Speech recognition and dysarthria: a single subject study of two individuals with profound impairment of speech and motor control

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This study investigated the use of the speech recognition system Dragon Dictate as an augmentative method of computer access for two individuals with cerebral palsy, including severe motor dysfunction and dysarthria. Single subject design was used and measures of computer access system effectiveness and speech production were used before, during and after intervention. The users’ original switch access system was compared to a combination of their switch access system and speech recognition, by counting the number of correct entries. Adding speech recognition increased the number of correct entries by 40% for one of the participants. The other participant did not complete the intervention protocol. An independent judge rated speech production. No changes in speech were observed. Dragon Dictate is time-consuming to learn and demands a high level of motivation, but can be beneficial to a person who has profound dysarthria and great difficulties in accessing the computer.

Key words: cerebral palsy, computer access, dysarthria, measuring efficiency, speech recognition.

INTRODUCTION

Health can be viewed from two perspectives according to the WHO international classification of function, disability and health (17): body function and structure on one hand, and activity and participation on the other. In the last few years, there has been a shift of focus in both research and clinical practice to the latter perspective, since it is significant for a person’s quality of life.

Communication with other people is the most basic requirement for participating in social life. For some people, a technical aid can provide the best way to communicate with others, and can help them to reach a higher level of independence. Computer access is becoming increasingly important for participation in society. Although there are alternative access methods for people who have difficulties using the traditional keyboard and mouse, there are few experimental studies comparing the efficiency of alternative or augmentative means of computer access (3).

People with severe physical impairments (for example those with cerebral palsy) often have both motor disabilities and dysarthria. Reports of the frequency of dysarthria in cerebral palsy range from 31% to 88% (16). These individuals are usually able to access the computer with adapted devices and software. A common means of achieving this is to use one or more switches combined with scanning. A thorough assessment and individual adaptations are necessary in order to make this efficient for each individual user (1). These access systems are often tiring, and in many cases they are slow and restrictive (15).

In Sweden speech recognition is a comparably new method of computer access; it began to be widely used in the mid-1990s. Speech recognition has primarily been used with normal speech as an alternative way of accessing the computer. The system most widely used is Dragon Dictate, which can replace all keyboard and mouse use. The system interprets the user’s speech through a microphone placed near the user’s mouth, and the speech production is compared to stored templates. Some templates in speech recognition systems are designed to adjust to the user (‘learn’ to interpret the user’s speech) during the introduction
phase. Some systems, including Dragon Dictate, also adjust continuously during everyday use (13).

Speech recognition is also used by people with physical disabilities, primarily spinal cord injuries and other similar impairments with unaffected speech, and has proven to be an efficient way of accessing the computer (11). Several studies have shown that speech recognition systems also can accept dysarthric speech (4–6, 10). The individuals in these studies had mild or relatively moderate dysarthria. These studies have focused more on how speech recognition handles dysarthric speech than how it can be applied in everyday activities.

A few studies have investigated how speech recognition can be used in practice as an aid for people with both dysarthria and other physical disabilities. Fried-Oken (7) introduced speech recognition for two people with motor disabilities, one with mild dysarthria and one with normal articulation but respirator dependent, which reduced his voice intensity. Both subjects gained increased motivation and independence. Lysyk and Smith (12) used Dragon Dictate with a subject who had spastic quadriplegia and moderate dysarthria. Only one study has used speech recognition with people with severe motor disabilities and profound dysarthria (15). This study used a speech recognition system that is not available in Sweden (the Voice Navigator recognition unit for Macintosh) in combination with scanning. This combination significantly increased the number of correct entries compared to scanning alone. Björklund-Wathén (2) used the Swedish version of Dragon Dictate with a subject who had cerebral palsy and moderate dysarthria, with good results. Another Swedish study (14) compared two speech recognition systems (Dragon Dictate and Infovox) used with two subjects with severe dysarthria. Both systems proved to be useful after a period of training, but no measurements of efficiency were made.

