ULTRAX2020

Ultrasound Technology for Optimising the Treatment of Speech Disorders

Clinicians' Resource Manual

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Contents

Foreword

The Ultrax2020 project follows on from a 2011-2015 Engineering and Physical Sciences Research Council Healthcare Partnerships Project, Ultrax, which developed and tested approaches to enhance ultrasound images of the tongue for use as biofeedback tool in speech therapy. The overall aim of Ultrax2020 is to develop an automatic ultrasound based diagnostic assessment for identifying and categorising speech errors in children with speech sound disorders (SSDs). To achieve this aim we need a large ultrasound dataset of children SSDs. In partnership with three NHS boards across Scotland we plan to collect ultrasound data from over 100 children. This resource manual provides the rationale and instructions for doing so. It is not designed to be read in its entirety (though if you are a complete beginner you may find it useful to do so). A clickable contents page is included to help you find the information you require.

The technical challenge of developing an automatic ultrasound tool is difficult and time consuming, with the final product not due to be delivered until the end of the three year project (2020). Therefore, to optimise the benefit to the children taking part in the project, we will analyse the data you collect by hand, giving you new insights into the speech disorders of the children on your caseload. While this project focusses on assessment, we recognise that many of you will want to provide ultrasound visual biofeedback (U-VBF) therapy for the children on your caseload. This resource manual provides information on how to do so, but doing so is entirely at your discretion. If you do choose to provide U-VBF, then we would also like to receive post-intervention recordings to allow us to build the evidence base. The flowchart on the following page shows the key processes in the project.

If you have any questions about the project, please contact the researchers:

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If you have suggestions or questions about the SonoSpeech software, please contact Articulate Instruments:

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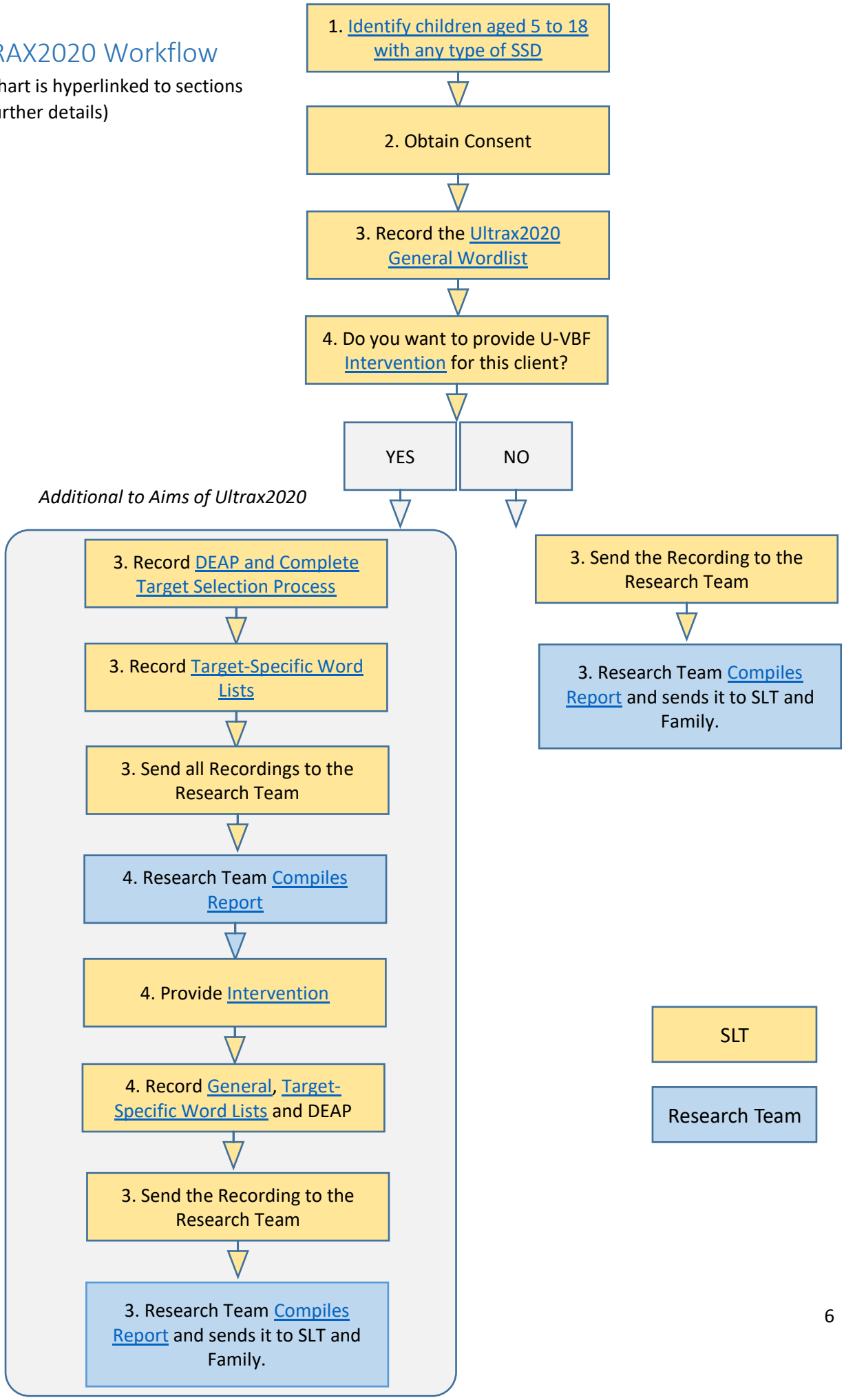
More information is also available on our website:
http://www.ultrax-speech.org/research/ultrax-2020

Or you can follow us on twitter: @UltraxSpeech

ULTRAX2020 Workflow

(This chart is hyperlinked to sections with further details)



Introduction to Ultrasound Visual Biofeedback

In phonetics there is a long tradition of using instrumental techniques to measure movement of the articulators directly. Techniques like x-ray and MRI (magnetic resonance imaging) give researchers data that can be used to create visual images of otherwise invisible articulators, especially the tongue. However, only a small number of imagining techniques allow data to be visualised in real-time in a way that is immediately meaningful to the viewer. These include electropalatography (EPG), Electromagnetic Articulography (EMA) and Ultrasound Visual Biofeedback (U-VBF). Since the 1980s (Dagenais, 1995) the potential for using visualisations of the articulators as a powerful speech therapy tool has been explored. Most of the research to date has focussed on EPG, with a large number of small studies showing its potential as a visual biofeedback (VBF) device (Gibbon, 2011). However, a growing body of evidence is beginning to show that ultrasound (U-VBF) is also likely to be an effective technique for both the assessment and treatment of speech sound disorders (SSDs).

U-VBF uses medical ultrasound to image the tongue in real-time. By synchronising the ultrasound images with the speech signal, and by using equipment which records the images at a fast frame rate, it is also possible to use ultrasound to reveal diagnostic information (Cleland et al., 2017). In contrast to EPG and EMA, which show a discrete number of points, U-VBF shows an anatomically accurate speaker-specific representation of the tongue. Most of the surface of the tongue is visible in a mid-sagittal view (see fig 1), and interpretation of the images is thought to be relatively intuitive (Bernhardt et al. 2005), especially when the speaker views their own tongue (since visual information is then coupled with both auditory and kinaesthetic feedback). Although the image is an anatomically correct representation of part of the tongue, other relevant anatomical information, such as the relation of the tongue to the hard palate, is not normally visible.

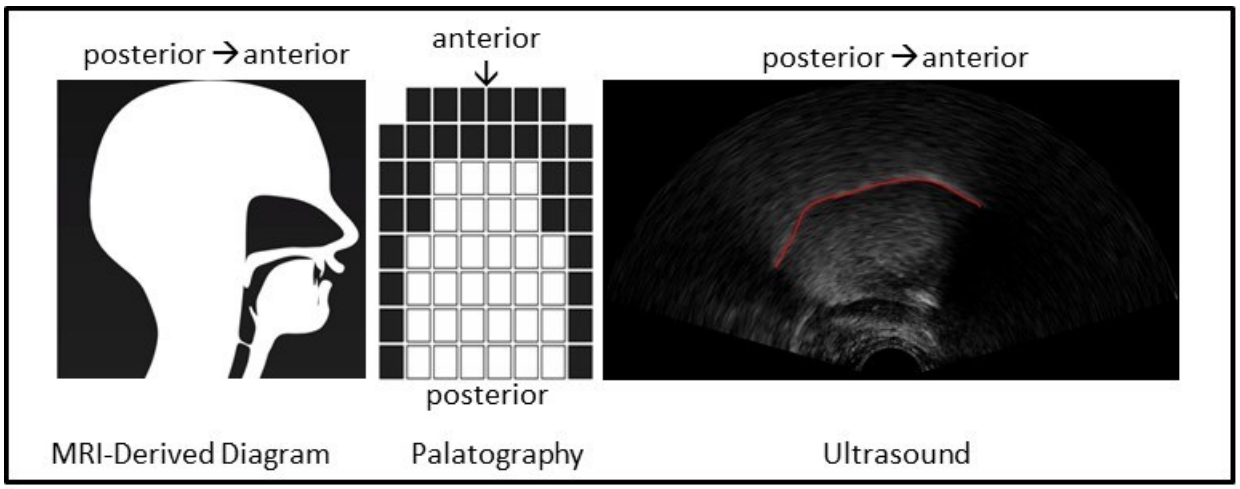


Figure 1: Instrumental articulatory techniques showing a single from the closure of [t] (not recorded simultaneously). From left to right: MRI-derived animation (reproduced with permission from Eleanor Lawson), electropalatography, Ultrasound.

