Grades 2, 4, and 6. Basically, all children, except Grade 2, showed a pattern very similar to the pattern obtained with adults: There was no difference in latency to jump to the subtitle between adults and children in Grades 4–6, and proportionally more time spent in the subtitles with two lines of text than with one line of text by the adults and children in Grades 4–6.

As pointed out above, participants in the standard subtitling condition of the present experiment showed less skipping of the subtitles, with slightly more fixations (resulting in more time spent in the subtitle) and less regressive eye-movements, when they were presented with two text lines than with one text line. Similarly, previous findings with standard subtitling (see d'Ydewalle & Gielen, 1992, for an overview) showed proportionally more time spent in two-line subtitles than in one-line subtitles (although the difference was not always significant). Taken together, this should bring us to the conclusion that in the standard subtitling condition there was a more regular reading pattern with two lines of text than with one line. This conclusion needs to be qualified, as there were more back and forth shifts between the subtitle and the visual image when two lines of text were presented than with one line of text. This, however, can easily be explained. Given the 6-second rule for presenting the subtitles, with two text lines there is ample time available to jump back to the visual image after a careful first reading of the subtitle; accordingly, a full-fledged reading behavior does not exclude the possibility of moving back to the visual image.

Praet et al. (1990) offered three explanations for why participants typically spent proportionally more time looking at a two-line standard subtitle than at a one-line standard subtitle. The first explanation assumed that two-line subtitles might be more difficult to process, as a result of their greater syntactic and semantic complexity. This explanation was dismissed as they obtained relatively more and longer fixations (reflecting more processing demands) in one-line sentences than in two-line sentences in a normal reading situation (i.e., without pictures and soundtrack). Second, it might be that the presence of two lines exerted more lateral (vertical) interference: As a line close to the one being read interferes with parafoveal processing, less information can be extracted during fixations (Bouma, 1980). Praet et al. manipulated the interline distance of the two-line sentences under the hypothesis that the interference effect would diminish as the interline distance increased. The absence of an effect of interline distance is inconsistent with the lateral interference explanation.

The third explanation drew upon the relationship between the information in the subtitle, the image, and the soundtrack. A standard one-line subtitle generally does not provide much more information than what can already be extracted from the picture and the auditory message. One-line subtitles often involve short exclamations and outcries, typically easy to infer from the picture and the vocal intonations. Therefore, it may not be necessary to read the subtitle carefully. To test this hypothesis, reading behavior in a subtitling condition (i.e., with pictures and sound) was compared with a normal reading condition (i.e., without pictures and sound). In the subtitling condition, the percentage of time spent in the (standard) subtitle was larger with two lines than with one line. In the reading condition, the results were in the opposite direction: The participants required proportionally more time to read a one-line sentence than to read a two-line sentence. Clearly, the information conveyed by one-line subtitles is far more redundant, given the available pictorial information, than is the case for two-line subtitles. This redundancy explains why there was less reading in the standard one-line subtitles of the present experiment.

The mean fixation duration in the subtitles was very short in the present experiment. With standard subtitling the mean fixation duration was 178 ms for adults and 248 ms for children. Similarly, d'Ydewalle et al. (1985) estimated an average fixation time of 124 ms per word in the subtitle by adults; in their experiment fixation time was not measured directly but inferred from regressing the number of words to the total time in the subtitle. In a normal reading situation, individual words are fixated by adults for about 200 to 250 ms (Rayner, 1998; Rayner & Pollatsek, 1987) and by 10- to 12-year-old children for 270 to 300 ms (Rayner, 1998; Spragins, Lefton, & Fisher, 1976; Taylor, 1965).

While in normal text reading children typically make more regressions than adults (Rayner, 1998), children in the present study made as many regressions as adults. In fact, the percentage of regressions in reading subtitles was globally, among children and adults, much higher than in normal text reading.

There are several reasons for the difference in fixation durations and number of regressions between subtitles and normal text. First, in the present experiment, the fixation duration was calculated as a function of the total fixation time in the subtitle, divided by the number of fixations in the subtitle, which also included the refixations (both interword and intraword). The number of refixations (with typically shorter duration) must have been high, as the percentage of regressive eye-movements was around 40%. Second, there is considerable information redundancy in the subtitling situation. Subtitle, soundtrack (including the voice and additional information such as intonation, background noise, etc.), and image all provide partially overlapping information, eliciting back and forth shifts with the image and more regressive eye-movements.

