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The slower the better? Does the speaker's speech rate influence children's performance on a language comprehension test?

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Abstract

The aim of this study was to examine the effects of speech rate on children's performance on a widely used language comprehension test, the Test for Reception of Grammar, version 2 (TROG-2), and to explore how test performance interacts with task difficulty and with the child's working memory capacity. Participants were 102 typically developing Swedish-speaking children randomly assigned to one of the three conditions; the TROG-2 sentences spoken by a speech-language pathologist with slow, normal or fast speech rate. Results showed that the fast speech rate had a negative effect on the TROG-2 scores and that slow rate was more beneficial in general. However, for more difficult tasks the beneficial effect of slow speech was only pronounced for children with better scores on a working memory task. Our interpretation is that slow speech is particularly helpful when children do not yet fully master a task but are just about to grasp it. Our results emphasise the necessity of careful considerations of the role dynamic aspects of examiner's speech might play in test administration and favour digitalised procedures in standardised language comprehension assessment.

Introduction

Language comprehension tests seldom include specific instructions to examiners about dynamic aspects of test administration, such as speech rate, pausing, stress and intonation. Consequently these aspects probably vary in test administration, which in turn constitutes a motive for exploring what impact such variations have for the performance on language comprehension tests.

The current study specifically examines the impact of the examiner's *speech rate* on preschool children's scores in one of the most widely used language comprehension tests, the Test for Reception of Grammar, version 2 (TROG-2) (Bishop, 2003). The study also addresses the interaction between the examiner's speech rate, children's working memory capacity and the degree of difficulty of the tasks in TROG-2 – an interaction of which there is limited knowledge.

The language comprehension targeted by TROG-2 is *temporally unconstrained* in the sense that the response to a test item is given *after* an entire sentence has been processed, and exploits the outcomes from all levels of sentence processing, including auditory, syntactic and semantic processing. Temporally unconstrained linguistic processing in this sense is sometimes called *off-line processing* (Love, Walenski, & Swinney, 2009) or *off-line (conventional) comprehension* (Montgomery, 2004) in contrast to *on-line processing* (Love et al., 2009) or *immediate (real-time) processing*, which can be measured by techniques such as cross-modal priming (McKee, Nicol, & McDaniel, 1993; Roberts, Marinis, Felser, & Clahsen, 2007). Studies have shown that a *slower speech rate* can have quite different effects on off-line versus on-line comprehension (Love et al., 2009; Montgomery, 2004). TROG-2 requires off-line processing and comprehension, which is why our literature review focuses on studies that, just like our own, address off-line processing and comprehension.

Fast speech has recurrently been shown to disrupt (Hayiou-Thomas, Bishop, & Plunkett, 2004; McCroskey & Thomson, 1973; McNutt & Chi-Yen, 1980) and slow speech to facilitate off-line language comprehension (Love et al., 2009; McCroskey & Thompson, 1973; Montgomery, 2004). These effects have been shown for both children with typical language development (TLD) and for children with language impairment (LI).

Related Research

Montgomery (2004) addressed how speech rate and phonological working memory capacity (which is a different working memory measure than the one used in our study) interacted to affect language comprehension in three different groups: 12 children with LI, aged 6;4 to 10;5; 12 children with TLD, who were matched according to age; and a group of 12 children with TLD aged 6;3 to 7;10, matched with respect to syntactic comprehension. The phonological working memory capacity, as measured in a nonword repetition test, was lower in the children with LI. The language comprehension tasks were of the same kind as those used in TROG-2, and two speech rates were included: *normal speech* at about 4.4 syllables/second (Ellis Weismer & Hesketh, 1996)[1] and *slow speech*, that was 25% time expanded, using a custom speech manipulation program. When normal speech rate was used, the group of children with LI – and lower phonological working memory capacity – performed significantly worse than the other two groups of children. When the speech rate was reduced by 25%, there were no effects on comprehension in the two control groups, but for children with LI comprehension was significantly improved and aligned with the results of the syntactically matched control group. Montgomery (2004) concluded that whereas slower speech does not have any effect on typically developing children, it can facilitate

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[1] A caveat when comparing results of different studies is that studies vary in how speech stimuli are constructed and how to define normal/regular, fast and slow rate.

comprehension in children with LI and their lower phonological working memory capacity is not an obstacle for this.