The Evidence Base for U-VBF

U-VBF is rapidly gaining popularity. To date 30 small studies have been published in the literature investigating the efficacy of U-VBF (an up-to-date list can be found here). Table 1 show the studies in chronological order, summarising the client group and whether the study had a positive impact on speech outcomes. All studies show at least some improvement in outcomes following U-VBF, though some of the group studies report "non-responders" or difficulties with generalization. U-VBF can be used to target correct production of any lingual consonant and any vowel, especially if the sound in error is produced at the wrong place of articulation. In the literature the production of the consonant /r/ is a popular target. This is probably because correct production of /r/ is socially important in North America where many of the studies are based, and also because /r/ is acquired particularly late. However, in the UK /r/ is not frequently a target for intervention, probably because minor distortions have limited effects on intelligibility and may be an acceptable variant in some parts of the UK (for example, labiodental productions).

Three recent studies looked at using U-VBF to treat lingual consonants other than /r/ in children with SSDs (Cleland, Scobbie, & Wrench, 2015; Heng, McCabe, Clarke, & Preston, 2016; Melo, Dias, Mota, & Mezzomo, 2016). While results for preschool children are mixed (Heng et al., 2016), Cleland et al. (2015) show promising evidence that a range of errors can be remediated in school-aged children with SSD, and Cleland et al., (under revision) extend the number of errors which have been successfully treated to include unusual pharyngeal articulations and vowel mergers.

Study	*N*	*Age*	*Dx*	*Speech Targets*	*+ve Result*	*Mixed Result*
Shawker & Sonies (1985)	1	9	DSSD	r	✓	
Bernhardt et al. (2003)	4	16 to 18	HI	s, ʃ, r, l, i, ɪ, u, ʊ	✓	
Bernhardt et al. (2005a)	4	16 to 18	HI	s, ʃ, r, l, i, ɪ, u, ʊ		✓
Adler-Bock et al. (2007)	2	12, 14	DSSD	r	✓	
Bacsfalvi et al. (2007)	3	18	HI	i, u, ʊ , ɪ, ɛ	✓	
Bernhardt et al. (2008)	13	8 to 15	RSSE	r		✓
Fawcett et al. (2008)	3	21 to 27	DS	r	✓	
Modha et al. (2008)	1	13	DSSD	r	✓	
Bacsfalvi (2010)	3	15 to 18	HI	r	✓	
Bacsfalvi & Bernhardt (2011)	7	14 to 19	HI	N/A		✓
Klein et al. (2013)	2	5, 6	DSSD	r	✓	
Lipetz & Bernhardt (2013)	1	15	DSSD	s, z, ʃ, t ʃ	✓	
Preston et al. (2013)	6	9 to 15	CAS	sequences e.g. re, kr		✓
McAllister Byun & Hitchcock (2014)	4	6 to 10	DSSD	r		✓
McAllister Byun & Hitchcock (2014)	4	7 to 15	DSSD	r	✓	
Preston et al. (2014)	8	10 to 20	RSSE	s, z, θ, ʃ, tʃ, r ; Clusters: r, s, l	✓	
Preston et al. (2014)	1	59	AoS	r		✓
Cleland et al. (2015)	7	6 to 10	DSSD	k, g, r, ʃ, t	✓	
Hitchcock & McAllister Byun (2015)	1	11	DSSD	r	✓	
Lee et al. (2015)	1	13	DSSD	r	✓	
Blyth et al. (2016)	2	53, 59	Glossectomy	s, t Participant 1; s, l, ʧ Participant 2	✓	
Bressmann et al. (2016)	4	7 to 10	DSSD	r	✓	
Heng et al. (2016)	2	4	DSSD	k,g Velar Fronting		✓
Melo et al. (2016)	1	5	DSSD	k,g Velar Fronting	✓	
Preston et al. (2016)	3	10 to 13	CAS	r		✓
Preston et al. (2016)	12	10 to 16	RSSE	r	✓	
Preston et al. (2016)	3	10 to 14	CAS	r (2 participants), sibilants (1 participant)		✓
Roxburgh et al. (2016)	2	6, 9	CLP	n for one participant; k,g for another	✓	
Sjolie et al. (2016)	4	7 to 9	DSSD	r		✓
Preston et al. (2017)	6	8 to 16	CAS	r (5 participants), r and s (1 participant)		✓
Preston & Leece (2017)	4	13-22	RSSE	r	✓	

Table 1: List of U-VBF papers. Note: RSSE= Residual Speech Sound Error; CLP= cleft lip and palate; CAS= Childhood Apraxia of Speech; DSSD= Developmental Speech Sound Disorder; AoS= (Aquired) Apraxia of Speech; HI=Hearing Impairment.

Selecting Clients

Ultrasound can be used to assess any child with any type of SSD who is able to co-operate with the recording procedure. However, the headset used to stabilise the probe is recommended for age four and over. The research team are interested in receiving recordings of any children who consent to take part in the project. However, you may wish to consider in advance which clients are mostly likely to benefit from U-VBF, should you choose to provide it.

The majority of studies in the literature look at children with persistent SSDs or residual speech sound errors. By definition, these children are normally over eight years old. While these children will have very intractable errors, they are able to cope with the cognitive demands and intensity of practice that U-VBF requires. In our own work we have used U-VBF with children aged five and over, with most children tending to be between six and nine. One study conducted in Australia (Heng et al., 2016) trialled U-VBF with four preschool children who were velar fronting with very mixed success. We would therefore recommend age five as a minimum for intervention (though note, assessment is still useful in preschool children who can co-operate).

U-VBF does require good attention and motivation; however, we have used the technique with children with quite a wide variety of concomitant disorders, including developmental language disorder, autism (high functioning, verbal children) and mild learning disability. For children with a more moderate to severe learning disability you should be prepared to offer more sessions as progress may be more protracted.

While you can treat any lingual error (which most speech sound errors are) with U-VBF, we would recommend prioritising children with errors you will clearly see in the mid-sagittal ultrasound view (see below for information about mid-sagittal and coronal views). That is, any error where the tongue is more front, back, higher, or lower than it should be (for example, velar fronting or gliding of /r/). This would also include vowel errors. Errors with voicing would not be a suitable target for U-VBF, nor would most errors with manner, as these are not shown in the ultrasound display. Having said that, errors such as deaffrication and stopping of affricates can be treated using U-VBF, as it can be helpful to show children that their tongue stays in the same place for the stop and fricative portion of affricates. We would not prioritise treating children with structural errors, though we have used U-VBF very successfully with a child with cluster reduction and with another who deleted onsets. The coronal view can be used to treat lateralisation errors, but it is difficult to tell which part of the tongue you are viewing. You can see which segments have been the target of intervention studies in table 1.

U-VBF can be used for treating any subtype of speech disorder except Inconsistent Phonological Disorder (though note, it may be a very good treatment for Childhood Apraxia of Speech

(CAS), so you need to be confident in your diagnosis). Since it is a motor-based intervention (see here) we would expect it to be most suitable for children with articulation disorders and CAS. However, Cleland et al. (under revision) argue that in children with more persistent SSDs there is often a motoric component to errors which appear phonological on the surface. Therefore, selection of U-VBF as an intervention tool is based on the presenting errors, rather than the speech disorder subtype.

Ultrasound Basics

Ultrasound Safety

Ultrasound uses high frequency sound waves that are beyond the range of human hearing. It is non-ionising radiation and is therefore safe and non-invasive. However, it should be remembered that the ultrasound probe (transducer) and processor are medical equipment and must be handled with care. You should only use ultrasound machines that are approved for use with humans like the one supplied by the Ultrax2020 project. Because the ultrasound does have the potential to heat the tissue it is in contact with you should keep exposure times to a minimum and switch the machine off when not in use. The Sonospeech software is set to freeze the display when not in use for this reason.

Use of ultrasound for foetal and ophthalmic imaging is subject to stricter controls than for the rest of the body. It is very important you do not use the ultrasound to investigate pregnancy or allow clients to put the ultrasound near their eyes. For this reason clients should be supervised when using the ultrasound and you should not use it to image any area of the body except the vocal tract.

You should only use the gel supplied by the Ultrax2020 project with your ultrasound machine, although water can be used if you do not have any gel to hand. Allergy (contact dermatitis) to the gel is very rare, but has been reported, so if this occurs you should discontinue use.

Care and Maintenance of the Ultrasound

The ultrasound probe is fragile and should be handled with care. If it becomes cracked or worn then it should not be used. You should only clean your ultrasound probe with ultrasound-safe disinfectant or wipes (supplied). **Alcohol wipes should never be used as they can degrade the probe.** The ultrasound gel is water soluble and can be wiped off the client's chin with a tissue or washed off with water.