Some of these studies report an interesting and unexpected additional effect for dysarthric users of speech recognition: as well as becoming more able to access the computer by using the accumulating speech recognition system (where the system continuously adjusts to the user’s speech), their speech also improved overall. Fried-Oken (7) found that the person with dysarthria improved his articulatory precision and could thus use the speech recognition system as a therapeutic tool to improve speech intelligibility. Lysyk and Smith (12) reported an overall improvement of their patient’s speech intelligibility. The patient began using strategies such as pausing between words, swallowing before speaking and self-monitoring his speech, which seemed to be reinforced by the computer feedback he received. Björklund-Wathén (2) also reports the use of speech recognition as a therapeutic tool: the subject was more easily understood over the telephone according to people in his environment. The speech improvement mentioned above has not, however, been formally evaluated.

Dragon Dictate was the most widely used and least expensive speech recognition system available on the Swedish market. It was chosen for this study primarily because it was the only system that could give total hands-free computer access. Another advantage is that it continually adapts to the user, making it suited to the dysarthric speaker.

Individuals with severe motor disabilities may be anarthric or have profound dysarthria resulting in little or no functional speech (16). These individuals would not usually be the first to be considered as candidates for speech recognition. However, considering the difficulties that individuals with severe physical disabilities have in accessing their computers, any alternative means of access is well worth investigating. By improving effectiveness (both speed and accuracy) in writing with a computer, the user obtains several benefits. A change in input speed affects the possibility to perform a written school or work task in a reasonable time. And when the computer is used as a communication aid, speed is of vital importance for taking part in a conversation. However, it is very difficult to measure effectiveness in natural communicative situations. Among others, Treviranus (15) advocates further research in the field of multiple input methods. This study addressed the following questions: 1) Could an individual with a profound impairment of speech and motor control use the Swedish version of the speech recognition system Dragon Dictate; could the system interpret the speech at all? 2) Could speech recognition augment the existing switch-accessed writing system and improve the efficiency with which it is applied? 3) Could ‘non-speaking’ individuals develop their speech by regular use of speech recognition?

METHOD

Research Design

This study employed an experimental single subject design known as the ABA withdrawal design (9). First, a baseline of the target behaviours was established. The first main target behaviour was quantified as the net rate of input measured in correct entries during five minutes. The second target behaviour was speech production assessed by an independent judge. When a stable baseline (A) had been established, speech recognition was introduced. A period of training and using speech recognition (B) followed, with contin-
uous measurements of computer access efficiency and speech production. Finally, speech recognition was withdrawn for one month (A) and alternative access system efficiency and speech production were measured again.

**Participants**

The following inclusive criteria were set: 1) Very severe or profound impairment of speech and motor control. 2) An existing personally adapted computer-based writing system that the user perceived as slow, inefficient or fatiguing. 3) An alphabet-based writing aid (i.e., not based on communication with symbols or pictures). Two individuals were chosen to participate in the study.

**Participant 1.** Participant 1 was 12 years of age and had cerebral palsy with spastic quadriplegia, functional head movement and profound dysarthria. He had been ‘non-speaking’ for most of his life, but in the past year had started to use speech in communication with parents and significant others. He communicated with a Bliss chart with manual scanning combined with speech. His literacy skills were normal for his age. He used a computer, a head switch and the scanning software SAW (Switch Access to Windows) for text entry and other forms of computer access. His automatic scanning speed was 0.8 seconds.

Initial speech evaluation by the first author, using parts of a clinical dysarthria test procedure (8), showed that Participant 1 had a severe dysarthria with major difficulties in initiating voice. He spoke primarily with vowels with prosodic variations, which were distorted due to ataxia. If he was calm, he could articulate syllables with consonant and vowel (CV) fairly well. He had major problems with consonant clusters, but could sometimes produce a nasal consonant in combination with another consonant (e.g., ‘nd’). Plosives often caused involuntary voice breaks, with difficulty in initiating voice again: this sometimes resulted in pauses that could last for several seconds. His performance was highly fluctuating, influenced by his physical and mental state on a particular day, and also varied between successive trials.

**Participant 2.** Participant 2 was 22 years of age and had cerebral palsy with spastic quadriplegia, functional head movement, no speech and severe diabetes, which sometimes influenced his performance. He communicated with a Bliss chart and a light pointer attached to his eyeglasses. He also used facial expressions and voicing when communicating with parents and significant others, but had no functional speech. He used a computer, a head switch, the scanning software SAW (Switch Access to Windows) for text entry and a scanning Bliss program. His scanning speed was 2.0 seconds. He did not use letters for communication but could read simple words, and liked to copy texts for training. He had a moderate developmental delay but could carry out a practical task with perseverance.