Hayiou-Thomas et al. (2004) studied a grammaticality judgment task for 120 6- to 7-year-old children with TLD. At normal speech rate all children achieved near-perfect performance. For fast speech rate – with the speech signal compressed to 50% of its original rate – the children displayed the same pattern of errors that is reported in children with LI: good performance on noun morphology (plural -s) and very poor performance on verb morphology (past tense -ed and third person singular -s). The authors argue that a faster speech is a way to simulate reduced processing speed – a characteristic of children with LI (Kail, 1994).

Love et al. (2009) studied how 43 children with TLD aged 5-13 were affected by a slow speech rate in two kinds of tasks. Tasks of the first kind were temporally unconstrained tasks, similar to those used in TROG-2, requiring the children to respond only after the complete sentence had been processed. Tasks of the second kind were temporally constrained cross-modal picture priming tasks. The two kinds of tasks varied similarly in linguistic constructions: pronouns vs. reflexives. The normal speech rate consisted of recorded natural speech with a mean of 5.0 syllables/second, which for the slow speech was digitally slowed to 2/3 of the normal rate, with a mean of 3.4 syllables per second. The study found that on-line and off-line comprehension were differently affected by slowed speech. In brief, slow speech hampered on-line comprehension but facilitated off-line comprehension. The authors concluded that aspects of language processing, which are well mastered and more or less automatized seem likely to be hampered by slow speech. On the one hand, automatized processes are possibly optimized for regular speech rate and break down if the rate is outside this normal speech rate (Love et al., 2009). On the other hand, for off-line comprehension, and in particular for aspects of language processing that a child does not fully master, but is struggling with, slower speech appears to improve processing and comprehension. This seemed to be the case for the participating children in the study when exposed to more complex grammatical structures (Love et al., 2009).

Task Difficulty

Similarly to the study by Love et al. (2009), the current study involves sentences of varying difficulty, which we investigated in relation to language comprehension and speech rate. A varying difficulty is built into TROG-2 in the following sense. The test consists of 20 blocks with four items in each, where each block assesses a specific grammatical construction. In the construction of the British version of the test, the degree of difficulty of the blocks was analysed and designed so that the degree of difficulty increases with each block. The degree of difficulty across the blocks is dependent on different factors: the grammatical construction involved, sentence length, semantic content, and presumably also the relationship between the distracters and the target picture. Swedish data have showed that this order does not strictly correspond to increasing degrees of difficulty for Swedish children. In particular, block L with zero anaphora constructions such as “the book lies on the scarf and is blue” and block O, with “neither-nor-constructions” such as “the girl does neither point nor run” – are more difficult than the subsequent blocks (Bishop, 2009). We take this into account in our analyses.

Working Memory Capacity

Language comprehension is intimately related to working memory (WM) capacity (Hansson, Forsberg, Löfqvist, Mäki-Torkko, & Sahlén, 2004; Sahlén, Reuterskiöld-Wagner, Nettelbladt, & Radeborg, 1999) which is another variable that we focus on in this study. The study is based on one of several current theories, namely Just and Carpenter’s (1992) Capacity Theory of Comprehension. According to this model, WM is responsible for the simultaneous processing and storing of information over a short period of time. An individual's WM capacity corresponds to the maximum set of resources that are accessible to support storage and processing of information. Since information storage and information processing share the same resources, the allocation of resources between functions may differ according to the character of a task. For instance, when dealing with a complex piece of information, more resources are allocated to processing and, as a consequence, less resources are available for storage. WM capacity differs between individuals which, according to Just and Carpenter (1992), is why individuals differ in speed and accuracy with which they can process and understand language. For instance, individuals with a more limited WM capacity can have difficulties with the processing of complex and/or long sentences (Bishop, 1997).

Aims and Hypotheses

The present study aimed to examine the effects that speech rate has on preschool children's score on TROG-2, and how speech rate and TROG-2 scores interact with task difficulty and children's WM capacity. The study was guided by the following questions and hypotheses.

1. *How does speech rate influence the scores on TROG-2 in preschool children?* Our expectations were that fast speech would reduce comprehension and result in lower scores, whereas slow speech would facilitate comprehension and result in higher scores.

2. *What role does task difficult have in relation to the effects of speech rate on the scores on TROG-2 in preschool children?* We expected that the slow speech would be particularly facilitating for the more difficult tasks in the test.

3. *What role does WM capacity play in relation to the effects of speech rate on preschool children's scores on TROG-2?* We expected that there would be a difference between children with lower WM capacity and higher WM capacity.