Setting up the Equipment

The Ultrax2020 project is using the MicroSpeech system and SonoSpeech Software supplied by Articulate Instruments Ltd. Instructions on setting up the hardware are supplied with your system and in the user guide found at the end of this manual. The software should be loaded and ready to go.

Fitting the Headset

This section will be updated in due course.

Figure 2: Ultrasound Headset

Checking the Ultrasound Image and Audio

Before you start recording the client it is important to check that you have a clear image of the child's tongue.

Firstly, check the probe is in contact with the soft area under the child's chin, is vertical, and is in the middle. If the probe it not in firm enough contact then the image may be out of range or weak. If the probe is not in the middle of the chin (e.g. in-line with the larynx) then the sides of the tongue can cause unusual reflections in the image which are difficult to interpret. The surface of the tongue shows as a white line, but disappears when the tongue touches the roof of the mouth. This is often a natural resting position, so if you can't see an obvious tongue surface it is worth asking the child to say /a/.

Since ultrasound does not travel through bone, shadows from the hyoid and mandible will appear as dark shadows. You should rotate the probe (in the mid-sagittal view rotate it forward or back, in the coronal view rotate it to the left or right) so that the shadows are symmetrical on the image.

Figure 3 shows an ideal images for both mid-sagittal and coronal views. Most assessment and intervention is done in the mid-sagittal view. The coronal view can be useful if you want to image lateral bracing, for example for a child who lateralises sibilants. Note that the headset is currently unable to be used in coronal view.

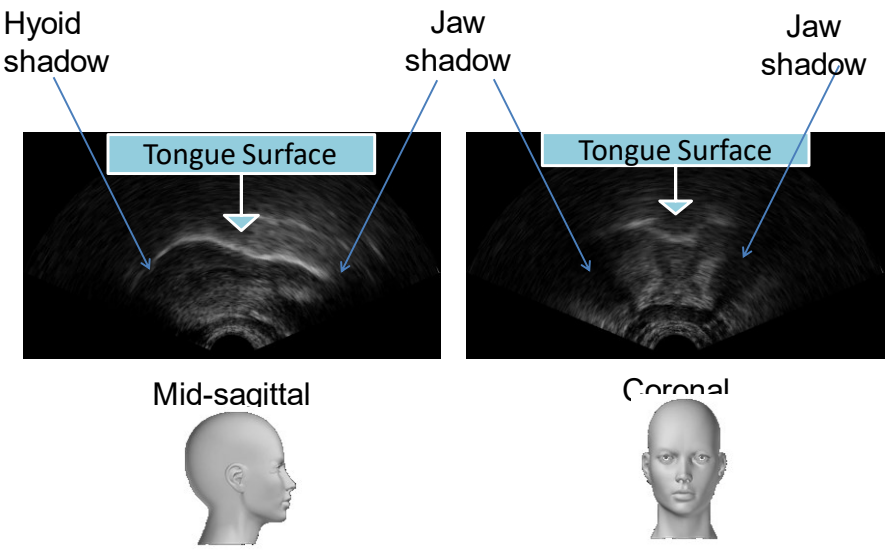


Figure 3: Ultrasound images in mid-sagittal and coronal view

It is also useful to check that you have a clear image for the whole articulatory space. You can do this by asking the child to say the corner vowels, which for Scottish-English are /i,a,o/. Click here for a video of the Scottish vowel space.

To check that the audio is working it is useful to record one item from the wordlist and play it back to check the sound and image before you begin.

Loading a Wordlist

See the section on loading wordlists in the SonoSpeech user guide.

Making, Saving, and Playing Back a Recording

Making, saving, or playing back a recording is easy. Click the hyperlinks for detailed instructions.

Transferring Recordings to the Research Team

Recordings can be transferred to the research team using the secure file share “Strathcloud”.

You will be provided details about how to do this (include log-in details) separately.

Using Ultrasound for the Assessment of Speech Disorders

Ultrasound assessment is an important pre-requisite of U-VBF. This is because U-VBF (and other biofeedback techniques) are often used for older children with intractable speech problems. In children where previous traditional interventions have been unsuccessful in instigating change, the root cause of this may be a previously undiagnosed articulatory or motor-speech disorder. Such as diagnosis may be missed because the child presents with a covert contrast or error which is not detectable by transcription alone (Cleland et al., 2017). By way of illustration: whereas an otherwise typically developing four year old with velar fronting might produce /t/ and /k/ in an identical way and respond well to a phonological intervention such as minimal pairs, an eight year old with the same error may mark contrasts in unusual and unexpected ways. For example 01F in the Cleland et al. study (2017) produced a variety of unusual tongue shapes during both /k/ and /t/ production. However, not all children with persistent SSDs make unusual articulatory errors. For these children, ultrasound assessment can also be used to confirm phonetic transcriptions. In both cases, by using ultrasound for assessment and treatment, the SLT and child have a shared understanding about the error the child is making and how to remediate it. Ultrasound measures can also be used to track progress in intervention in a systematic manner.

Selecting Wordlists for Assessment

Ultrasound assessment is a two stage approach. First, a general wordlist for all children which covers all lingual consonants is used to identify specific areas of difficulty, and secondly a target-specific wordlist designed to probe specific errors is used for children who require U-VBF. Not all children will benefit from U-VBF (see above) but assessment can be useful even if a different intervention is then used. For the Ultrax2020 project we have provided you with a general wordlist and several target-assessment specific wordlists (though note these are not exhaustive as children may present with disordered error types which cannot be predicted in advance).

The **general wordlist** is based on the CLEFTNET protocol and comprises a list of sounds, words, and sentences to record with each child. It should take approximately 10 minutes to record. Even if you know what you want to target in intervention you should ***always record the general wordlis*t** because this list is required by the research team for the technical aspects of the project. We expect that you will record this list with many more children than you provide U-VBF to. It is also very useful to have a full-inventory of tongue-shapes for each child for intervention.

Target-specific assessment word lists are important for two main reasons. Firstly, they allow an assessment of the likely intervention target in a variety of vowel environments and word positions. This is useful because some children may be able to achieve the target sound in a particular context- this is a good starting point for intervention. Secondly, these wordlists are very useful for monitoring progress because they allow you to measure exactly what you are treating. For example, if you wanted to treated post-alveolar fronting of the sibilant /ʃ/. The phonology subtest of the DEAP only contains four examples of this sound in "splash, sheep, toothbrush, fishing", if the child you are treating is only able to achieve /ʃ/ in word initial position by the end of intervention (i.e. they say sheep correctly on reassessment, but not before intervention) it is possible that the child's score on the DEAP will only go up by one point which incorrectly suggests your intervention was unsuccessful. In contrast, a word list which contains several examples of WI /ʃ/ will be able to quantify progress in a far more robust way.

The target specific assessment wordlists provided in this manual contain suggested 'untreated' and 'treated' words. By including the suggested 'treated' words in a pre-intervention assessment, you will have a baseline measure of the child's performance from which you can objectively measure change and the child's response to intervention. This will allow you to monitor the child's production of targets over time, as well as check for generalisation to non-treated words.

The suggested treatment words also appear in another list for easy reference. Please note that these word lists can also be used to treat a phonological process: where this is the case, minimal pairs have been provided for you to use (although you are of course welcome to use other words). Three to five minimal pairs are sufficient for treatment.

Choosing Target-Specific Wordlists

For some children it will be obvious which target-specific wordlist to choose for assessment, for example if a child is only velar fronting or only lateralising sibilants then the choice is obvious. However, for other children with multiple errors it can more difficult to choose where to begin intervention. For these children we have developed a target-selection strategy (see Cleland et al., 2015).

Firstly, complete the phonology subset of the Diagnostic Evaluation of Articulation and Phonology (Dodd, Zhu, Crosbie, Holm, & Ozanne, 2002). Using the phonology subtest form, complete the pattern analysis (phonological and phonetic errors) following the DEAP manual instructions, including summing the number of errors. The most errorful systemic pattern affecting a lingual segment (mild /r/ distortions excepted), can then be selected from the target-specific wordlists. If a child has a very unusual error or you aren't sure what to target you can contact the research team

with the results of the DEAP and the ultrasound recording of the general wordlist and they will provide advice and new wordlists for you.

Then record the target-specific wordlist and send the recording to the research team. We will provide an analysis for you of the ultrasound images and some suggestions for intervention. Normally children are required to score less than 20% target segment correct prior to intervention. You may wish to calculate this before you send the recording to the research team. To calculate it, transcribe the child's productions onto a print out of the target-specific wordlist (you can do this live) and for each word score 1 for correct target consonants/vowels (indicated on the sheet) and 0 for an incorrect production. Then calculate the % segments correct as indicated on each sheet. Where children scored over 20% correct, and the child presented with a lot of errors on the DEAP, a further option is to then record the wordlist for the next most errorful segment. This can be helpful as the DEAP does not contain equal numbers of each segment.

Qualitative Assessment and Interpreting Ultrasound Images

You will need to interpret ultrasound images throughout this project. Interpreting ultrasound images accurately will be essential if you are providing U-VBF intervention. Information about how to do this (as well as links to some handy resources) is provided below, and you are always welcome to contact the research team for assistance.