Except for the fixation duration, the saccade amplitude, and the percentage of regressive eye-movements, all dependent variables showed a significant main effect of the

subtitling condition. As compared with standard subtitling, with reversed subtitling there was more skipping of the subtitles, a longer latency to jump to the subtitle (see also Pavakanun, 1992), less time spent in the subtitle (see also Pavakanun, 1992), less fixations, and less image-to-subtitle shifts.

While with standard subtitling several findings have suggested more regular reading in a two-line subtitle than in a one-line subtitle, the opposite could be stated with reversed subtitling, leading to significant interactions between subtitling mode and number of text lines. In a two-line reversed subtitle, as compared with a one-line reversed subtitle, there was a much longer latency to shift attention to the subtitle, slightly less time spent in the subtitle, and less but longer fixations. Less than half of the words (.48) in a two-line reversed subtitle were looked at. Moreover, the long mean latency-time (610 ms) also suggested that the participants only occasionally grasped some keywords in two-line reversed subtitles, without really reading the sentences as a whole. Again, this needs to be qualified with a few exceptions. More one-line than two-line reversed subtitles were skipped, and there were more regressive eye-movements with one text line than with two lines of text.

In short, there was more regular reading in a two-line than in a one-line standard subtitle and less regular reading in a two-line than in a one-line reversed subtitle. The comparison between standard and reversed one-line subtitles was, however, less clear-cut. Although there were more skipped subtitles, a higher percentage of time spent in the subtitle (as a result of more fixations being made), and larger saccade amplitudes with one-line standard than with one-line reversed subtitles, no differences were found for latency time, fixation duration, percentage of regressive eye-movements, and number of image-to-subtitle shifts.

Apparently, with standard subtitling attention was tuned to the information available. As two text lines in a standard subtitle contained verbal information that could not easily be inferred from the pictures on the screen, more regular reading occurred; one-line standard subtitles were often redundant to the information in the picture, and consequently less reading was apparent. Reversed subtitling showed even less characteristics of regular reading behavior, as the native language was in the soundtrack.

Nevertheless, participants in the reversed subtitling conditions did spend some time looking at the subtitles (26% of the subtitle presentation time), despite the availability of the native language in the soundtrack. d'Ydewalle, Praet, Verfaillie, and Van Rensbergen (1991) reported two experiments in which the soundtrack and the subtitles both were in the native language (Dutch for Dutch-speaking participants, and English for US participants): All participants looked extensively at the subtitles. Dutch subjects are used to watching subtitled television programs; accordingly, subtitle reading may have been the result of long-term experience leading to habit formation in reading. American participants lacked familiarity with subtitles, but still spent considerable time in the subtitle area, suggesting that reading the subtitles is preferred because of efficiency in following and understanding the movie. However, the reversed subtitles in the present study were basically meaningless. Reading reversed subtitles was not functional when the soundtrack provided all of the necessary information in the native language.

One possibility is that the sudden appearance on the screen of a subtitle captured attention to some extent. However, this does not explain why the average latency to jump to the subtitle was considerably longer with reversed than with standard subtitles. If the change in visual stimulation distracted and captured attention, a separate population of short latency times (i.e., the time before a first eye- movement to the subtitle is made) was to be predicted, even more so in the reversed than in the standard subtitling condition, because of the meaningless nature of the information provided in the former condition. However, plotting and comparing the frequency distributions of latency times in the several conditions did not reveal such a class of short latencies. Furthermore, given that the subtitles appeared throughout the testing session, participants should have become desensitized to the visual onset of the subtitles. It follows that average latency time should be longer in the later parts of the movie fragment than in the beginning. To investigate this assumption, we divided the movie fragment into three equal parts of 4 min, and carried out an analysis of variance with movie part, subtitling condition, age group, and number of lines in the subtitle as independent variables. Mean latency time in the middle (491 ms) and last parts (471 ms) of the movie fragment was, indeed, significantly longer than in the first part (331 ms), independently of age group and subtitling condition. There was a significant interaction between movie part and number of lines in the subtitle, indicating that the differences in latency time between the movie parts only reached significance with two-line subtitles. Although these results suggest that the explanation of subtitle onset capturing attention cannot be completely ruled out, the same analysis (including movie part as an independent variable) for other dependent variables such as percentage of skipped subtitles, percentage of time spent in subtitles, fixation duration, and word-fixation probability revealed no significant effects involving movie part, and, thus, no crucial differences in reading behavior during the various parts of the movie fragment.