Method

Participants

Fifty-one girls and 51 boys in an age range from 5;0 to 6;1, all typically developing and attending different preschools in southern Sweden (Malmö) participated in the study. Two children who had contact with speech-language pathologists (SLPs), two children with attention problems, one child with severe stuttering and six multilingual children with Swedish as second language were excluded prior to the study. The remaining 102 children all used Swedish at school, and had, according to their parents and teachers, normal hearing.

Instruments

The participants' WM capacity was assessed with *Sentence Completion and Recall, SCR* (Towse, Hitch, & Hutton, 1998; Swedish translation by Andersson & Göransson, 2005). SCR is a task with a processing part and a recall part. Each test item consists of pairs of short sentences where the child is asked to fill in the last word in the second sentence of the pair (e.g., Cucumbers are green. Tomatoes are … [red]). There are six blocks, each with three levels corresponding to two, three and four sentences to complete. After each block the child is asked to repeat the words s/he filled in.

TROG-2, *the Test for Reception of Grammar, version 2,* was originally constructed by Bishop (2003) and has been translated into Swedish, with Swedish norms (Bishop, 2009). The test consists of 80 items, grouped into 20 blocks with four items in each block. Each block targets a specific grammatical construction. For each item a sentence is read aloud to the child and four pictures are shown, one of which corresponds to the content of the sentence. The three pictures that do not correspond to the sentence are either lexical or grammatical distracters.

For the current study, a digital version of TROG-2 in Swedish was created at the Department of Logopedics, Phoniatrics and Audiology at Lund University with permission from Pearson Publishers and on the basis of the English digital version of TROG-2 (which uses identical sentences and visual materials as in the printed version). An experienced female speech-language pathologist read the 80 sentences at her habitual speech rate, corresponding to 4.2 syllables per second. From this recording, two other versions of the sentences were created: *a slow speech rate version* with 160% of the duration compared to the original sound files and *a fast speech rate version* with 60% of the duration compared to the original sound files. The sound files were altered using linear interpolation in Praat (Boersma & Weenink, 2012). A criterion for the choices was that the speech, in terms of the speech rate, would still correspond to speech that one may encounter in real life and not sound unnatural. This evaluation was made by the authors, whereof two are speech-language pathologists. Furthermore, all actions in the program were logged and time-tagged, providing an exact time for when a sentence being read starts and finishes, when a picture is clicked, whether and when a child changes her choice of picture, etc.

Procedure

The children were randomly assigned to one of the three speech rate conditions: slow, normal or fast speech rate. Twenty-eight children received the slow rate, 35 the normal and 39 the fast speech rate. The distribution is uneven because at each preschool the first child was tested at the fast rate, the second with the normal rate and the third with the slow rate etc. If the number of children tested at the preschool was not divisible by three, more children were administered the fast and possibly the normal rate conditions. The children were tested individually in a room at their preschool, together with one of three examiners. For some of the shyer children, their preschool teacher was also present in the room. When the SCR-test was completed, the TROG-2 test was started with test instructions including exercise examples, and the sound was adjusted to a volume that the individual child found comfortable. Children unfamiliar with using a computer mouse pointed directly at the screen and the test leader, seated beside the child, simultaneously clicked the computer mouse. The children were allowed to make self-corrections, and in this case the second picture choice counted as their response. A session lasted approximately 25-40 minutes.

The present work follows the code of ethics of the World Medical Association (Declaration of Helsinki). The children's parents were informed through the school about the purpose and design of the study. The children participated voluntarily and if their parents had given written consent. The data were collected for a master's thesis in logopedics (Amnell, Sandberg, & Tulin, 2011).

Results

All statistical analyses were performed with the statistical software R v. 2.15.0 (R Development Core Team, 2012).

TROG-2 Scores in Relation to Speech Rate

Table 1 shows the TROG-2 test scores (*items* and *blocks*) for the three speech rate conditions (*slow*, *normal*, and *fast*). The three speech rate conditions unveil standard deviations of the same magnitude both for item scores and block scores. Notably, the mean block scores for children in the normal and slow speech rate groups correspond to the norm mean for five year olds (the children's actual age), whereas the mean block score for children in the fast speech rate group corresponds to the norm mean for children aged 4;5-4;11.

[table 1 about here]

Figure 1 presents notched boxplots of the TROG-2 item and block scores plotted against speech rate, showing similar distributions for both item and block scores over the three speech rate conditions.