Some articulatory errors are very subtle and can only be identified through quantitative analysis using specialised software. However, it can be equally as helpful to do a qualitative analysis of the ultrasound data to help identify errors for therapy planning. During intervention, interpreting images becomes an easier task as typically children begin the intervention process by producing slowed-down versions of single consonants or vowels in quite limited contexts. This, combined with the fact you only tend to be concentrating on one segment at a time makes it quite easy for both the client and the therapist to interpret the image.

It is very helpful to have a good understanding of what typical speech *looks* like before beginning intervention. The Seeing Speech website provides a very helpful clickable IPA chart of ultrasound, MRI, and animations for all consonants. It should be noted, however, that these charts contain recordings of only two adults and tongue-shapes can vary considerably between even typical speakers due to differences in anatomy. Tongue-shapes for vowels will be very accent dependent.

The Sonsospeech software contains videos of typical children producing most of the consonants of English that can be used to show children. Your interpretation of ultrasound images will improve with practice (especially if you have the opportunity to record ultrasound images of typical

children and adults). The printable workbooks for children show typical productions of the key consonants.

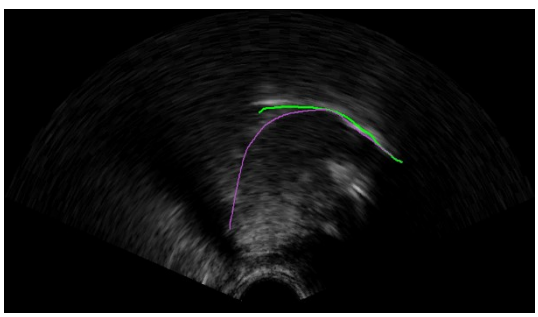
Error Types

There are several different types of errors that children with SSDs make. Often a child will produce a segment with the tongue-shape we would expect for a different segment. For example, children who have a complete neutralisation of contrast may produce both /k/ and /t/ with the same tongue-shape. However, a number of different articulatory errors have been described in the EPG literature (see Gibbon, 2004 for a good overview) that we might also expect to see in ultrasound images (though note they have not all been described in the research literature yet). Some new error types have also been documented, for example retroflex productions (Cleland et al., 2017) which are not feasible to identify with EPG. We have designed a recording sheet for you to chart error types in the children you record using the general wordlist . You should complete the recording sheet for each child you assess. You can either do it live, at the same time as recording the child, or after the session. Instructions are provided on the recording sheet, however, the error types are described in more detail here. The following examples of errors (classified using the descriptions in Gibbon, 2004) have been found in the speech of children with persistent SSDs.

Increased Contact

This error type occurs when there is more contact between the tongue and the hard palate that we would expect. Normally this is identified when a child is attempting to produce a velar or alveolar articulation, but it is possible to have increased contact during any production. Increased contact results from a lack of differentiation between the tip/blade and the dorsum of the tongue and is also described as an undifferentiated lingual gesture. It is indicative of a motor-based disorder (Gibbon, 1999). You will only be able to identify increased contact if you superimpose a hard palate trace on the image (see the Sonospeech Manual).

Click here to watch the video

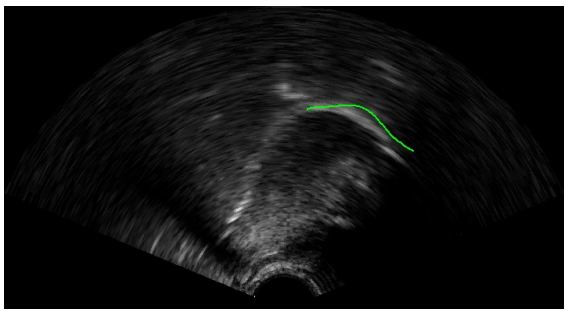


In this example, the child is attempting “tomato”. During both productions of /t/ the entire tongue body comes into contact with the hard palate.

Retraction to Velar or Palatal POA

This error type occurs when any anterior articulation is produced at a velar or palatal place of articulation. In other words, with retraction to a place of articulation (PoA) which is part of the phonological inventory of English. This error type is usually audible.

Click here to watch the video

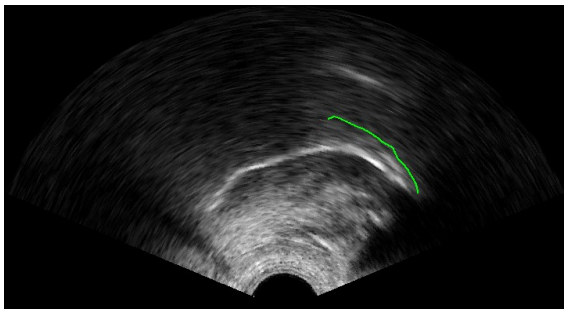


In this example, the child produces the /t/ at the beginning of the word “tie” at the velar place of articulation. Note, in the picture the tongue tip body is also raised, but not in contact with the palate.

Fronted Placement

This error type occurs when any posterior articulation is produced at a palatal, post-alveolar or alveolar articulation (note, fronting to a labial place of articulation would not be visible on the ultrasound so is classified separately). This error type is usually audible.

Click here to watch the video

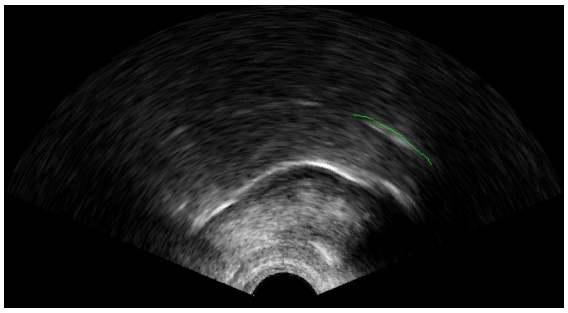


In this example the child produces the /k/ at the beginning of “cub” with the front of the tongue touching the hard palate (note the tip may be in shadow).

Open Pattern

This error type occurs when the tongue is not in contact with the hard palate when a lingua-palatal consonant or high vowel is expected. It is so-called an “open pattern” since in an EPG image there would be no visible contact. Using ultrasound, it might be possible to differentiate articulatory errors where the tongue is close to the palate (articulatory undershoot) from those in which it is very far from the palate. Additionally, open patterns occur in EPG when a post-velar articulation is produced. Ultrasound, on the other hand, shows uvular and pharyngeal articulations clearly (though note it is not possible to superimpose the pharyngeal wall or uvula on the image to check the PoA as these are soft moveable structures).

Click here to watch the video

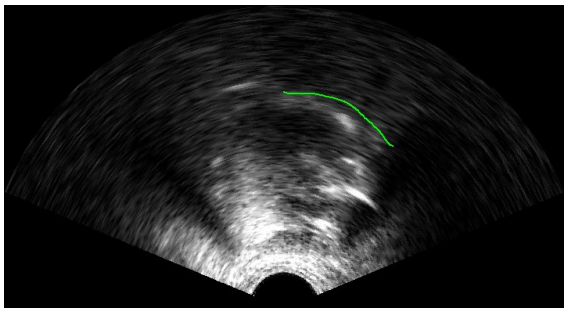


In this example, the child produces the /d/ at the beginning of “down” with no tongue-palate contact. This particular child produced most alveolars at a pharyngeal PoA.

Double Articulation

This error type occurs when two places of articulation are used simultaneously. Alveolar-velar articulations tend to be very difficult to hear and will often have an alveolar *or* velar percept, depending on whether the front or the back of the tongue is released first. This can have the overall effect of variably correct productions. These are quite difficult to distinguish from increased contact on ultrasound because the whole tongue is necessarily raised and identification relies on accurate identification of the place of the hard palate. Labial-alveolar or labial-velar double articulations are also relatively common, though you will have to rely on watching the child’s face to identify the labial component.

Click here to watch the video

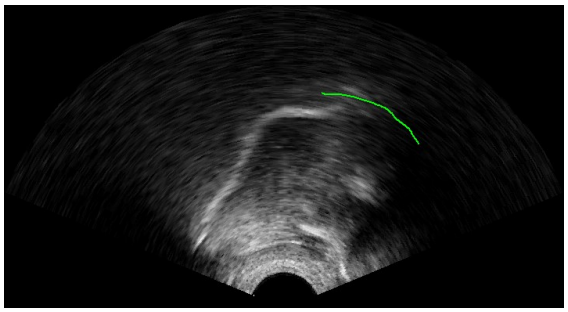


In this example, the child produces a k-t double articulation during production of /p t k/ in a diadochokinesis task. While the still shows a raised tongue body, the video shows a misdirected velar articulation followed by a perceptible [t].

Retroflexion (see Cleland et al., 2017)

This error occurs when the tongue tip is retroflexed during any non-retroflex consonant or vowel. This error has not been reported in the EPG literature as EPG cannot reveal tongue shape. Retroflexion may be subtle or extreme. It was reported as a covert error in a child with velar fronting who was explicitly attempting to produce a more posterior articulation for /k/ during intervention in Cleland et al. (2015). It has also been reported in Cleland et al. (2017) for a variety of lingual targets.

