Table to Tablet (T2T): A Novel Intervention Framework for Children With Speech Sound Disorders

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This study is a randomised control trial. The first step was the creation of partnerships between the University of Aveiro and schools in the Aveiro region (Jesus, Martinez, Valente, & Costa, 2017). Teachers were asked to identify children that they thought had immature or poor speech. All identified children were then assessed (T1). Due to the fact that the project was only selecting children with SSD, most other children (with different diagnoses) were referred to external (to the project) SLPs. The children who fitted the inclusion criteria were then randomly allocated to one of two groups (tabletop or tablet) and were assessed again after a waiting period of 3 months (T2). After this second assessment, the children had intervention and were assessed at post-intervention (T3).

Participants

Twenty-two Portuguese children (four girls and eighteen boys) with phonologically-based SSD, with a mean age of 57 months were selected. This disproportionate number of males-females is a typical distribution (70-80% boys) in the Portuguese population, and has been reported in previous studies (Jesus, Lousada, Domingues, Hall, & Tomé, 2015). Children were assessed and diagnosed as having phonologically-based SSD after an extensive assessment by a Speech and Language Pathologist (SLP), an audiologist and a psychologist.

Participant inclusion criteria were:

- Age range from 3;6 to 6;6;

- European Portuguese as first and only language;

- No impairments on oro-motor structure and function (assessed with the Protocolo de Avaliação Oro Facial – PAOF (Guimarães, 1995);

- No symptoms of verbal dyspraxia;

- Age appropriate receptive language (assessed with the Teste de Linguagem ALPE – TL-ALPE (Mendes, Afonso, Lousada, & Andrade, 2014));

- Audition of 20 dB or lower in the frequencies 500, 1000, 2000 and 4000 Hz;

- Age appropriate non-verbal IQ assessed with the Wechsler Preschool and Primary Scale of Intelligence-Revised – WPPSI-R (Wechsler, 2003);

- Presenting at least two phonological processes at pre-intervention time (Crosbie, Holm, & Dodd, 2005; Dodd, Zhu, Crosbie, Holm, & Ozanne, 2002).

The children's phonological abilities were assessed by a SLP with a single-word naming (67 words) task (Mendes, Afonso, Lousada, & Andrade, 2013). All the children were also assessed for consistency of production. All participants scored below 40% in the Inconsistency Assessment of the Teste Fonético-Fonologico ALPE (Mendes et al., 2013), and were considered to be consistent (Dodd et al., 2002).

Ethical permission was obtained from an independent ethics committee (*Comissão de Ética da Unidade Investigação em Ciências da Saúde – Enfermagem da Escola Superior de Enfermagem de Coimbra*, Coimbra, Portugal) and informed consent was collected from all carers prior to any data collection. The study was also registered at ClinicalTrials.gov.

Intervention

In order to build an intervention that mirrored existing evidence-based and well defined speech and language therapy practice for working with children with SSD (Lousada,

Jesus, Hall, & Joffe, 2014; Lousada et al., 2013), tabletop and digital SSD intervention programes were developed which incorporated key target areas that have been shown to be effective. These included: (1) Auditory Bombardment (focusing on the target phoneme or phoneme combination) (Hodson & Paden, 1991); (2) Hearing and Discriminating (to incorporate sounds into the phonological system) (Lancaster, 2008); (3) Grapheme-phoneme correspondence (knowledge of phoneme-grapheme relationships) (Gillon & McNeill, 2007); (4) Phoneme identity (to identify phonemes in words) (Gillon & McNeill, 2007); (5) Segmentation (to analyse words at the phonemic level) (Gillon & McNeill, 2007); (6) Blending (to blend isolated sounds together to form words) (Gillon & McNeill, 2007); (7) Rhyme (to identify phonological similarities in spoken word pairs) (Gillon & McNeill, 2007); and, (8) Phoneme manipulation (to analyse and manipulate sounds) (Gillon & McNeill, 2007). The intervention was identical across the two delivery modes: Tabletop and tablet.

There are a total of eighteen different activities grouped by target area (mean number of activities per area of two). As a companion to the activities, homework in the form of a set of games and worksheets were specifically developed for the project. Regular homework is recommended for maximising progress (Gunther & Hautvast, 2010).

Parents/caregivers were invited to be present in therapy sessions either at their child's school or at the clinic, and short homework tasks were given at the end of each session to complete for the following session.

In the tabletop group the homework activities were work sheets focusing on the targeted phonological processes, and in the tablet group, homework was based on four different computerised games.

Each child allocated to the tablet group received a tablet with the games installed at the beginning of the intervention. In each session an information sheet about the game that should be played that week was given to the caregiver.

Furthermore, generalisation tasks for each phonological process were created. These tasks are included to allow SLPs to test if changes in a child's phonological system go beyond the treatment words and targets (Bowen, 2015).