[figure 1 about here]

Table 1 and figure 1 both indicate that the fast speech rate condition may have a significant effect in comparison with the other two conditions, especially for item scores. A one-way ANOVA was conducted to compare the effect of speech rate (slow, normal, and fast) on the TROG-2 item and block scores. There was a statistically significant effect of speech rate on both item and block scores for the three speech rate conditions [item: $F(2,99) = 8.98$, $p < 0.001$; block: $F(2,99) = 6.26$, $p = 0.003$].

Post-hoc comparisons using the Tukey HSD test indicated that, for both TROG-2 item and block the mean score (cf. table 1) for the fast speech rate condition was significantly different than for the normal and slow speech rate conditions [item(fast-normal): $p = 0.009$; item(fast-slow): $p < 0.001$; block(fast-normal): $p = 0.017$; block(fast-slow): $p = 0.005$]. However, there was no significant difference between the slow and normal speech rate conditions [item(slow-normal): $p = 0.50$; block(slow-normal): $p = 0.85$]. Furthermore, figure 1 shows that for the slow speech condition, both the median and the maximum scores for items and blocks are higher compared to the other two conditions.

WM Capacity in Relation to Speech Rate

For children in all three groups, the working memory capacity (SCR) mean scores were around 50% correct with similar distributions [*slow*: $M = 9.07$; *normal*: $M = 8.83$; *fast*: $M = 8.74$], see table 2.

[table 2 about here]

A one-way ANOVA showed no significant difference on the SCR mean scores between the three speech rate groups.

TROG-2 Item and Block Choices in Relation to WM Capacity and Speech Rate

With working memory capacity and speech rate as predictors, the TROG-2 scores for both blocks and items were analysed using multilevel logistic regression through the *lme4* package (Bates, Maechler, & Bolker, 2012) in *R* (R Development Core Team, 2012), see table 3.

Multilevel logistic regression analysis enables an assessment of the basic non-aggregated binary data (correct vs. incorrect response on each item or block task) for each participant, i.e. evaluating item or block responses (being the lowest level of analysis) at a participant level. In this case a multilevel approach is able to separate random effects due to within-subject factors of the participants from fixed effects stemming from the model predictors: working memory capacity, speech rate, and item or block index (cf. models below). This provides a more sensitive analysis that can account for differences due to the individual item or block based data sets of each participant.

TROG-2 item and block responses (for each participant) were entered as criterion variables, working memory capacity as a continuous predictor, item and block number together with speech rate as ordinal predictors, and participants as grouping factor (controlling participant level analysis) resulting in two models – one for TROG-2 items and one for TROG-2 blocks, see models below.

Item ~ SCR + Speed + ItemNo + SCR × Speed + Speed × ItemNo + (1|participant)

Block ~ SCR + Speed + BlockNo + SCR × Speed + Speed × BlockNo + (1|participant)

Variable coding notes: Item or Block (response on each TROG-2 item or block task): [0 incorrect; 1 correct], SCR (working memory capacity score range for the Sentence Completion and Recall test): [0–14]; Speed (factorized speech rate levels): [1 slow; 2 normal; 3 fast], ItemNo or BlockNo (index for each TROG-2 task on item or block basis): [items 1–80; blocks 1–20]; (1|participant) (grouping factor for participants as controlling participant level analysis): [participant levels/groups 1–102]. Additional notes: (i) an increase in the order of TROG-2 item or block indexes (ItemNo or BlockNo) reflects an increased task difficulty in accordance with the construction of the TROG-2 test, (ii) the slow speech rate condition (Speed[*slow*]) was chosen as referent in order to specifically illustrate the contrast between the slow and fast speech rate. The other two contrasts are comparatively smaller and non-significant.

Prior to the analysis, the models were evaluated with age and gender as additional predictors. Neither age nor gender contributed significantly to the models. Also, the three-way interaction (SCR × Speed × ItemNo) was evaluated prior to the analysis and did not contribute to the model. It was furthermore assured that the model variables fulfilled the assumptions underlying regression prior to the analysis: (i) linearity between outcome and predictor variables by examining residuals against individual continuous predictors; (ii) heteroscedasticity by examining residuals against predicted values; (iii) clustering by examining residuals against participants; and (iv) normality of residuals.