Click here to watch the video

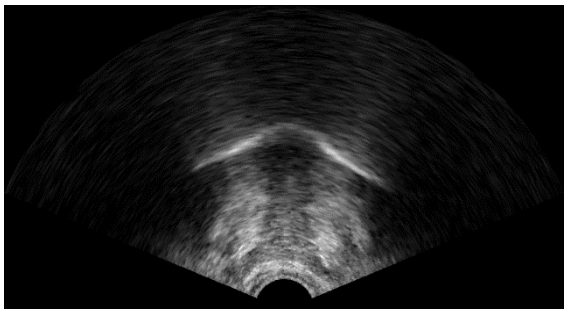


In this example the child produces a perceptually acceptable production of “pot”, but the tongue tip is retroflexed during the /t/.

Loss of grooving

This error occurs when a central fricative is produced without the central groove. It is normally highly perceptible as lateralised fricative (though central+lateral fricatives are harder to distinguish). This error-type can be identified using the coronal view. Instead of a typical “butterfly wing” shape, the image shows no central dip.

Click here to watch the video

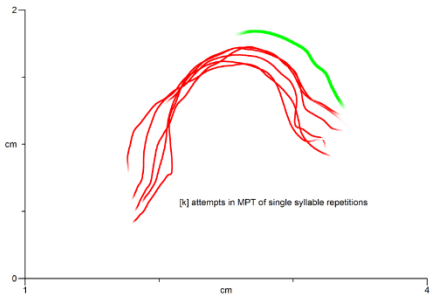


In this example the child produces the /s/ at the beginning of “sea” with the sides of the tongue lowered. The tongue shape is very similar to the following vowel.

Increased variability

This error occurs when multiple productions of a segment are produced with different tongue-shapes within the same context. It is very difficult to identify this viewing real-time videos. Normally variability refers to subtle sub-phonemic articulatory variation: it is therefore different to the type of variation we might expect to see in inconsistent phonological disorder. Variability can only be identified by comparing productions of a segment from the same word produced at least six times. Normally, these productions would have identical broad phonetic transcriptions (unlike in inconsistent phonological disorder where we would expect wildly different token-to-token variability). This type of error is an indication of immature speech motor control.

Click here to watch the video



In this example the child is repeating [kə] in a diadochokinesis task. While each production is an acceptable /k/, by tracing the tongue shapes for each attempt and superimposing them (left) we can see a high degree of variation in the position of the tongue.

Abnormal Timing/ Articulatory Groping

This error occurs when there is evidence of articulatory groping (struggling to "find" a target) or abnormal timing. It can only be identified dynamically (hence no still image for this error). Click here to see an example of a child struggling to hit target articulations in the word "vegetable".

Intervention using U-VBF

Visual biofeedback techniques are often considered as adjuncts to more traditional types of intervention (Bacsfalvi et al. 2007). U-VBF supplements traditional techniques such as articulation therapy (Van Riper & Emerick, 1984) or motor-based intervention (Preston et al., 2013). One key ingredient of articulatory VBF is that it can be used to demonstrate complex articulations that are normally difficult to describe. Describing articulatory movements is an essential part of traditional articulation therapy (Van Riper and Emerick, 1984). Normally this is achieved with verbal descriptions (e.g. "put your tongue at the back of your mouth"), or perhaps diagrams, but in U-VBF a video (or live) model of the target articulation is used. In a sense, then, U-VBF consists of two theoretically distinct aspects: 1. A visual articulatory model and 2. Biofeedback. Cleland and Scobbie (in press), unpick the theoretical aspects which might underpin these two separate stages, but in short, watching an accurate visual model capitalised on the mirror neurone system while biofeedback capitalises on the principles of motor learning by allowing the child to access a new type of visual information and bootstrap this to their auditory and haptic feedback.

Ultrasound as Motor Intervention

Children who make inappropriate phonetic realisations of certain speech sounds may do so because they have an inappropriate motor plan for that sound (Preston et al., 2014). Cleland, Scobbie and Wrench (2015) suggest that these erroneous motor plans can be ascribed to one of three categories: 1. It is identical to that of another phoneme, resulting in homophony in the system (as in canonical velar fronting); 2. the motor plan is abnormal or underspecified resulting in something homophonous-sounding but different in some way (as in covert contrast, Gibbon and Scobbie, 1997), for example /t/→[t] and /k/→[t̠]) or; 3. the motor plan is abnormal to the extent that it results in the realisation of an obviously non-native speech sound, for example a lateral lisp in English speaking children. Acquisition and mastery of a new sound requires laying down of a new general motor programme (Preston et al., 2014).

Like acquiring any new motor skills (compare with learning the piano for example) it is a gradual process involving practice. Unlike in phonological intervention where we might expect sudden generalisation of phonetically accurate productions, in U-VBF we see various types of phonetic gradience in the short-term longitudinal change, potentially in addition to rapid categorical change (if the child does have homophony in their system). For example, children who are velar fronting might at first produce their new "velar" as a uvular articulation which is poorly co-articulated with following vowels. Following further practice, the new articulation can move to a more phonetically accurate

realisation with better co-articulation. In fact, co-articulation is a good measure of speech-motor control.

Given the aforementioned importance of the principles of motor learning in U-VBF, it is important to understand these before providing therapy. Maas (2008) and McLeod & Baker (2017) provide very good tutorials on the topic; however, we summarise the main features below.

The Principles of Motor Learning

The principles of motor learning provide guidance as to how we can structure intervention to best promote and facilitate learning of a motor skill (such as speech). In motor learning, two phases are needed: pre-practice and practice. In pre-practice (similar to stimulability), the aim is for the *acquisition* of a new motor skill (such as the production of velars). In the practice phase, the aim is to promote learning so that the new speech sound is *retained* (a permanent or long-term change in speech production) and *transferred* (the new movement/production effects related but untrained speech sounds or contexts).

Pre-Practice

All intervention sessions start with a period of pre-practice. In pre-practice, the child is taught how to produce the target speech sound. This is where you explain to the child how sounds should be made and ensure that the child is able to produce the target. Children may require a lot of support to initially achieve success in pre-practice. You may find that you spend a lot of time (particularly in early sessions) in the pre-practice phase of intervention, as you need to ensure that the child has a high success rate producing the target in limited contexts before you can progress to the practice phase of therapy. In fact, you may spend several sessions entirely in the pre-practice phase of intervention.

See the section below for more information on what to do during the pre-practice phase of intervention using U-VBF.

Practice

The practice phase is where a child practices the motor skill (e.g. a speech sound) so that the skill becomes automatic and retained. The conditions of this practice (including the amount of practice, the distribution of practice, the variability of practice, the practice schedule, the child's attentional focus, and the complexity of the target) influence how well a skill is acquired, retained, and generalised to other related speech sounds. The practice conditions, and recommendations for pre-practice and practice, are shown in Figure 4.

Practice amount

This refers to the amount of practice provided in a session (e.g. small vs large). The evidence for speech therapy indicates that large amounts of practice of a target speech sound (that is, a high dose) should

be provided during each intervention session. In the Ultrax2020 project, we ask that you aim for a dose of at least 100 trials/practice attempts in the practice phrase of a session.

Distribution of practice

This refers to how a particular amount of intervention is scheduled over time. Practice can either be massed (e.g. 3 sessions per week for 4 weeks) or distributed (e.g. one session per week for 12 weeks). The evidence for distribution of practice indicates that massed practice may facilitate the initial phases of skill acquisition but that distributed practice may be better for long-term retention of a skill and transfer/generalisation to new skills. In the Ultrax2020 project, we suggest that intervention sessions be provided no more than one week apart.

Practice variability

Practice can be constant or variable. An example of constant practice is practising the same target in the same context (e.g. initial [k] in the syllable [ko]). Variable practice involves practising a target in different contexts (e.g. different vowels contexts or positions within a word). Constant practice is helpful for the initial acquisition of a skill, but once a target is acquired to a pre-determined level of accuracy (e.g. 80% over 10 trials) therapy should progress to variable practice.

Practice schedule

Practice of targets can either be blocked or random. Blocked practice involves practicing a speech target a certain number of times before moving onto the next target (e.g. practising the word *cop* 10 times then practising the word *cape* 10 times). Random practice would be presenting the words in a random order (e.g. *key, cape, car, coat, cat*). The evidence for blocked vs. random practice in speech therapy is mixed; however, a combination of blocked and random may be useful (e.g. 10 trials of word initial /k/, followed by 10 trials of word-final /s/).

Attentional focus

Attentional focus can be internal or external. An internal focus would be instruction and feedback that focuses children's attention on mouth movements (e.g., "focus on what your tongue is doing when you say [k]. Try to use the back part of your tongue" [McLeod & Baker, 2017]). External focus involves directing the child's attention to the accuracy of the sound produced. In pre-practice, you might include both an internal and an external focus of attention; however, as the child enters the practice phase of intervention, attentional focus should become more external (see below for more information).

Target complexity

Targets can be simple (e.g. a target in isolation, /s/) or complex (e.g. a target in a cluster, a whole word or phrase, such as *eat the spaghetti*). Research recommends starting with simple targets and progressing to more complex targets as the child achieves success.

