Effect of Caption Rate on the Comprehension of Educational Television Programmes by Deaf School Students

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ABSTRACT
Television captioning has great potential to provide deaf children with access to the audio track of programmes. However, use of captions may be limited by the lower English literacy skills of the deaf population compared to the general population. Here, we investigate how the rate of caption delivery affects the comprehension of educational programmes by better- and poorer-reading deaf school children. Participants watched three short documentaries, with captions presented at 90, 120, or 180 words per minute (wpm). Across both reading levels, comprehension was uniformly higher at 90 and 120 wpm than at 180 wpm. Independent of caption rate, better readers scored higher overall than poorer readers. These results suggest that the rate of captions in children’s television programmes can safely use 120 wpm as a slowest speed. Future research should seek to pinpoint the optimal rate, which appears to lie between 120 and 180 wpm. Copyright © 2009 John Wiley & Sons, Ltd.

Key words: deaf children; captions; caption speed; reading rate; comprehension
INTRODUCTION

The widespread popularity of television captioning among deaf adults and children is due to the access that it provides to the audio track of television programmes. However, deaf and hard of hearing students tend to have considerably lower English literacy skills than the general population (see Musselman, 2000, for one discussion of the many reasons for this), and this may create a barrier to accessing television captions and other media (Ward et al., 2007). In the USA, for example, the median reading comprehension level of deaf and hard of hearing students aged 15 years is comparable to the reading comprehension level of hearing students aged eight to nine years (Karchmer and Mitchell, 2003). Reading proficiency has been shown to be the most important factor determining success in the comprehension of television captions by deaf and hard of hearing adults (Burnham et al., 2008) and children (Jelinek Lewis and Jackson, 2001).

Reading speed is an aspect of reading ability that constrains success in reading captions, and is also generally lower in the deaf population than the general population. Whereas American college students have been shown to read static text for detail at 291 words per minute (wpm) and for a general overview at 461 wpm (Samuels and Dahl, 1975), the average reading rate of deaf people aged 17–20 is only 135 wpm (Shroyer and Birch, 1980). Burnham et al. (2008) showed that deaf adults’ low reading rates affect the comprehension of captions: comprehension was better when captions were presented at 130 wpm than at 180 wpm or 230 wpm, but only for more proficient readers. Less proficient readers had poor comprehension regardless of caption rate, suggesting that presentation rates even slower than 130 wpm might be required for less reading-proficient viewers.

Reading speed among deaf children is also slower than in the general population. Samuels and Dahl (1975) found that fourth graders in the USA read static text for detail at 188 wpm and for general overview at 286 wpm, whereas deaf students aged nine to 14 years have been shown to have an average reading rate of 116 wpm (Shroyer and Birch, 1980). While the reading rate for static text is certainly informative, it should be noted that the task of viewing a captioned television programme may involve different processing demands (e.g. visual attention is shared between picture and caption text; Jensema et al., 2000). In spite of reading rate findings, US television caption presentation rates are typically higher than deaf children’s reading rates, at 124 wpm for children’s educational programmes (range 87 [Sesame Street] — 154 [Bill Nye the Science Guy], 125 wpm for children’s animation (range 105–148) and 131 wpm for children’s action movies (range 95–152) (Jensema et al., 1996). By comparison, the Deafness Forum of Australia’s (2004) Captioning Quality Code of Practice states that children’s programmes in Australia should be captioned at 120 wpm, and at 90 or 60 wpm for very young children. The corresponding captioning rate for adults is 180 wpm (Deafness Forum of
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Australia, 2004), higher than the 145 wpm rate that Jensema (1998) suggests to be the most subjectively comfortable caption speed for both teenagers and adults.

Given that less-proficient readers in the adult deaf community have poor caption comprehension at presentations of 130 wpm (Burnham et al., 2008), it is possible that deaf children may require presentation rates that are much lower than 120 wpm. Baker (1985) recommended an optimum caption presentation rate of 60 wpm for secondary school children, and reported that virtually all children in his research indicated that a rate of 120 wpm was ‘too fast’. He concluded that caption presentation rate (60 vs. 120 wpm) was a better predictor of comprehension than language level. In contrast, other researchers have found that caption rate (60, 90 and 120 wpm) did not significantly affect comprehension among elementary and secondary school students yet language level of the captions did (Braverman and Hertzog, 1980). These authors suggested that thresholds be examined for those caption rates beyond which comprehension declines, however, there is no study to our knowledge that has systematically demonstrated the effect of captioning in children’s programmes at rates beyond 120 wpm.