The allocation to one of the interventions (with same content but different delivery method – tabletop or tablet) took place during the waiting period, after the selection process and before the pre-intervention assessment. Each child was given a number from 1 to 22 and randomly allocated to one of the two groups. The numbers were randomised using an online tool (True random integer sequence generator based on atmospheric noise data https://www.random.org/sequences/; RANDOM.ORG; Randomness and Integrity Services Ltd).

The phonologically based intervention consisted of a combination of phonological awareness activities (Lousada et al., 2013) adapted from Gillon and McNeill's (2007) phonological awareness programme, Hodson and Paden's (1991) auditory bombardment, and discrimination and listening tasks from Lancaster (2008).

The criteria taken into account to choose the target phonological processes were: Frequency – occurring at least at a 40% rate in the child's speech (Hodson & Paden, 1991); intelligibility (Dodd & Bradford, 2000; Lousada et al., 2014) – less than 2/3 (66%) of the utterances of a child can be understood by unfamiliar listeners (Gordon-Brannan & Hodson, 2000, p. 146); stimulability – including stimulable sounds (Dodd & Bradford, 2000); developmental – earlier acquiring sounds (Dodd & Bradford, 2000; Mendes et al., 2013).

Each session had a total of three activities, one from each of the eight target areas with the exception of the first two sessions, where the focus was on auditory bombardment, listening and discrimination (Gillon & McNeill, 2007), and some advice on tongue placement, using the materials developed by Pedro et al. (2018), to help elicit the target sound. The organisation of the activities per session was based on Lousada et al. (2013), with sessions divided into two blocks.

One group was treated with the tabletop materials and the other group with an app running on a tablet. The intervention approach was identical across both groups, the only difference being the method of presenting the materials (tabletop versus tablet - based). The tabletop materials consisted of printed cards, board games, stuffed animals, cardboard boxes, a large dice, fishing rods, and other similar materials used in therapy. In the tablet group all the activities were run in an eight inch screen ASUS MEMO Pad 8, with 1 GB of RAM and Android 4.4.2 KitKat (Jesus, Santos, & Martinez, 2018).

The intervention for both groups consisted of 12 weekly individual sessions of 45 minutes, across a three-month duration.

The intervention was divided into two six-session blocks with no breaks (there was an assessment between them and a change of focus – a different phonological process). A duration of six sessions is enough to significantly impact phonological skills, but a greater total intervention duration is needed to demonstrate an intensity effect (Allen, 2013). For each child, one phonological rule was chosen as an intervention target for each block. Both groups were treated by the same SLP trained in both methods. Parents/caregivers were invited to be present in therapy sessions either at their child's school or at the clinic, and short homework tasks were given at the end of each session to complete for the following session.

Targets

The activities included were based on a phonological therapy approach. The selection of words used in therapy was based on: Syllabic structure (CV, CVC or CCV) (Brooks & Kempe, 2014); number of syllables (one or two) (Flipsen, 2006); being age appropriate (Fenson et al., 1993); being easily illustrated; and being different from words used for assessment (Lousada et al., 2013; Mendes, Afonso, Lousada, & Andrade, 2013). Words used in therapy were those with which children had difficulty, a criteria used in previous research (Gillon, 2008), and included initial, medial and final word (where applicable) position of the target sound. A list of minimal pair words were selected for *Hearing and Discriminating* and *Phoneme Manipulation*. For the *Rhyme* activity, a list of monosyllabic rhyming words were identified. The criteria used to select these words were: They are all phonologically simple and high frequency, well known by most Portuguese children; two syllable (*Hearing and Discriminating* and *Phoneme Manipulation*) or one syllable (*Rhyme*) words that would rhyme and could be represented by an illustration. Nineteen short stories (one for each phonological process) that used at least twenty words with the target sound were also created, as used by Bowen (2015).

Each target word was illustrated by a professional designer resulting in more than 350 illustrations. A set of three background images was also created (by the same designer) for each short story.

Testing

Assessments of the children with SSD took place at three time points:

- T1 – Baseline and pre-randomisation;
- T2 – Pre-intervention and after a waiting period of 3 months;
- T3 – Post-intervention.

The baseline assessments (T1), pre and post-intervention assessments (T2 and T3), were carried out by the same SLP blind to the study's aims, children allocation and intervention.

In all the assessments (T1, T2 and T3), children's productions were recorded to allow a careful offline analysis (Lancaster, Keusch, Levin, Pring, & Martin, 2010). The recordings were made with a Behringer ECM8000 electret microphone, held by a table support at approximately 1 meter and aligned with the mouth of the children. The microphone was connected to an Olympus LS-100 multi-track linear PCM recorder. The data was recorded in mono format .wav (Windows PCM) without compression at a sample rate of 48000 Hz, with 16 bits per sample. The assessments were made in one of two places: University of Aveiro's Speech, Language and Hearing Laboratory (SLHlab) clinic or the child's school in a quiet room.