Feedback in intervention

The principles of motor learning also consider the type, frequency and timing of feedback provided in therapy. These principles, and how they relate to pre-practice and practice, are shown in Figure 4.

Type of feedback: KR and KP

Two different types of feedback are considered: knowledge of results (KR) feedback and knowledge of performance (KP) feedback. KR feedback tells the child whether their production was correct or incorrect. Examples of KR feedback include saying "that was great" or "not that time". KP feedback tells the child about their articulatory movements, and why their response was correct or incorrect. Examples include using U-VBF to display the tongue movement (although U-VBF can in itself also provide KR feedback).

KP and KR feedback are both helpful in the pre-practice phases of therapy to help shape accurate responses. However, as children progress through the practice phase of intervention, more KR feedback should be provided: this encourages the child to develop and use their own internal feedback mechanisms, which in turn promotes retention and transfer of the targeted motor skill.

Frequency of feedback

This refers to how often feedback is provided. High-frequency feedback would be, for example, providing KP or KR feedback after every trial or production. Low-frequency feedback, on the other hand, would be providing feedback on 50% or fewer attempts. High-frequency feedback is considered helpful in the early stages of intervention when a child is learning the articulatory requirements of the target (i.e. in pre-practice). However, low-frequency feedback is thought to beneficial during the later stages of therapy (e.g. in the practice phase) as it encourages children to rely on their own intrinsic forms of feedback. Thus, therapy should commence with a high-frequency of feedback, which is then reduced as the child makes progress.

Feedback timing

Feedback timing refers to when feedback is provided relative to the production of the speech target. Feedback can either be provided concurrently with an attempt, immediately after a response, or delayed by a few seconds. While it may be natural and intuitive to provide feedback to the child immediately after their response, research evidence indicates that motor learning is enhanced when feedback is delayed. This gives the child an opportunity to detect and hopefully self-correct any errors. Thus, during the practice phase of intervention, you should try to give delayed feedback to children. An unobtrusive way to do this is to transcribe the child's production before giving any feedback. However, during the pre-practice phase, a combination of immediate and delayed feedback can be provided. There are many ways that you can use the ultrasound machine to provide delayed feedback: see the section below for more information.

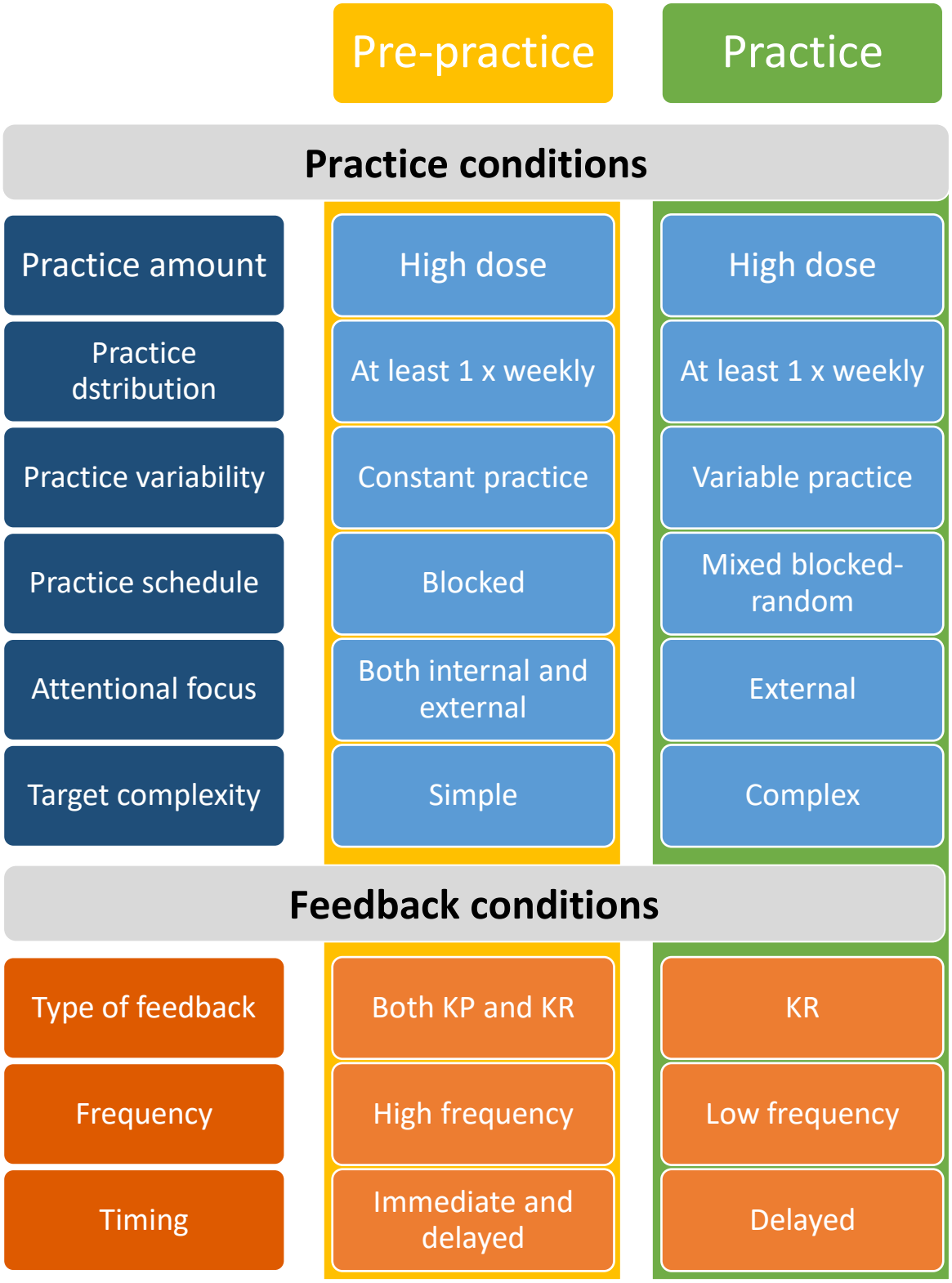


Figure 4. Principles of motor learning in therapy for SSDs

Dosage and Intensity of Intervention

Number of Sessions

To our knowledge, no study has given children less than 10 sessions of U-VBF to children (Cleland et al., under revision). In the Cleland et al., (under revision) study none of the children were stimulable for the chosen intervention target. However, most children were able to achieve their new articulation in the first or second session of intervention. Lack of success in the first or second session of intervention does not indicate that the treatment will not be successful. Four children only achieved the new articulation on or after the sixth session, showing that for U-VBF persistence can pay off. Once children are able to produce their new articulation in CVC contexts, progression tended to be rapid and to generalize to untreated words, suggesting perhaps that a good success measure of U-VBF will be accurate productions in CVC, with further non-U-VBF therapy perhaps required after that point if the child struggles to generalise.

Dosage: Practice Attempts within Sessions

As mentioned above, a high number of attempts within a session is important for motor learning to be successful. In the research on U-VBF to date, an average of between 60 and 366 attempts have been provided in the practice phase of a session. While 366 may seem high, it is important to remember that the dose/attempts per session is likely to increase as therapy progresses: this is likely due to the changes in practice and feedback conditions aligning with the principles of motor learning (Preston & Leaman, 2014).

We would recommend that in a 45 minute session you aim to elicit at least 100 trials during the practice phase of the session. During pre-practice, you will need to elicit as many trials as needed to reach the 80% criteria (from a block of 10 trials) required to move to the practice phase. Games which are useful for this include tasks with dice throws etc. where the child has to say the target the number of times on the dice. Other suggestions include requiring 5-10 productions before a turn of a game, or asking the child to count 5-10 trials on their fingers.

Intervention Protocol

Intervention is normally 10 to 12, 45min to an hour therapy sessions. There is evidence that more intensive sessions could also be used. We would not recommend scheduling sessions more than a week apart. Normally sessions consist of no more than 30 minutes spent using ultrasound and around 30 minutes doing table-top activities (depending on the child this could be input activities or practice without the ultrasound) and discussing progress with parents/carers. Most children will not be stiumulable for the sound you want to work on so you need to begin by eliciting a new articulation (pre-practice). This is the most challenging part of the intervention for both the client and the SLT. Figure 5 shows the normal sequence of U-VBF.