The aim of this study is to investigate the comprehension of television captions in deaf Australian school students at different presentation rates, namely, 180, 120 and 90 wpm. Due to the rarity of captioning at 60 wpm in real world settings (Jensema et al., 1996), this rate was not included, and a rate of 90 wpm was included given the inconsistency in past research described above. To achieve caption presentation rates of 90 wpm, it is necessary to reduce the text so that fewer words carry the same basic message (cf. the discussion by Baker, 1985). This raises the question of whether text reduction itself will lead to comprehension difficulties. While there is some suggestion in the literature that comprehension is better for unreduced text (Ewoldt, 1984; Israelite and Helfrich, 1988; Sundbye, 1987; Yurkowski and Ewoldt, 1986), Burnham et al. (2008) found no detrimental effect of text reduction for deaf adults, whether good or poor at reading, and others have shown that text reduction actually improves comprehension for deaf and hard of hearing children (Boyd and Vader, 1972; Braverman, 1981; Braverman and Hertzog, 1980). Whatever the effect of reducing the text so that it can be displayed at 90 wpm, here we have sought to control for the effects of text reduction by presenting text reduced to the same extent, but displayed at different rates by varying the length of time that each caption is left on the screen. We prepared three captioned versions of three educational videos at 90, 120 and 180 wpm. It was predicted that comprehension would be higher at 90 and 120 wpm than at 180 wpm.

Given the generally poorer English literacy skills among people who are deaf compared with the general population, we also sought to test whether reading level would affect caption comprehension in Auslan-signing deaf school children, and whether any interaction might exist between reading level
and caption rate. Following results from American deaf children (Jelinek Lewis and Jackson, 2001) and recent findings among the adult deaf population (Burnham et al., 2008), we predicted that more proficient readers would have better comprehension than less proficient readers irrespective of any effects of caption rate.

**METHOD**

**Design**

A $2 \times (3)$ Reading Level (more/less proficient) $\times$ Caption Rate (90, 120, or 180 wpm) design was employed. Caption rate was a within-subjects factor, such that each participant watched three different programmes, one at each rate. Programme presentation was counterbalanced so that the three programmes were presented an equal number of times at each caption rate across participants in the experiment. The dependent variable was per cent correct responses on a comprehension questionnaire completed by participants after viewing each programme.

**Participants**

Participants were 20 deaf students (7 females) at a sign-bilingual (i.e. bilingual-bicultural) school for the deaf in Sydney, Australia. Ages ranged from nine to 16 years ($M = 12.75$, $SE = 0.45$) and all used Auslan as their preferred language of communication. As a group, sign language users are heavily, if not exclusively, dependent upon captions for access to the sound track of television programmes. In this study, all 20 participants reported that they used captions exclusively as their means of accessing the auditory content of broadcast television.

Up-to-date assessments of students’ reading ability were obtained using the Woodcock Reading Mastery Test (Form G). All participants were administered the Reading Comprehension Cluster (i.e. the Word Comprehension and Passage Comprehension subtests). Students’ reading ages, $M = 8.89$, $SE = 0.37$, were significantly lower than their chronological ages, $t(19) = 8.90$, $p < 0.05$, but there was a significant medium-level positive correlation between the two measures, $r = 0.45$, $p < 0.05$. The sample was divided into two groups of ten students (more/less proficient readers), according to whether their score was above or below the median w-score score on the comprehension cluster of the reading test, Median = 479. W-scores, rather than age-referenced standard scores, were analysed on the assumption that, for these deaf participants, reading ability was affected by factors other than their age. Further, it was considered that raw capacity in reading, rather than ability relative to age, was likely to be the most relevant correlate of their capacity to use captions. The more proficient readers were slightly older, on average, than the less proficient
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readers, but this difference was not significant; more proficient $M_{\text{age}} = 13.75$, $SE = 0.66$; less proficient: $M_{\text{age}} = 12.14$, $SE = 0.57$; $t(18) = 1.84$, $p > 0.05$. There were slightly more females among the less proficient (5 females) than the more proficient readers (2 females).

Materials

Captioned material and comprehension tests

The materials comprised three television science documentaries, one for each caption rate. Each documentary was approximately 5 min long. Initially, 24 short children’s television documentaries were obtained from the Australian Broadcasting Corporation’s Our Animals series, and three university lecturers in secondary education (all themselves experienced teachers) were asked to indicate those featured animals about which students would have the least prior knowledge. The resultant shortlist of eight documentaries was further reduced to five by selecting only those with sufficient information conveyed in spoken dialogue alone, rather than visual images, and with a minimum of potentially disturbing scenes (e.g. prey being eaten).