[table 3 about here]

The multilevel logistic regression analysis reveals a significant positive correlation between WM capacity (SCR) and TROG-2 item and block scores (table: SCR), specifically, an increase in SCR score corresponds to an increase in both TROG-2 item and block score. There is a significant negative correlation between the fast speech rate condition and TROG-2 item score (table 3: TROG-2 Items: Speed[*fast*]) – the fast speech rate corresponds to lower TROG-2 item scores. This finding is not repeated for the TROG-2 block scores (table 3: TROG-2 Blocks: Speed[*fast*]).

Furthermore, there is a significant interaction effect of working memory capacity (SCR) and speech rate on the TROG-2 item responses as well as block responses (table 3: SCR × Speed[*fast*]). The significant interaction effect is present for the contrast between the slow and fast speech rate conditions, whereas the other two contrasts are non-significant. (Corresponding analyses with the normal speech rate as referent displayed no significant effects for the contrast between slow and fast speech rate conditions.)

[figure 2 about here]

The interaction plots in figure 2 illustrate and clarify the findings in table 3: (i) there is an increase in SCR scores correlating with an increase in TROG-2 item and block scores, (ii) the difference between the lowest and the highest TROG-2 item and block scores as well as the impact of the SCR score on the TROG-2 item and block score is considerably larger for the slow speech condition than for the two other speech rate conditions – the gradient of the line representing the slow speech condition is considerably steeper, (iii) the impact of the SCR score on the TROG-2 item and block score is considerably less pronounced for the fast speech condition than for the two other speech rate conditions, (iv) the difference in item and block scores between the three speech rate conditions is largest for high SCR-scores, and (v) the positive relation between increasing working memory capacity (SCR) and TROG-2 item and block scores is most prominent for the slow speech rate condition and least for the fast speech rate condition.

In conclusion, the findings above can be expressed as follows: the higher the SCR score the higher the impact of speech rate on scores on TROG-2. The slow speech condition is the most favourable for a high item and block score on TROG-2, but only for children with high scores on the working memory (SCR) test. For results on TROG-2 in the fast speech condition, the SCR scores do not have an effect.

TROG-2 Scores in Relation to Speech Rates and Task Difficulty

Table 3 shows that there is a significant negative correlation between the order of presentation and the number of correct answers for both items and blocks (ItemNo and BlockNo).The higher the item or block number, the fewer correct answers, which is in accordance with the increasing task difficulty of items and blocks, reflecting the underlying structure of the TROG-2 test.

[figure 3 about here]

In figure 3 this correlation between TROG-2 block scores and increasing block number is clearly illustrated. Recall that in the Swedish version of TROG-2, block L and O deviate from the order of continuous increasing task difficulty by being more difficult than the proximate blocks. Furthermore, the slow speech rate appears to be the most favourable condition for 11 of the 20 blocks (Speed[*slow*]: 11 blocks, Speed[*normal*]: 7 blocks, Speed[*fast*]: 0 blocks; block S and T excluded due to possible floor effects).

A closer inspection of figure 3 demonstrates that the differences between the three speech rate conditions tend to be more prominent in the latter half of the test (block K-T): (i) the slow speech rate is now significantly favourable (Speed[*slow*]: 7 blocks, Speed[*normal*]: 1 block, Speed[*fast*]: 0 blocks; block S and T excluded due to possible floor effects), (ii) the difference between the three speech rate conditions with regard to the block results increases with block number. One-way ANOVAs on participants' TROG-2 block scores over the three speech rate conditions for the first and second half of the blocks (blocks A-J and K-T) respectively demonstrate a significant difference among the speech rate conditions for the second half of the blocks [blocks K-T): $F(2,99) = 9.57$, $p < 0.001$] but not for the first half [blocks A-J]: $F(2,99) = 2.94$, $p = 0.058$]. Post-hoc comparisons for the second half of the blocks (block K-T) using the Tukey HSD test, while compensating for the floor effect on the last two blocks (excluding the data for block S and T), indicated that the mean score for the fast speech rate condition [fast: $M = 20.8$, $SD = 20.1$] was significantly different from the normal and slow speech rate conditions [normal: $M = 35.0$, $SD = 22.4$; slow: $M = 46.9$, $SD = 30.6$] with adjusted p-values of: fast-normal: $p = 0.035$; fast-slow: $p < 0.001$], and normal-slow: $p = 0.133$.

In other words, only in the second half of the test does a speech rate deviating from normal – faster or slower – result in scores that deviate considerably from the mean scores across all three groups. Thus, with increasing task difficulty the effects of fast and slow speech rate become more evident.