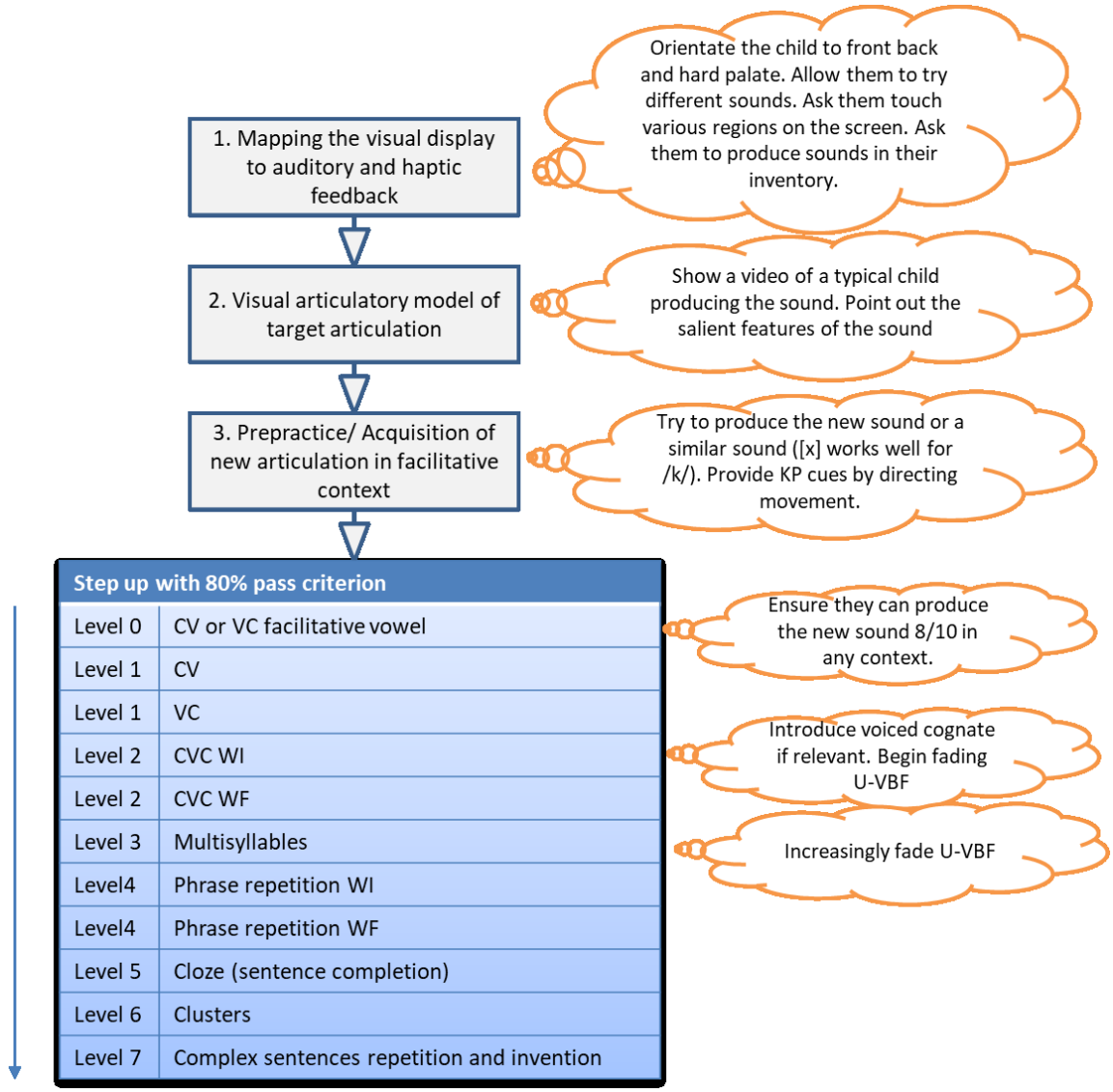


Figure 5: Sequence of U-VBF

Mapping

After the assessment, but before you begin the actual intervention, it is important to be sure the child understands the ultrasound display and understands that it is live biofeedback- i.e. they "map" the movements on the screen to the movements of their own tongue. This is essentially integrating a new modality and is normally done implicitly, however it is possible that some children will be unable to relate to the display (in this case the ultrasound is still useful for intervention because the SLT can see exactly where the child is going wrong and provide verbal cues). Begin by orientating the child to the screen and pointing out the front and back of the tongue and the hard palate. A diagram of a head can be useful for this. Next, point to (either with your finger or the cursor) various regions of the screen and ask the child to use the tip of their tongue to hit the target.

Visual Articulatory Model

Demonstrate the target consonant or vowel to the child with an ultrasound video of a typically developing child producing the segment (videos are part of sonospeech). You may also demonstrate it live yourself (or ask a parent or sibling to do it) but note that your tongue may be a lot bigger than the child's. It is normally best to demonstrate consonants in a vowel context- either schwa or /a/. Play the videos in both real-time and slow motion (4 times slower) and explain the salient features of the segment to the child. A range of sheets explaining the most common targets in child friendly language are available which will be helpful at this point. For example, when demonstrating a /k/ the clinician points out dorsal raising combined with keeping the anterior tongue low in the mouth. If you are very lucky, this demonstration will be enough for the child to then imitate the segment accurately, however most children require careful shaping to achieve the new articulation.

Pre-practice/ Eliciting a New Articulation

Next attempt to elicit (level 0, from Figure 4) the target consonant or vowel in CV or VC context likely to facilitate production, for example when treating /k/, a high back vowel, the GOAT vowel /o/ is useful. If the child is able to achieve the consonant or vowel in any context (the assessment will have revealed that), then start with that context. If the child is able to say a consonant at the same place of articulation but with a different manner/airflow then start with that. For example, some children are able to say the velar nasal, but not the velar stop so you could start with [ŋkə] (though be very careful with nasals as a true velar nasal is hard to distinguish auditorily from a nasal produced with increased contact).

Once a child is able to achieve an acceptable production of the target articulation a video recording can be made of their best attempt (click here for instructions on how to do this), and subsequently used as a target. It can be helpful to print out a picture of this to send home with the children or even give them a video of their best production to take away.

Practicing in Different Contexts

Once the child can achieve the new sound in any context in 8/10 attempts then move quickly to expanding the contexts by introducing new vowels (or consonants for vowel merger) and increasing complex contexts (see figure 5). When treating a consonant a child will find it easier to move through nearby vowels before moving to more challenging coarticulatory contexts- for example when treating velar fronting, if the child is able to achieve [ko] then [ka] will be easier than [ki]. Move as quickly as you can to real words (see the suggested treated words and avoid using the untreated words). Once a child is able to produce the new consonant or vowel reliably in CVC contexts then it is useful to introduce the voiced cognate (where relevant) and then work on two targets simultaneously. You should fade the ultrasound as soon as the child is able to produce the new segment reliably in any

context by practicing without the ultrasound at the end of every session (as you normally would in speech intervention). Once the child is able to reliably produce the sound, homework can be given. All practice should contain a high number of trials.

Delayed Feedback

Most intervention studies use live biofeedback only. However, in the studies in Scotland, following in the tradition of EPG we have also used delayed feedback (not to be confused with delayed auditory feedback). The Sonospeech software allows you to record a client's attempts and play it back. In delayed feedback, you record the child producing the target segments/word(s) several times without giving KP or KR feedback and then have them watch and rate their own productions immediately afterwards. We recommend you do this as soon as the child is achieving more than around 30% success (i.e. you are confident at least 3/10 attempts are correct). This allows the child to fully understand how to achieve a correct production as you can discuss errors together. It also allows meaningful quantification of progress for the child. This approach is also useful when the child is producing sentences and it allows you to select only words of interest for playback.

Using the SonsoSpeech App in Intervention.

The SonoSpeech software contains several features which are designed to make intervention easier.

Creating hard-palate traces

One of the key benefits of using the probe stabilising headset is that you can then reliably add a hardpalate trace to the image. This is important because tongue-palate contact is an important source of tactile feedback for the child and an important source of articulatory context for the clinician. You should not add a hard-palate trace if you are not using the headset as the image will move around too much on the screen for this to be useful.

Using the live display, instruct the speaker to swallow (either a dry swallow or with water) and freeze the display at the point in the swallow when the tongue is fully in contact with the palate (this takes a little practice, so you may want to try it on yourself before asking a child to do so). You can then draw a palate trace from the alveolar ridge to the end of the hard palate.

Using the SonoSpeech Software for Articulatory Models

The SonoSpeech Software comes with pre-loaded visual articulartory models called "exemplars". Click here for information and how to load these. These can be helpful to use in intervention to show the child what they should be 'aiming' for in their articulation.

Saving and Loading a Child's Best Attempt.

Once a child is able to produce an acceptable version of a target (even very occasionally) it is useful to save a video of their production to use as a visual articulatory model. To do this you need to record the child and then extract the best part of the recording to use as a model. You can use the spectrogram to identify the part of the recording you want to use. See here for detailed instructions.

Other features of SonoSpeech (markers, animations, freezing)

The SonoSpeech software allows you to add markers to the screen. This can be a very useful way of adding "targets" to the screen- for example adding a ☺ where the back of the tongue should be during a [k] production.

The SonoSpeech app also has pre-loaded animations that you can use to reward the child throughout a session.

Finally, the SonoSpeech software allows you to freeze, unfreeze, and make/playback recordings of the child's productions. These can be helpful to discuss the target articulation, as well as for providing delayed feedback to the child.

Measuring Progress

The Ultrax2020 project is not a clinical trial with strict levels of control. However, it is important to measure children's progress and therefore intervention should follow at the very least a simple pre-post design. This means the same measures should be recorded before and after intervention. The key outcome measure is therefore percentage segments correct on the target-specific (assessment) wordlists . The same word list should be recorded immediately before and immediately at the end of a block of intervention to measure change. An increase of 20 percentage points is likely to indicate clinically significant change. It is also useful to record the target-specific wordlists more frequently where possible and we recommend doing so every third session.