Comprehension tests were devised for each documentary in the form of ten questions, mostly short answer with a few true/false or multiple choice, and piloted with 55 hearing students aged 11–13 years from a local regular school. A number of questions showed correct responses greater than 65 per cent and were judged to be of limited discriminative ability. To rectify this, one documentary was ruled out and in the remaining documentaries, all but two questions were converted to short-answer responses in an effort to make the correct response rate closer to 50 per cent. Example short-answer questions are given in the Appendix. Of the four remaining documentaries, the three requiring the slowest rate of text and the fewest scene changes were selected to allow captioning at the slowest rate to be used (i.e. 90 wpm). The three chosen documentaries were Quolls, Sea Dragons and Fur Seals. A final set of questions for each was piloted again with the same hearing students, but each student watched a different documentary than in the previous session. The mean per cent correct responses were 45.1 per cent for Quolls, 51.9 per cent for Sea Dragons and 57.8 per cent for Seals and an item analysis showed these scores did not differ significantly from each other, $F(2,27) = 1.45$.

Each video was originally captioned at a rate of 90 wpm (median frame duration corresponded to a reading rate of 90 wpm for all three documentaries, with mean caption rates of 90 wpm for Quolls and Sea Dragons, and 92 wpm for Seals). Subsequently, the display duration of each frame was shortened by the same amount to produce three versions of each documentary at rates of 90, 120 and 180 wpm. Differences in caption rate were achieved by having the same captions displayed on the screen for varying amounts of time (see Burnham et al., 2008, for a full description of the captioning procedure).
Measure of reading level

As indicated previously, the Woodcock Reading Mastery Test Comprehension Cluster (Word Comprehension and Passage Comprehension subtests) was used to estimate global reading level. This was consistent with the assessment policy of the school and the determination that this cluster of subtests was most representative of the reading comprehension ability of signing deaf children.

Measure of functional visual acuity

To test whether the participants were able to read words on the television screen, a VHS videotape was used with 18 single-meaning English words, in captioned style, presented one at a time on a neutral grey background, with no audio and a 3-s interval between words.

Procedure

Testing was conducted in a quiet classroom at the students’ school, with an accredited Auslan interpreter whom the students knew. The sound was off during all documentary viewing. Testing was done in three groups, each comprising approximately equal number of students (6, 7 and 7 students) of different ages and both genders. A 63-cm colour television was positioned in front of the group. They first performed the visual acuity test, in which they were asked to read the words presented on the screen and also indicate how well they could see them. During this process, the viewing distance was adjusted so that it was the most comfortable for all. Students watched each of the three videos, answering the corresponding question set immediately after each. Participants were not able to confer and answered the comprehension questions individually in writing. The videos and conditions were counterbalanced so that each documentary and each caption speed was presented in first, second and third place across the three groups. As required, the interpreter was able to assist any students to understand the questions. Testing was completed in one 45-min session per group. A single research assistant scored the comprehension questions.

RESULTS

Scores for the comprehension questions were converted to percentages and mean per cent correct responses were obtained for each caption rate and at each reading proficiency level. These are presented in Figure 1. It was predicted that comprehension would be higher at 90 and 120 wpm than at 180 wpm.

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1 The visual acuity measurement video was created by the Australian Caption Centre, now Media Access Australia.
Accordingly, a planned contrast analysis of variance was performed, with two repeated-measures planned contrasts (90 and 120 wpm vs. 180 wpm; 90 vs. 120 wpm) and one between-group contrast (more proficient vs. less proficient readers). Overall, students performed better at slower caption rates (90 and 120 wpm) than at the faster rate (Mean Difference = 6.81%, SE = 2.68%, F(1,18) = 6.47, 95%CI: 1.19%–12.44%) and there was no significant difference between performance for the 90 and 120 wpm rate. In addition, more proficient readers scored significantly higher than less proficient readers (Mean Difference = 26.97%, SE = 6.74%, F(1,18) = 16.02, 95%CI: 12.81%–41.13%), and there was no interaction between reading proficiency and caption rate.

