A NEW EPG PROTOCOL FOR ASSESSING DDK ACCURACY SCORES IN CHILDREN: A DOWN'S SYNDROME STUDY

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ABSTRACT

Recent research has suggested that eliciting diadochokinetic (DDK) rate and accuracy in young children is difficult [1], with analysis being time-consuming. This paper details a new protocol for assessing DDK in young children or children with intellectual impairment (Down's syndrome) and a method for calculating accuracy scores automatically. Accuracy scores were calculated from auditory and electropalatographic analyses and found to correlate in some instances. The children with Down's syndrome presented with similar DDK rates to typically-developing children but reduced accuracy.

Keywords: Diadochokinesis, electropalatography, Down's syndrome, motor control.

1. INTRODUCTION

The assessment of oro-motor skills in children with speech disorders is essential in order for clinicians to make differential diagnoses and plan appropriate interventions. Measuring diadochokinetic (DDK) rate is one commonly used oro-motor assessment in the paediatric clinic. DDK is defined as the study of motor control assessed by performance in rapidly alternating movements [3]; in the case of oro-motor assessment this usually involves repetition of single syllables, /t t t/, or sequences of syllables, /p t k/, at maximum rate. In typical development, DDK rates increase with age [3] and slow DDK rates may be indicative of speech disorders [7]. Recent literature has focused on the power of DDK tasks as a tool for differentiating dysarthria and dyspraxia. Thoonen et al. [6] demonstrated that inaccuracy in sequencing syllables was indicative of dyspraxia whereas reduced DDK rates were indicative of dysarthria. This highlights the need for DDK assessments to incorporate accuracy measures alongside rate measures[6].

1.1. Assessing DDK

Cohen, Waters and Hewlett [1] highlight that assessing DDK in young children is a "methodological minefield", with most studies not clearly describing data collection procedures. They point out that children often need a demonstration of what is required for the task, resulting in the child trying to imitate the clinician. This is problematic since the clinician cannot standardise her DDK rate when demonstrating the task and the rate may be too fast for the child to imitate. Williams and Stackhouse [7] also point out that children approach the DDK task in different ways, with some children aiming for accuracy at a slower speed whereas other children may sacrifice accuracy in order to achieve a higher rate. Similar problems occur when attempting to measure DDK rates in children and adults with intellectual impairment. These people may have difficulty understanding the instructions usually given in DDK tasks and may be unable to count the number of repetitions for themselves.

Cohen et al. [1] recommend that DDK tasks always be audio recorded to allow accurate calculation of rate and analysis of errors. However, this in itself does not allow the clinician to identify silent groping or atypical articulations that may be indicative of dyspraxia. Calculating the rate and identifying errors is also time consuming. One way of identifying these types of errors is to use an instrumental technique such as electropalatography (EPG). From the EPG recordings, rate and accuracy can be calculated automatically (for consonants involving tongue-palate contact) enabling faster and more accurate assessment of DDK.

This study investigated DDK rate and accuracy in children with Down's syndrome (DS). Children with intellectual impairments are usually excluded from research into speech motor control disorders, resulting in them rarely receiving a diagnosis of a specific type of speech disorder, which in turn makes focused intervention difficult. Recent research by Kumin [4] shows that dyspraxia is rarely diagnosed in DS even though the majority of children with DS show signs of the disorder. Despite this, no previous studies have used objective, instrumental techniques to investigate oro-motor skills in DS.

1.2. AIMS

The principal aim of this study was to design a method of assessing DDK which would overcome the limitations of previous studies and be suitable for all children, including those with severe intellectual impairments. A secondary aim was to determine if a time-saving, automatic measure of accuracy from EPG was possible.

In order to be sure of eliciting the best accuracy from the children, an imitation task was devised which standardised the DDK rate in a pre-recorded prompt. To control for vowel environment all the prompts were recorded using a neutral vowel (schwa), and to eliminate the problem of requiring children with intellectual impairments to count their own repetitions or listen for the tester saying "stop", the number of repetitions in the prompt was fixed. Children were not required to repeat the syllables a set number of times since DDK rate was measured as syllables per second, regardless of the number of syllables. To elicit different rates, each DDK task was repeated up to six times, each time prompted at a faster rate. The children were not required to imitate the rate exactly.

2. METHOD

2.1. Participants

Preliminary data from 12 young people with DS aged 10.08 to 18.75 (mean=15.02, SD=2.68) and 4 typically-developing (TD) children aged 5.4 to 7.1 (mean= 6.17, SD=0.72) is presented. This represents a subset of data from a larger project investigating speech motor control and EPG therapy for children with DS. All of the children with DS presented with mild to severe speech disorders but none had a diagnosis of dyspraxia.