Eye movements do not always reflect ongoing cognitive activities to process and understand information; predetermined oculomotor strategies may also emerge in text-like materials. There is evidence that even when the task does not require linguistic processing of text (as is the case in the reversed subtitling condition in the present experiment), looking at the words is almost obligatory: Even when facing a meaningless string of letters, reading-like behavior may emerge. Vitu, O'Regan, Inhoff, and Topolski (1995) compared the oculomotor behavior of readers scanning meaningful and meaningless (i.e., a string of letters) materials. The results showed that global eye-movement characteristics (such as saccade size and fixation duration)

as well as local characteristics (such as word-skipping rate, landing site, refixation probability, and refixation position) were very similar with the two materials, suggesting that the eyes were generating an autonomous oculomotor scanning strategy in the absence of any linguistic information to process. However, contrary to Vitu et al. (1995), Rayner and Fischer (1996) showed that eye movements are different in reading, the scanning of transformed, meaningless text, and visual search.

An autonomous process might have occurred with the foreign language subtitles in the reversed subtitling condition in our study. However, this is unlikely since participants watching a movie fragment with reversed subtitling do seem to process the foreign language information in the subtitle to some extent. In some of our former studies (see e.g., d'Ydewalle & Pavakanun, 1997), participants unexpectedly received foreign language word and sentence recognition tests after watching a movie fragment. Participants who watched the movie with reversed subtitling performed well above chance level, and displayed foreign language (word) acquisition as strongly as (or even more strongly than) participants with standard subtitling. This can only be possible when the foreign language is processed in a less incidental or superficial way than suggested by either an explanation referring to subtitle onset capturing attention, or an autonomous oculomotor scanning strategy. Since the focus of the present study was on eye-movement behavior in subtitles, and not on language acquisition, we did not administer a foreign language acquisition test. An experiment that directly links a detailed analysis of eye movements in reversed subtitles with foreign language acquisition is needed in order to make more conclusive inferences on the linguistic processing of foreign language subtitles in the presence of a native language soundtrack.

Research on subtitling may appear to be a rather exotic issue in experimental psychology. However, the topic has considerable practical relevance in a continent such as Europe with only a few large language communities of people but with a large number of small countries and small language communities. Dubbing for a small audience of people is often financially prohibitive; subtitling is then the manageable solution. In many respects, subtitling is not necessarily a disadvantage. Roughly from 1980 until 1992 (as reviewed in d'Ydewalle & Gielen, 1992), our research showed that processing the subtitles was inescapable, and largely occurred effortlessly and automatically. In the present study, we showed that the processing of the subtitles involves typical reading behavior. From the mid-1990s, our research program has collected a considerable amount of data suggesting that simply watching a subtitled movie, through the incidental reading of the subtitles in the mother language and hearing the voices in a foreign language, greatly contributes in the incidental acquisition of the foreign language vocabulary (see, e.g., d'Ydewalle & Van de Poel, 1999) but not of its grammar (see, e.g., Van Lommel, Laenen, & d'Ydewalle, 2006).

Research on subtitling can also be related to more theoretical issues. With subtitled movies, there are at least three different input channels: the visual image, the soundtrack (including the foreign voices), and the subtitles (a translation of the voices). The main question is how a person is able to divide and shift his or her attention in such a complex situation. Implications from the earlier studies of Broadbent (1958) are straightforward: At any given time, only one among the sensory inputs is fully analyzed. Moreover, it should take time to switch the inputs. If some parallel processing or multiple-resource allocations are accepted, more flexibility within the human system is likely to occur. As most film and television research does not address attention and processing issues, the purpose of our studies was also to look at the dynamics of attention.

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