Given the marginal difference in age between the more and less proficient reader groups, it could be argued that the differences between the two groups are based on age rather than reading level. To test this, we regrouped the participants into older and younger, using a median split, and ran the same analyses. The overall difference between the two slower and the fastest caption speeds was maintained (Mean Difference = 6.61%, SE = 2.67%, F(1,18) = 6.15, 95%CI: 1.01%–12.21%), but there was no reliable difference between the age groups (Mean Difference = 8.77%, SE = 9.08%, F(1,18) = 0.93). We also examined the correlations between comprehension scores at each caption speed and chronological age versus their standardised reading test scores. As shown in Table 1, correlations between comprehension scores and chronological age are

![Figure 1: Mean per cent correct comprehension scores for more proficient versus less proficient readers at 90, 120 and 180 wpm caption rates. Error bars represent standard error of the mean.](image)
not significant, whereas strong and significant correlations are observed between comprehension scores and reading ability. Thus, it appears that group differences in comprehension are more appropriately explained by reading ability than age.

**DISCUSSION**

We aimed to test the effect of caption rate, independent of text reduction, on the comprehension of short documentaries by deaf school children. The results clearly show that comprehension is poorer at 180 wpm than 90 or 120 wpm, regardless of reading ability; this is the first study to systematically demonstrate this result. We also sought to investigate whether a slower caption rate than is currently used would provide additional benefits. Consistent with findings reported by Braverman and Hertzog (1980), we did not find additional benefit by slowing captions from 120 to 90 wpm. These results support the appropriateness of industry guidelines for captions in children’s programmes provided by the Deafness Forum of Australia (2004). In stark contrast to the markedly lower 60 wpm recommended by Baker (1985), it appears that the optimal caption rate for deaf children (defined as the fastest rate which sustains comprehension at a similar level to their hearing peers) is somewhere between 120 and 180 wpm. It should be noted that 180 wpm is the captioning speed for adults recommended by the Deafness Forum of Australia (2004), and that many children do watch adult programmes; our results indicate that caption speed probably limits comprehension over and above issues related to mature programme content. With recent advances in digital broadcasting it may become possible for television viewers to select from a number of captioning alternatives (see Neves, 2007). If such technology becomes available, our results suggest that captions should be offered at 180 wpm and 120 wpm for programmes frequently watched by both adults and children.

We also split the sample by reading ability to test whether more proficient readers would comprehend captions more effectively than less proficient readers, as is the case with American deaf children (Jelinek Lewis and Jackson, 2001) and the adult deaf population (Burnham et al., 2008). Comprehension by the

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<th>Table 1: Pearson’s correlation coefficients for comprehension scores at each caption rate with chronological age and reading score.</th>
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<tr>
<td>Chronological age</td>
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<td>Reading score</td>
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*p < 0.05.
less proficient readers could be characterised as poor, with scores of around 15 per cent correct on the comprehension tests, whereas more proficient readers scored around 50 per cent correct, which was the level attained in pilot testing with hearing 11–13-year olds. Importantly, an additional analysis, split by age rather than reading ability, showed that the marginal difference in age between the reading proficiency groups was not responsible for the differing performance, as the older and younger ages performed equivalently. This was also supported by an analysis of correlations that showed strong positive correlations between reading ability and comprehension, but not age and comprehension.

It could be argued that the more proficient readers scored higher on the comprehension test because they were simply faster readers and had more time to benefit from contextual information in the video portion of the programmes. This is unlikely because the effect of caption speed was the same regardless of reading level. That is, there was no interaction between caption speed and reading ability — both reading ability groups performed better at 90 and 120 wpm than 180 wpm (see Figure 1.) Alternatively, less proficient readers may attend less to the captions, relative to the video image, than more proficient readers. Future research could investigate this by tracking eye movements (as in Jensema et al., 2000) or by including a control condition in which captions are presented on a blank screen.

In conclusion, the results of this study show that children’s television programmes captioned at 120 wpm will be understood better by deaf children than programmes captioned at 180 wpm. Additionally, the finding that there is no added benefit of slowing captions to 90 wpm suggests that future studies with this age group can safely use 120 wpm as the slowest speed. Future research should seek to pinpoint the optimal caption rate between 120 and 180 wpm, but in the meantime we recommend that the caption rate of children’s television programmes be limited to 120 wpm, in line with the Deafness Forum of Australia’s (2004) recommendations. This will provide the best opportunity for deaf children whose first language is a sign language to access information in captioned television programmes.

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APPENDIX

Example Short-Answer Questions

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<tr>
<th>Documentary</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Quolls</td>
<td>What are quolls sometimes called?</td>
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<tr>
<td></td>
<td>How do they find food?</td>
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<tr>
<td>Sea Dragons</td>
<td>How many eggs can a sea dragon lay at a time?</td>
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<tr>
<td></td>
<td>About how big is a full-grown sea dragon?</td>
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<tr>
<td>Fur Seals</td>
<td>What are things fur seals usually eat?</td>
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<td>What is a breeding place of seals called?</td>
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