The children with DS had cognitive age equivalents ranging from 3.25 to 7.25 (mean=4.63, SD=0.86) and the TD children had cognitive ages ranging from 5.6 to 9.58 (mean=7.83, SD=1.71). It was not possible to match the TD children to the DS children by cognitive age exactly since EPG palates cannot be made for children under 5 years.

2.2. Prompts

DDK rates for the single syllable prompts were taken from Robbins and Klee [5] and rates for sequences were taken from Williams and Stackhouse [7].

Five repetitions of single syllables, /pə/, /tə/ and /kə/ and sequences /pə tə kə/ and /tə kə/ were recorded at six set rates by a native English speaker using a metronome. In order to give a gradation in difficulty, each stimulus was recorded at -3 to +2 standard deviations of the mean rates given in [5] and [7]. The rates of the prompts are given in table 1.

	Syllables per Second					
	-3SD	-2SD	-1SD	Mean	+1SD	+2SD
p	2.09	3.01	3.93	4.85	5.77	6.69
t	2.07	2.98	3.89	4.8	5.71	6.62
k	1.87	2.75	3.63	4.51	5.39	6.27
t k	1.32	2.09	2.86	3.63	4.4	5.17
p t k	2.45	2.9	3.35	3.8	4.25	4.7

Table 1: Prompt rates in syllables per second.

2.3. Procedure

EPG recordings were made using the WinEPG system and Articulate Assistant software. Participants were instructed to " listen to the computer saying some sounds and try to copy it, the first sound you are going to say is [pə], can you say that?". Each participant imitated each syllable accurately before continuing with the recording but some of the participants with DS required several attempts to produce /k/. All participants started with the slowest rate, if he or she was able to produce the syllables or sequence accurately then the next rate was attempted. If the participant was not accurate then he or she was given three attempts before the recording was discontinued. The whole procedure took 5 to 10 minutes.

In addition to the DDK tasks all participants completed the DEAP (Diagnostic Evaluation of Articulation and Phonology [2]). The phonology subtest of this assessment allows calculation of percentage consonants correct in single words covering all the phonemes of English.

2.4. Acoustic and Auditory Analyses

Acoustic analysis software was used to calculate the number of syllables per second produced by each participant for each syllable, or sequence of syllables, at each prompt rate. It did not matter how many syllables the participant produced but a minimum of three without pauses (e.g. for an in-breath) was used. Calculation of rate included all accurate or inaccurate syllables. The maximum rate for each syllable or sequence was then calculated for each participant.

Accuracy was calculated by transcribing each participant's first imitation of the target syllable or sequence and giving a score of one for a correct imitation and zero for an incorrect imitation [7]. Since each syllable/sequence had six prompt rates this gave a maximum score of six for each (or 30 for all syllables at all rates). If a child did not attempt a given rate due to inaccuracy at a slower rate (see 2.3) then he was given a score of zero for that rate. Scores were converted to percentages.

2.5. EPG Analysis: Accuracy

A set of accuracy scores for /t/, /k/, and /t k/ was separately derived from the EPG data alone. The process used has the potential to be fully automated but for the purpose of this paper it was carried out in a partially automated manner. The following procedure was used.

A measure of the degree of closure across the palate was derived for the first two rows (alveolar closure) and the last two rows (velar closure). These two analysis values were then thresholded to create labelled closure regions. The alveolar closure measure was thresholded at a level indicating there was complete closure across the palate. The velar closure measure was thresholded at a level that allowed for incomplete closure across the posterior two rows. This is because complete closure often occurs posterior to the border of the hard and soft palate (where the EPG palate ends). The preceding analysis and labelling was carried out automatically for the first attempt at each of the 6 rates. For most recordings this resulted in a mixture of alveolar and velar, labelled regions. For /t/ productions the ratio of the number of regions labelled alveolar to the total number of labelled regions (alveolar and velar) was recorded by hand as a percentage. Percentages were averaged across all six attempts. The absence of an attempt was scored as 0%. Similarly, for the /k/ task the ratio of the number of velar regions to the total number of regions was recorded as an average percentage. For the /t k/ task the number of transitions from /t/ to /k/ and from /k/ to /t/ were counted and the score was expressed as a percentage of the total number of possible transitions. To cope with cases where regions overlapped, the start time of each region was used to determine the sequence and the end point of each region was ignored. A composite score was derived from the average of the three DDK scores.