To ensure the accuracy of the annotation of the children's phonological abilities, their productions were transcribed phonetically based on perceptual and acoustic analysis using Praat Version 6.0.17. These transcriptions were annotated on two levels: The child's actual production, transcribed phonetically using the SAMPA (Wells, 1997) machine-readable phonetic alphabet; and the child's syllabic structure, using the code C for consonants, V for vowels and G for glides.

The Speech and Language Therapy assessments used were: University of Aveiro's Case History Form for Child Language (Jesus & Lousada, 2010); TFF-ALPE phonetic-phonological test (Mendes et al., 2013); TL-ALPE language test (Mendes et al., 2014); PAOF oro-motor abilities test (Guimarães, 1995); an adaptation to Portuguese of the Speech Participation and Activity of Children - SPAA-C children's questions (McLeod, 2003). Images from the Test of Childhood Stuttering (TOCS) (Gillam, Loga, &

Pearson, 2009) were used to engage the children in conversation and generate spontaneous speech (Limbrick, McCormack, & McLeod, 2013).

Children's transcribed productions were entered into the Automatic Phonological Analysis Tools (APAT) (Saraiva, Lousada, Hall, & Jesus, 2017) by a SLP blind to the study's aims and group allocation using SAMPA (Wells, 1997). The APAT is a valid and reliable tool (Saraiva et al., 2017) to analyse phonological parameters in an automatic way.

The baseline period occurred between the first assessment at baseline (T1) and the pre-intervention assessment (T2). This period was used to organise all the logistics, schedules and places to deliver therapy (clinic and schools). It was also used to assess the children's non-verbal IQ and hearing. The children did not receive any intervention in this time period. All the children waited three months (the same duration as the intervention) before treatment and therefore acted as their own control (Sadlier, Stephens, & Kennedy, 2008). This period allowed us to see the impact of natural maturation on the children's speech and to compare it to performance after intervention.

The mean PCC scores (Shriberg & McLeod, 1982) were used to compare performance of the two groups. The PCC index is one of the most commonly used indexes to quantify the severity of speech impairment in children with SSD during both evaluation and intervention (Wren, McLeod, White, Miller, & Roulstone, 2013). This quantitative measure is highly sensitive to differences in phonological deficits because it provides information pertaining to the two main error types: Omissions and substitutions (Shriberg, Austin, Lewis, McSweeny, et al., 1997; Shriberg, Austin, Lewis, & McSweeny, 1997).

Although there is evidence that only a small number of children have difficulties producing vowels, Watts (2004) recommends doing a more detailed analysis at this

level using the percentage of vowels correct (PVC) in addition to percentage of phonemes correct (PPC).

Generalisation

After each block of intervention, non-intervention words, which included the process targeted in intervention, were given as generalisation words, in order to assess generalisation to non-targeted words (Palle, Berntsson, Miniscalco, & Persson, 2012). The words were selected based on the phonological process trained. They were different from those used during intervention but targeted the same phonological processes and were a close match in terms of production difficulty, frequency in the Portuguese language and syllable structure.

Each child had five opportunities to produce the correct target. These words were used to determine if the child generalised the targeted speech skill and provide important insight into the impact of intervention on a child's phonological system (Baker & McLeod, 2004).

Reliability

The production of all isolated words of two randomly selected children from the three assessment periods (baseline, pre- and post-treatment) were annotated and transcribed by a trained SLP not involved in the study and blind to its aims. Point-to-point reliability was 95.52% (baseline assessment – T1), 94.74% (pre-treatment assessment – T2) and 96.46% (post-treatment assessment – T3). These values are comparable with those reported in other studies in disordered child phonology (Shriberg, Tomblin, & McSweeny, 1999; Shriberg & Lof, 1991) and were considered adequate for the objective of this study. Two children (for each assessment point) represents 9% of speech samples and this percentage is equivalent to what is reported when checking

reliability in other effectiveness studies (Crosbie et al., 2005; Dodd & Bradford, 2000; Lousada et al., 2014; Lousada, Jesus, Capelas, et al., 2013).

Data analysis / statistics

Non-parametric Wilcoxon and Mann-Whitney tests were used to compare data between groups and time periods and multi-comparisons corrections for type-one errors have been made using Bonferroni's correction for every pair of comparisons involving both tabletop and tablet groups. Effect sizes were calculated using Cohen's d with the bias correction given by Hedges's g for the independent samples case (Lakens, 2013). For the purpose of interpreting the effect sizes, the following commonly used benchmarks were used (Field, 2017): Small (d=0.2), medium (d= 0.5), and large (d=0.8). The statistical analysis was made using IBM SPSS Statistics version 22. The level of significance used was 0.05.

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