Discussion

In summary, the results of the study support several of our hypotheses. Fast speech rate did have a significantly negative effect on the TROG-2 scores. In contrast, slow speech rate was the most beneficial condition for reaching high TROG-2 scores. However, the study did not demonstrate significantly higher scores for the slow speech rate condition *as a whole.* Instead, in line with another of our hypotheses, slow speech was only beneficial for children with higher WM capacity. One of our hypotheses was related to the role of task difficulty of the test items. We predicted that slow speech would be particularly facilitating for the more difficult tasks in the test, which turned out to be true.

Regarding the significantly negative effect of *fast speech* on the TROG-2 item scores, it can be added that the results from children in this group were weak regardless of their WM-capacity. The finding that *slow speech* can facilitate children's comprehension is in line with several previous studies (Love et al., 2009; McCroskey & Thompson, 1973; Montgomery, 2004). It is also in line with findings from a different but related research tradition that explores effects of speech rate on children's comprehension of brief spoken prose passages as measured in terms of their recall of them. In two studies by Riding and Vincent (1980, 1981) 160 and 120 children, respectively, age 7-15 participated, and the percentage of recall was significantly higher for those who had listened to a brief prose passage in slow speech than for those who had listened to the passage in normal speech.

Again and importantly, our study did not support the notion that slower speech always facilitates comprehension. The correlation between the speech rate condition and TROG-2 outcome was considerably higher for children who scored higher than for those who scored lower on SCR, with the correlation being strongest for the slow speech rate condition. This indicates that the higher WM the greater the benefit from slow speech. The significant positive correlation between SCR and TROG-2 score indicates that children with lower SCR scores showed a weaker result on TROG-2 than children with higher SCR scores independent of the speech rate.

Regarding *task difficulty*, our study found that the effects of both fast and slow speech on the children's performance were significantly more pronounced for the more difficult TROG-2 tasks. The scores differed mostly and largely between fast and slow speech rate for blocks K-P and R. All of these involve complex sentences (both in terms of structure and length), which is probably why the slow speech rate facilitated comprehension and the fast speech rate hampered comprehension. One way to put this is that with increased task difficulty the speech rate seems to matter more. For simpler tasks in this study the speech rate had no significant impact, probably because most children had a stable comprehension of these grammatical structures. Conversely, for the four most difficult items in TROG-2, the mean item score was close to zero for all three groups, indicating that when the task/item is *too* difficult, as well, speech rate loses its relevance to comprehension. Our results suggest that when children are on their way to master a certain linguistic structure they may be helped by a slow speech rate (and, in TROG-2, manage more items within a block, even if not all). These results can be related to those of McCroskey and Thompson (1973), Ellis Weismer and Hesketh (1996), and Love et al. (2009), who all conclude that slow speech only has facilitating effects for language tasks that are to some extent difficult for a child (i.e. not well mastered). That is, using the wording of Hirsh-Pasek and Golinkoff (1996), slower speech facilitates comprehension for structures where children are still in a stage of "fragile comprehension", for which they need more cues than offered in the test.

Our result that slow speech facilitated comprehension for the children with higher WM capacity but not for the children with lower WM capacity may at first seem to contradict the results from Montgomery (2004). However, the two studies are different in some important regards. First, our study measures WM capacity whereas Montgomery's study measures phonological working memory capacity. We lack specific information about the general WM capacity for the individual children with LI in Montgomery's study that improve their result and not in the slow speech condition; notably, children with LI represent a heterogeneous population with respect to whether they demonstrate WM limitations (Archibald & Joanisse, 2009). Second, the comprehension tasks in Montgomery's study seem to have been easier than the tasks in our study. The group of children with TLD in Montgomery's study reached 94% correct responses already in the normal speech rate condition. Thus the fact that they did not improve their result in the slow speech rate condition may arise from the lack of a sufficiently difficult task – not yet mastered but possible to master –for any facilitating effect from slow speech to appear. In contrast, in our study (which only included children with TLD), there was plenty of room for potential improvement.

Our main interpretation of the current results is that "slower can indeed be better" – under the condition that the child does not have too low WM capacity and that the comprehension tasks are difficult, yet within reach for the child.