Initial speech evaluation by the first author, using parts of a clinical dysarthria test procedure (8), showed that Participant 2 had no functional speech, but had relatively good control of voice initiation and could increase his voice intensity voluntarily. However, he had major difficulties with articulation and was practically unable to perform voluntary tongue movements. His speech motor control was very slow and he was often caught up in a pattern of perseveration when given a new speech task. He appeared to be unaware of the auditory feedback he got when he attempted to say the words. His speech consisted primarily of the vowels [a] and [e] and the semivowel [w] which sometimes varied to [m] or [b].

**Equipment**

The equipment used is presented in Appendix 1, and consisted of a computer with Windows 98; the Swedish word processor TalEdit; the access software Switch Access to Windows (SAW); the computer game Peters Par; the speech recognition system Dragon Dictate with the standard microphone and also the microphone Labtec C 315; the switches Buddy Button, Jelly Bean and Wobble Switch; the Swedish keyboard Bläckfisken with switch connections and a custom-made device for connecting switches to the computer game port; a standard VHS camera; a standard Polaroid camera.

**Intervention**

**Copying original computer adaptations.** Initially, visits to the participants’ schools were made and they were photographed and video-filmed as they were working with their writing systems. The software adaptations were copied to disc so that the work conditions were identical in the room where the study took place. This included identical software, work position and placing of switches and other adaptations.

**Measuring original access system efficiency.** The participants were given a text appropriate to their level of literacy. Participant 1 copied a crime story adjusted for young readers, while Participant 2 copied short phrases from simple poems including only short words. In order to measure the access system efficiency of the original system, the participants copied the text
using their screen keyboard software during a five-minute typing test. The number of correct entries was counted with deduction for uncorrected errors. This was documented on videotape to enable recalculation. Repeated measurements were made until a stable baseline (without any positive trend) was established. As the original access system efficiency was measured, frequently used and time-consuming functions were observed, e.g., 'space', 'backspace' and restarting scanning.

Measuring perceived performance and comfort. In order to get an idea of how the participants themselves experienced working with the different computer adaptations, they were asked to rate their perceived performance and comfort, from one to ten on two separate interval scales. Participant 1 spoke the number he had chosen and Participant 2 used his light pointer to indicate on the scale. This was repeated after every five-minute typing test.

Measuring speech production. The speech production measurement consisted of two parts: repetition after the first author’s model (single words and short sentences) and naming of pictures (single words which together contain all the Swedish phonemes). The naming task was individually adapted in that Participant 1 also named a few words with consonant clusters. All measurements were videotaped to enable recalculation.

Because the participants’ performances were highly fluctuating, every speech task was repeated three times in succession. An experienced speech and language pathologist later judged the best of these from the videotape recordings. Their performances were rated on a descriptive equal appearing scale from 1–5 where 1 = normal and 5 = severely deviant/cannot perform the task. The independent judge received written instructions on how to perform the ratings. In order to estimate intra-judge reliability, eight of the tasks were duplicated and thus rated twice.

As the testing material was relatively extensive and because there was limited time available at training sessions when the introduction and training of speech recognition had begun, a division of the tasks was made so that the participants performed repetition and naming on alternate sessions.

Training of speech recognition. The speech recognition program Dragon Dictate was introduced in a simple computer game (Peters Par) accessed by two switches. An initial choice of speech material was made from the speech evaluation and the participants’ own suggestions. The participant tried to say a selected word, which replaced one of the switches; hence he used a combination of switch access and speech recognition. When this worked, another word was introduced, which meant that the two-switch program was accessed by speech recognition alone. This procedure was then repeated for every new word. It also served as initial training for word pronunciation. When Dragon Dictate repeatedly misinterpreted a word, it was abandoned and another word was introduced. The functioning words were then transferred to the writing system, where they replaced frequently used and time-consuming functions previously accessed by SAW.

Measuring computer access efficiency when using speech recognition. After four to six sessions of training, the measurements of efficiency during a five-minute typing test were resumed. New words were tried continuously and were transferred to the writing system when they were considered reliable.