3. RESULTS AND DISCUSSION

3.1. Percentage Consonants Correct (PCC)

The DS group presented with PCC scores ranging from 18.18% to 80% (Mean=52.23, SD=25.58). Although the DEAP [2] is only standardised up to age 6;11 none of the children with DS achieved a ceiling score. Most (67%) of the DS group failed to meet the basal age equivalent (3.0 years) on the PCC, suggesting severe speech disorders. In contrast the TD scores ranged from 97.30% to 100% (Mean= 99.0, SD=1.29).

3.2. Rate

Table 2 shows the rate in syllables per second for both the DS and TD children.

	Rate in syllables per sec	
	DS	TD
p	5.78 (SD=0.98)	5.11 (SD=0.65)
t	5.78 (SD=0.98)	4.84 (SD=0.77)
k	5.30 (SD=0.88)	4.52 (SD=0.30)
t k	4.13 (SD=1.31)	4.94 (SD=1.46)
p t k	3.32 (SD=1.49)	3.99 (SD=1.24)

Table 2: Mean maximum rates in syllables per second.

At this preliminary stage it is not possible to determine whether the rates for the TD children and the DS children are statistically different. However, in many cases (/p/, /t/ and /k/) the DS group did in fact produce faster DDK rates than the TD group. This suggests that children with DS do not show reduced DDK rates in comparison to cognitive-matched peers. In addition, the rate measures did not correlate with PCC suggesting that DDK rate is not a good predictor of degree of speech disorder in DS.

3.3. Accuracy

Table 3 shows low accuracy for the DS group, with sequences being particularly problematic. This is consistent with Thoonen et al. [6] who suggest that low accuracy in sequencing may be indicative of dyspraxia. In contrast to the measures of rate, the composite auditory accuracy score correlated highly with PCC (r=.822; p=.001) as did the composite EPG accuracy score (r=.837; p=.001).

	TD % Accuracy: Auditory	DS % Accuracy: Auditory	DS % Accuracy: EPG	Corr: DS auditory & EPG
p	83.33 (SD=23.57)	47.22 (SD= 36.81)	/	/
t	95.83 (SD=8.33)	47.22 (SD= 28.28)	68.60 (SD=25.01)	r=.491; p=.105
k	95.83 (SD=8.33)	38.89 (SD=32.05)	58.20 (SD=30.20)	r=.553; p=.062
tk	83.33 (SD=13.61)	47.22 (SD=22.84)	19.93 (SD=19.83)	r=.907; p<.0005**
ptk	66.67 (SD=45.13)	1.39 (SD=4.81)	/	/
Comp	85.00 (SD=14.01)	29.17 (SD=20.80)	48.91 (SD=15.71)	r=.826; p=.001**

Table 3: Mean % accuracy scores for auditory and EPG analyses. **Correlation significant at the 0.01 level (two-tailed)

In order to determine whether accuracy as measured by EPG was reliable, these scores were correlated with the auditory accuracy measures for the DS group. Both the /t k/ and composite accuracy scores correlated well with the corresponding auditory assessment scores, suggesting that at least for these measures it is possible to calculate DDK accuracy automatically. However, there are two underlying weaknesses in the application of accuracy scores based purely on EPG data. Firstly, EPG cannot discriminate between alveolar consonants /t/ /d/ /n/ and in some cases /l/; nor can it discriminate between the velar consonants /k/, /g/ and /ŋ/. This may explain why the /t/ and /k/ accuracy scores did not correlate, since the auditory analyses assessed errors in voicing as incorrect. Secondly, the traditional ‘Reading’ style EPG palate does not always extend far enough back to register velar closure. This leads to errors in velar closure labelling that are based only on EPG patterns.

4. CONCLUSIONS

The protocol for assessing DDK detailed in this paper was a successful way of eliciting DDK rate and accuracy from young people who are usually unresponsive to traditional DDK tasks. Measuring DDK in this way has the potential to be useful in the clinic setting as clinicians can subjectively determine whether a child’s rate is likely to be within -3 to +2SDs of the rates reported in the literature for TD children [5 & 7]. Calculating accuracy using auditory analysis is time consuming but correlates well with degree of speech disorder as measured by percentage consonants correct. Automatic calculation of accuracy using EPG is possible but has some limitations (see 3.3), which may only be overcome by combining acoustic information with the EPG data.

Preliminary results suggest that contrary to the assertion of Williams and Stackhouse [7] that slow DDK rates are indicative of speech disorder, DDK rates are not reduced in people with DS but accuracy, especially of sequences, is greatly reduced. This is consistent with the view of Thoonen et al. [6]that the speech disorder evident in DS may be dyspraxia.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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