Methodological Discussion

It has been shown that the adult brain adapts to a particular speech rate after 10-20 sentences[2] (Adank & Devlin, 2010). Children may be more distracted by an atypical speech marker such as a very fast speech rate, due to more pronounced reliance on bottom-up processing than a cognitively and linguistically more advanced adult. Yet it is likely that the participants in our study adapted to the speech rate they were listening to. In turn, this means

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[2] At least for speech up until 30-35% compression.

that when a child in the fast speech group reached the more difficult part of the test, they were accommodated to the new tasks. However, since the test scores were significantly lower for the fast speech rate condition, there was obviously no complete habituation or adaptation in the sense that the speech rate did not matter.

Given our research question of exploring the role of speech rate for how well preschool children score on a language test such as TROG-2, together with a strive for ecological validity pertaining to the situation where a human examiner reads the sentences, it was also not an option to shift back and forth between speech rates within the test. From a purely methodological point of view, randomised speech rates for the test items and a sufficiently large group of participants could have provided an alternative design. But our focus is on the use of TROG-2 in practice, and therefore from a validity point of view we wanted to simulate SLPs, who generally use a fairly stable speech rate throughout a testing session with TROG-2, rather than shifting between speech rates. Furthermore, if one frequently shifts between speech rates, *all* speech rates become more difficult to process and thus comprehension is generally hampered (Adank & Devlin, 2010).

The speech in the slow and fast speech versions of TROG-2 was digitally compressed or expanded with all phonemes and pauses evenly effected, which is not the case when a person is asked to speak slower of faster. Also, the prosody is affected by the artificial manipulation. In natural speech prosody gives clues to the listener (Håkansson, 1998). Nevertheless, the results of the study show that both the median item score and the maximum item score on the TROG-2 test are higher for the slow, manipulated, speech than for the normal, non-manipulated, speech.

Implications

Our study involves typically developing children. However, findings on the influences of speech rate on comprehension are likely to have a bearing also for children with language comprehension difficulties. This is particularly important since TROG-2 is often used repeatedly over time to follow up on development with the same child and therefore possibly used by different examiners.

Assessment of language comprehension should of course be related to the purpose of the assessment. For SLPs the purpose is mostly twofold: to diagnose language impairment and to generate implications for therapy. To reach the first aim a standardised procedure must be used. However, this may strongly underestimate the child's capacity to reach a certain behaviour in less decontextualized settings than the standardised test setting. For the second purpose a dynamic assessment is needed. There is a risk that standardised and dynamic test administration are confused with each other. TROG-2 should be administered in a similar way by clinicians. Otherwise normative data lose instrumental reliability. Our study specifically showed that the result on TROG-2 can vary due to the examiner's speech rate. Children may under-perform if an examiner speaks fast. Conversely, some children can reach considerably higher scores on the test if the examiner speaks slowly, whereas others are not influenced by this. Children may also under-perform if an examiner speaks in a hoarse voice, as indicated in a parallel study to the present one (Lyberg-Åhlander et al., 2013). For some children these factors (or combinations of them, e.g., an examiner that both has a cold and speaks fast) can have a disproportionate impact.

Finally, we wish to propose three implications of the study results. First, we need more knowledge about the ways in which speech dynamics influence language comprehension in different groups of children, in order to design reliable diagnostic tools and be able to intervene in adequate ways. Second, since the dynamic aspects of speech, as indicated by our study, can influence the result on a diagnostic standardised language test such as TROG-2, performance on a conventionally administered language test should perhaps not be directly taken as an index of language knowledge or as an objective diagnostic result.

One possibility is to introduce instructions for dynamic speech aspects. However, some of these aspects can be hard to control even if they are accompanied with instructions. Third, we therefore advocate the use of a digital version of TROG-2. This would ensure that voice quality, speech rate, gesturing, etc. are controlled for. Consequently, an unexpectedly large improvement by a child could not be due to the examiner speaking somewhat slower than the former examiner, and vice versa, an unexpectedly weak test result by a child (compared to, say, the test result 1-2 years ago) could not be due to the examiner having a cold the second time. Another advantage of a digitalised version lies in ensuring that it is always one and the same voice that occurs at different test occasions, since it has been shown that whether one has heard a voice before or not has an effect on comprehension (Pisoni, 1993). However, an important question is whether and how the visual input from live presentation affects children’s responses. In parallel to spoken input, there is a risk that visual live input will differ between test occasions. For instance, some speech-language pathologists may be seated beside the child and others may be seated face-to-face with them. In order to ensure that the visual input accompanying speech is equivalent between test occasions, one possibility is to make use of a digital character. With a digital character and not a video of a living person, which would be an alternative, there is flexibility to create several versions with respect to ethnicity (and dialect for that matter). Given what is known about role modelling and group association there may be reasons for this in multicultural settings.