Measuring level of success in word recognition. After the introduction of speech recognition, the percentage of successful word recognition by Dragon Dictate (the number of correct recognitions over the total words spoken) during the five-minute typing test was counted.

Reliability. In order to test the test-retest reliability of measuring computer access system efficiency, the sessions were recorded on videotape and reanalysed on the first four occasions. The agreement was 100% for both participants.

An independent judge rated the speech production and received written instructions on how to perform the ratings. Eight of the tasks were duplicated in the videotapes and thus rated twice to secure intra-judge reliability. The mean point-by-point agreement was 83%, varying between 64% and 95%. In the other 17%, the difference was one or two scale values.

Dependent Measures

Computer access system efficiency. The efficiency was measured as the number of correct entries during a five minute typing test. Uncorrected errors were deducted from the result, corresponding to the number of entries necessary for correction.

Perceived performance and comfort by participant. The participants rated their perceived performance and comfort from one to ten on two separate scales after every five-minute typing test.

Level of success in speech recognition. The ratio of recognized items to the total number of spoken items was averaged over a five-minute test. This was noted as percentage of word recognition success.
At the end of every session, speech production was recorded on videotape and later rated by an experienced speech and language pathologist. Speech production consisted of two parts; repetition of single words and short sentences and naming of single words that contained all the Swedish phonemes.

RESULTS

Participant 1

Computer access system efficiency. Four baseline measurements of alternative access system efficiency (number of correct items during a five minute period) were performed before the introduction of speech recognition, and a stable level was achieved (Fig. 1).

A training phase of four sessions followed the baseline phase. No measurements were made during the training phase. The trained words were subsequently transferred to the writing system. The measurements commenced again (from session number five). During this period, Participant 1 had four or five functioning words. However, due to the participant’s lack of motivation and some practical problems, only two additional measurements were carried out. Since it was not possible to continue the original study design, a decision was made to continue speech recognition to access computer mouse functions. As was expected, this momentarily increased the participant’s motivation, and the previously used words were used in this context and four new words were introduced one by one. This worked to the extent that he was able to play the game using speech recognition only. With this, the study was terminated for Participant 1.

Level of success in speech recognition. The number of successful trials using speech recognition was counted during the five minute typing test. At the first session, Participant 1 succeeded in 66% of the trials and at the second in 100%.

Perceived performance and comfort by participant. The participant rated his perceived performance and user comfort from one to ten on a scale, and varied between eight and ten. There was no relationship between this and the measured input rate or the level of success in using speech recognition.

Speech. The two baseline sessions, including two different measures, did not indicate any trend in speech improvement. This was also the case also during his work with speech recognition. His participation was poor on several occasions, for example in session number six, when his mean performance was markedly lower than in the other sessions (Fig. 2).

Participant 2

Computer access system efficiency. Five baseline measurements of alternative access system effectiveness were performed before the introduction of speech recognition, and a stable level was achieved (Fig. 3).

Dragon Dictate was introduced during a training phase, and testing was resumed after this. At this point, Participant 2 had two functioning words (session 6). After this he had a hand operation, which caused a break and then influenced his performance on the two following sessions when his arm was in plaster and he seemed to be in pain (session 7 and 8). For five to six weeks he attended his treatment sessions regularly, sometimes twice a week, which improved his performance. At session 13 he produced 17 entries.

Speech recognition and dysarthria

Fig. 2. Participant 1: Speech rating during baseline, intervention and withdrawal. The circles represent the repetition task and the triangles represent the naming task.
 during five minutes. At session 14 and 15 technical problems made it necessary to restore the speech recognition system to a back-up profile saved two weeks earlier. This led to lower performance. After withdrawal for one month, his input rate without speech recognition was 12. The mean number of entries was averaged over the baseline phase and the intervention phase respectively and the means were compared. During baseline, the mean number of entries was 9.4, and during the intervention phase it was 13.7. The number of entries therefore increased by 46% when using speech recognition. When adding the result from the withdrawal phase to the baseline, the mean number of entries was 9.8 using the original access system. The rate of input when using Dragon Dictate was 40% higher.

**Level of success in speech recognition.** The number of successful trials using speech recognition varied between 75% and 100%, with a gradual increase over time. The mean value was 91%.

**Perceived performance and comfort by participant.** Participant 2 rated his perceived performance and comfort on a scale from one to ten and always rated it ten.