This study has shed light on several aspects of language comprehension test administration. It would be interesting to approach the processes behind different outcomes more thoroughly. In a forthcoming study the authors want to explore the reaction times to the instructions in TROG-2, that is to say how fast the choices of the pictures were made and also the number of self-corrections in different speech rate conditions.

Declaration of Interest

The authors report no conflict of interest. The authors alone are responsible for the content and writing of the paper.

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Table 1. Results on the Test for Reception of Grammar, version 2 (TROG-2) for the three speech rate conditions (slow, normal, and fast).

TROG-2 results	Speech rate	*n*	*Min*	*Max*	*M*	*SD*
TROG-2 item scores Test score range: 0-80	Slow	28	41	77	63.54	8.91
	Normal	35	36	73	60.86	9.13
	Fast	39	36	72	54.38	9.55
TROG-2 block scores Test score range: 0-20	Slow	28	3	19	10.61	4.56
	Normal	35	2	16	10.09	3.63
	Fast	39	2	14	7.62	3.30

Table 2. Results on working memory capacity as measured by the Sentence Completion and Recall test (SCR) for the three speech rate conditions.

SCR results	Speech rate	*n*	*Min*	*Max*	*M*	*SD*
SCR score	Slow	28	6	14	9.07	2.07
	Normal	35	5	13	8.83	2.36
	Fast	39	3	14	8.74	2.72

Table 3. Multilevel logistic regression analysis on the Test for Reception of Grammar, version 2 (TROG-2) item and block responses respectively (varying over participants) in relation to working memory capacity measured by the Sentence Completion and Recall test (SCR), speech rate (Speed), and task difficulty (ItemNo and BlockNo) as represented by the order of the items and blocks in the TROG-2 test. For the speech rate variable (Speed), slow speech rate (Speed[*slow*]) is the referent and the tables presents the contrast for Speed[*slow*] against Speed[*normal*] and Speed[*fast*].

Model	Variables	Estimate	Std. Error	z value	Pr(>|z|)	
TROG-2 Items	(*Intercept*)	3.432	0.200	17.15	< 2e-16	***
	SCR	0.238	0.067	3.56	0.0004	***
	Speed[*normal*]	0.053	0.267	0.20	0.8422	
	Speed[*fast*]	-0.606	0.250	-2.43	0.0153	*
	ItemNo	-0.043	0.003	-14.86	< 2e-16	***
	SCR × Speed[*normal*]	-0.128	0.084	-1.54	0.1248	
	SCR × Speed[*fast*]	-0.194	0.078	-2.48	0.0132	*
	Speed[*normal*] × ItemNo	-0.005	0.004	-1.34	0.1804	
	Speed[*fast*] × ItemNo	-0.002	0.004	-0.67	0.5002	
TROG-2 Blocks	(Intercept)	2.222	0.294	7.558	4.1e-14	***
	SCR	0.339	0.099	3.421	0.0006	***
	Speed[*normal*]	0.279	0.397	0.701	0.4832	
	Speed[*fast*]	-0.438	0.378	-1.160	0.2461	
	BlockNo	-0.200	0.020	-9.873	< 2e-16	***
	SCR × Speed[*normal*]	-0.188	0.125	-1.505	0.1324	
	SCR × Speed[*fast*]	-0.254	0.117	-2.170	0.0300	*
	Speed[*normal*] × BlockNo	-0.036	0.028	-1.282	0.2000	
	Speed[*fast*] × BlockNo	-0.039	0.028	-1.409	0.1589	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Figure captions

Figure 1. Notched boxplots of the Test for Reception of Grammar, version 2 (TROG-2) item and block scores for the three speech rate conditions.

Figure 2. Plots displaying the interaction effects of working memory capacity measured by the Sentence Completion and Recall test (SCR) and speech rate on the Test for Reception of Grammar, version 2 (TROG-2) item and block scores. (The SCR scores are centred with the SCR score mean set to 0 with increasing scores to the right and decreasing scores to the left.)

Figure 3. The percentage of the participants giving correct responses on the Test for Reception of Grammar, version 2 (TROG-2) for each block and each speech rate condition (slow, normal, and fast).