**Speech.** This participant’s three baseline sessions, including two different measures, did not indicate any trend in speech change either. This was also the case during and after his work with speech recognition. His performance was fluctuating (Fig. 4).

**DISCUSSION**

Participant 2, who was at first considered to have too poor speech to be able to participate in the study, did best out of our two participants. This was thought to be due primarily to his high motivation, which was consistent even when his general health condition was poor. Even though he had practically no functional speech, he was able to increase his computer access system efficiency by 40% compared to his original scanning system. This is in concordance with the findings of Treviranus (15), who described a significant increase in input rate with a combination of speech recognition and scanning for individuals with profound dysarthria, and Lariviere et al (11), who found an average increase of 20% in the subject’s input rate. However, no change in Participant 2’s speech was observed. This was possibly due to the relatively short period of use of speech recognition, and the fact that the period was also interrupted by hand surgery and the following convalescence.

Of the speech recognition systems that were available on the Swedish market during the time of the study, Dragon Dictate was the most widely used and the least expensive. It continually adapts to the user and is therefore a good choice for the dysarthric speaker. Hence, it was considered important to investigate its potential more closely. A disadvantage of Dragon Dictate was problems with the microphone. One of the participants had difficulties with microphone positioning and it became necessary to change to another microphone. This change of microphone caused problems with the speech recognition since different microphones have different sensitivity.

The fact that Dragon Dictate is a very comprehensive system can also be seen as a disadvantage. It can manage all types of computer access, such as dictation, mouse functions, etc. If one only uses a few of these, the system is oversized. It is possible to remove
Participant 2 proved to be the more successful at using speech recognition. A contributing factor is probably that he was a calmer person and he was not as easily excited or irritated as Participant 1, and so his speech was more consistent.

In his copying tasks, Participant 2 was careful about writing every word himself and did not want to use the word prediction function available in the system. When asked about this he confirmed that he considered it an important task to write the whole word himself, and that using the word prediction would be an ‘easy way out’. A possible explanation to this is that he is not using writing as functional communication but as a specific task to copy a text as accurately as possible. Another explanation might be that his level of literacy is not high enough to enable him to understand the function.

Participant 2 had three functioning words and though repeated attempts were made at introducing new words, this always turned out to decrease the stability of the system. His articulation was improved when he increased the semantic and contextual impact, such as nodding when he said the Swedish word for ‘yes’. We interpret this as an expression of his lack of experience when it comes to using speech or voicing in a structured way, and a lack of phonological awareness. As it turned out, he was the one with the best results, which we believe was due to his very positive attitude and stamina.

Despite the fact that there were only two subjects, our conclusion is that the user's motivation is probably the most important factor when deciding who should be a candidate for speech recognition.

Participant 2 repeatedly expressed his satisfaction at being able to use his speech. He also had a slower writing system from the start, so even a moderate increase of the input rate would make a fairly big difference when measuring access efficiency. His system was not as extensive from the beginning, and speech recognition could give him access to new functions in the future.

Single subject design proved to work well for this type of study. It gave a good overview of computer access effectiveness and speech before, during and after the use of speech recognition. Unfortunately, Participant 2 had only one measurement of input rate during the withdrawal phase due to the unexpected delays resulting from his hand operation. The original intention was to make at least three measurements, but the time limits for the study did not permit further extension. This lack of flexibility was a clear disadvantage.

More time and more integration into the everyday activities of the participants would have been desirable. The present study design meant that any slight change of the participants' routines caused problems...
with attending the training sessions as planned. Continuity in training and using speech recognition is important. When Participant 2 could not attend the treatment sessions regularly, this immediately influenced his performance. For a period he was able to attend the treatment sessions twice a week, which had a positive effect on speech recognition and his ability to remember the strategy. For a future study in this field, we believe that training sessions about two or three times per week would be better in order to see a positive result more quickly. It would also be interesting to assess severely dysarthric speech over a longer period of continuous use of speech recognition in order to document any speech improvement.

The participants’ own ratings of their performance were generally very high and did not vary with the measured input rate. On some occasions, Participant 1 seemed unhappy with the level of successful speech recognition, but afterwards he rated his performance as highly as usual. We interpret this as a sign that in general the participants have been content with using speech recognition, but that the scales have not served as an efficient instrument in showing changes in the user’s perceived performance or user comfort. We believe this can be associated with the participants being unused to rating themselves.

The method of introducing new words in a simple computer game and then transferring these to the writing system worked well. The participants had no problems in understanding that the same word had different functions in different activities. In view of the experimental design of this study, the results are not directly transferable to the participants’ everyday setting, for example school. Factors such as background noise, the staff’s knowledge of speech recognition and how well the system is adapted to the tasks required, may affect the system’s usefulness in the everyday setting. However, the observation that the participants could cope with the same word being connected to different functions in different settings implies a potential for extended use in the future.

A limited number of words could be used to increase a person’s independence in accessing the computer. For example, two to five words could be used for augmenting and increasing efficiency in the present writing system, accessing the Internet, e-mail functions or computer games. Participant 2 could use speech recognition to access his Bliss system more efficiently. People with severe dysarthria could therefore access several different systems by using speech recognition with a limited number of words.

New speech recognition systems using different methods that are developed may prove to work better for people with severe dysarthria. Future comparisons between these systems are important for potential users. In these cases, more work should be done with everyday use.

In the home, environmental control is an important tool for increasing independence. For people with severe motor handicaps, including severe dysarthria, it can be difficult to find a good way to access this. It would be interesting to investigate whether speech recognition could be a useful access method.

ACKNOWLEDGEMENTS

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REFERENCES


APPENDIX 1

Equipment

Bläckfisken, manufactured by Östra Hargs Data & Elektronik, Östra Harg, Torpången, SE-585 91 Linköping, Sweden.
Buddy Button, manufactured by Tash Inc., 3512 Mayland Ct., Richmond VA 23233, USA.
Dragon Dictate, manufactured by DragonSystems Inc., 320 Nevada Street, Newton, MA 02160, USA.
Peters Par, manufactured by LäraMera Program AB, Paradisgatan 1, SE-223 50 Lund, Sweden.
SAW, developed by ACE Centre, available free of charge on the Internet and by SIH Läromedel, Nygatan 18-20, SE-903 27 Umeå, Sweden.
Wobble Switch, manufactured by Prentke Romich Company, 1022 Heyl Road, Wooster, OH 4491, USA.
## APPENDIX 2

### Speech material

#### Naming:

<p>| | | |</p>
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<thead>
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<tr>
<td>A1</td>
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<td>/ɑː:pa/</td>
</tr>
<tr>
<td>A2</td>
<td>bil (car)</td>
<td>/biːl/</td>
</tr>
<tr>
<td>A3</td>
<td>kaka (cookie)</td>
<td>/kəːka/</td>
</tr>
<tr>
<td>A4</td>
<td>damma (dust)</td>
<td>/dɑːma/</td>
</tr>
<tr>
<td>A5</td>
<td>tåg (train)</td>
<td>/toːɡ/</td>
</tr>
<tr>
<td>A6</td>
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<td>/moːla/</td>
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<td>får (sheep)</td>
<td>/foːr/</td>
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</tr>
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<td>bok (book)</td>
<td>/buːk/</td>
</tr>
<tr>
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</tr>
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<td>A21</td>
<td>duscha (shower)</td>
<td>/dʊʃɑː/</td>
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#### Repetition:

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<table>
<thead>
<tr>
<th></th>
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<tr>
<td>1</td>
<td>pappa (dad)</td>
<td>/papa/</td>
</tr>
<tr>
<td>2</td>
<td>målar (paints)</td>
<td>/moːlar/</td>
</tr>
<tr>
<td>3</td>
<td>bilen (the car)</td>
<td>/biːlɛn/</td>
</tr>
<tr>
<td>4</td>
<td>pappa målar bilen (dad paints the car)</td>
<td>/papa moːlar biːlɛn/</td>
</tr>
<tr>
<td>5</td>
<td>titta (watch)</td>
<td>/tɪtta/</td>
</tr>
<tr>
<td>6</td>
<td>på (on)</td>
<td>/poː/</td>
</tr>
<tr>
<td>7</td>
<td>TV (TV)</td>
<td>/teːvɔː/</td>
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<td>kakor (cookies)</td>
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<td>11</td>
<td>goda kakor (tasty cookies)</td>
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</tr>
</tbody>
</table>