To measure generalisation to other phonemes it is useful to also complete the general wordlist and the DEAP Phonology Subtest immediately after intervention. All recordings can be sent to the research team and we will send a report detailing each child's progress. If the child returns for a review appointment, or you decide further U-VBF intervention (perhaps with a different target) is required then further recordings can also be sent to the research team.

Tracking Progress during Intervention

It is useful to record a client at the beginning of every session to track progress and plan intervention. It is also useful to have recordings to playback to clients so that they can also appreciate their progress.

You can record the treatment wordlists at the beginning of every session and/or any self-devised client specific wordlists. In order to work through the various levels of the articulatory hierarchy it is useful to record ten attempts of words/nonwords at the level the client is currently performing at in order to decide when to move to the next level.

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Appendix A: Ultrax2020 General Assessment Word List

1. Ten Repetitions of consonants at all places of articulation in an open vowel context:

apa
ama
afa
ata
ana
ara
atha
asa
asha
ala
aya
aka
awa
acha

2. Counting from 1 to 10

3. Sentences from the CLEFTNET protocol, read or imitated (based on GOS.SP.ASS 98)

1. Naughty Neil saw a robin in a nest
2. Tiny Tim is putting a hat on
3. My daddy mended a door
4. I saw Sam sitting on a bus
5. Funny Sean is washing a dirty dish
6. Cheeky Charlie's watching a football match
7. Jolly John's got a magic badge
8. Happy Karen is making a cake
9. Baby Gary's got a bag of Legos.
10. The puppy is playing with a rope
11. Bouncy Bob is a baby boy
12. The phone fell off the shelf
13. The hamster scrambled up Stewart's sleeve
14. The nasty boy tossed the basket into the box

4.Minimal sets from CLEFTNET protocol. /k/ has been added.

Vowel	**/s/**	**/sh/**	**/ch/**	**/t/**	**/k/**
/i/	A seat	A sheet	A cheat	A team	A keep
/ɔ/	A sob	A shop	A chop	A top	A cop
/o/	A sore	A shore	A chore	A tore	A core
/ɪ/	A sip	A ship	A chip	A tip	A kip
/u/	A Sue	A shoe	A chew	A tomb	A coop

5. Diagnostically Useful Words

ambulance

hippopotamus

spaghetti

computer

vegetables

helicopter

caravan

caterpillar

butterfly

animals

Appendix B: Target Specific Assessment Wordlists

Velar fronting

Word	Transcription	Score	Word	Transcription	Score
Pat			*Cone		/1
Gear		/1	Cape		/1
Team			Deer		
Tore			Cop		/1
Keep		/1	Core		/1
Tan			Monkey		/1
Cool		/1	Goal		/1
*Poking		/1	*Call		/1
*Cap		/1	Car		/1
*K		/1	Hoot		
Beak		/1	Peeking		/1
Tape			Tall		
Pack		/1	Pink		/1
Top			Hook		/1
Beat			Tar		
*Back		/1	Can		/1
*Book		/1	Dawn		
Tea			Gap		/1
Gone		/1	*Key		/1
Tool			*Peak		/1
*Cook		/2			
Packing		/1	Happy Karen is baking a cake		
Tap					
Goose		/1			
	Subtotal	/15	Subtotal		/15
			Total Targets Correct		/30
			Percent Targets Correct		

Blue = target sound

Asterisk and Italics = suggested treated words

Alveolar Backing

Word	Transcription	Score	Word	Transcription	Score
Pat		/1	*Toe		/1
Gear			Cape		
Team		/1	Deer		/1
Tore		/1	Cop		
Keep			Core		
Tan		/1	Bendy		/1
Cool			Door		/1
*Loading		/1	Call		
Cap			Car		
*Tail		/1	Hoot		/1
Beak			Reading		/1
Tape		/1	*Tall		/1
Pack			Mint		/1
Top		/1	Hook		
Beat		/1	Tar		/1
*Mat		/1	Can		
*Boot		/1	Dawn		/1
*Tea		/1	Dam		/1
Gone			Key		
Tool		/1	*Bead		/1
*Toot		/2			
Adding		/1	Tiny Tim is putting a hat on		
*Tap		/1			
Doom		/1			
	Subtotal	/18	Subtotal		/12
			Total Targets Correct		/30
			Percent Targets Correct		

Blue = target sound

**Asterisk and Italics = suggested treated words*

Labialised /r/

Word	Transcription	Score	Word	Transcription	Score
Read		/1	Berry		/1
Sewing			*Rude		/1
Wood			Whale		
*Rope		/1	*Pour		/1
Tourist		/1	Rot		/1
*Rug		/1	Bowing		
Weed			*Scary		/1
Run		/1	*Pier		/1
Boring		/1	*Rail		/1
Wok			Wake		
*Reel		/1	Wool		
*Car		/1	*Soaring		/1
*Rock		/1	Rake		/1
Sorry		/1	Carry		/1
Wheel			Woah!		
Boar		/1	Beer		/1
Curry		/1	Row		/1
Won			Earring		/1
Rack		/1	Rule		/1
Bar		/1	Whack		
*Rat		/1			
Tearing		/1			
What?					
Fur		/1			
	Subtotal	/17	Subtotal		/14
			Total Targets Correct		/31
			Percent Targets Correct		

Blue = target sound

Asterisk and Italics = suggested treated words

Post-alveolar fronting

Word	Transcription	Score	Word	Transcription	Score
She		/1	*Shoe		/1
Suit			Shrink		/1
*Shop		/1	Puss		
Sam			Crashing		/1
Shave		/1	Save		
Sea			Sharp		/1
*Cash		/1	Sew		
Leash		/1	*Shape		/1
Shack		/1	Shore		/1
Sore			Treasure		/1
*Mashing		/1	*Bush		/1
Seat			Mash		/1
Push		/1	Shock		/1
*Quiche		/1	*Sham		/1
Sock			Sack		
Shoot		/1	*Show		/1
*Shark		/1			
Mushroom		/1	Sean is washing a dirty dish		
*Sheet		/1			
Sue					
	Subtotal	/13	Subtotal		/12
			Total Targets Correct		/25
			Percent Targets Correct		

Blue = target sound

**Asterisk and Italics = suggested treated words*

Stopping of affricates

Word	Transcription	Score	Word	Transcription	Score
Coach		/1	*Cheap		/1
Pat			Top		
Chart		/1	Dam		
Angel		/1	*G		/1
Chair		/1	Dog		
Tart			*Patch		/1
*Fudge		/1	Bad		
Badge		/1	Match		/1
Chop		/1	Deep		
Jam		/1	*Charm		/1
Juice		/1	Jaw		/1
*Peach		/1	Tap		
Jeep		/1	Tear		
*Chalk		/1	*Poach		/1
Cheer		/1	Mat		
*Chance		/1	Beat		
Chap		/1	2		
*Catching		/1	*Choke		/1
Chore		/1	Doll		
Talk			*Tune		/1
*Jar		/1	Jog		/1
Coat			D		
Watching		/1	Tore		
Tear			*Chain		/1
Tea			Cheeky Charlie's watching a football match		
Badger		/1			
Chew		/1			
Beach		/1			
	Subtotal	/23	Subtotal		/11
			Total Targets Correct		/33
			Percent Targets Correct		

Blue = target sound

*Asterisk and Italics = suggested treated words

Deaffrication

Word	Transcription	Score	Word	Transcription	Score
Cheap		/1	Cheer		/1
Shin			Watch		/1
Watching		/1	Catching		/1
Peach		/1	Shane		
Chap		/1	Share		
Chin		/1	Chance		/1
Cash			Ship		
Witch		/1	Crutch		/1
Chop		/1	Chart		/1
Charm		/1	Match		/1
Chain		/1	Washing		
Mash			Shore		
Chore		/1	Sheer		
Sheep			Chew		/1
Coach		/1	Wash		
March		/1	Leash		
Chair		/1	Choose		/1
Shoe			Marsh		
Shop			Catch		/1
Crush			Wish		
Leech		/1	Chip		/1
Cashing			Choke		/1
Chalk		/1	Poach		/1
Shoes					
Cheeky Charlie's watching a football match					
	Subtotal	/15	Subtotal		/13
			Total Targets Correct		/28
			Percent Targets Correct		

Blue = target sound

**Asterisk and Italics = suggested treated words*

Sibilant distortions (fricatives)

Word	Transcription	Score	Word	Transcription	Score
*Shark		/1	Sharp		/1
Zap		/1	*Straw		/1
Snail		/1	Suit		/1
Shoot		/1	Buzzing		/1
*Moose		/1	*Smoke		/1
Push		/1	She		/1
*Police		/1	Zoo		/1
*Mashing		/1	Shrink		/1
Shock		/1	Save		/1
*Sam		/1	*Shoe		/1
*Shape		/1	*Bush		/1
*Stamp		/1	Lose		/1
Spot		/1	*Sew		/1
Shave		/1	Strong		/1
*Zoom		/1	Treasure		/1
*Shop		/1	*Snow		/1
Scream		/1	*Sob		/1
Shore		/1	*Screw		/1
*Seat		/1	Shack		/1
Piece		/1	Sore		/1
*Shoes		/2	*Sail		/1
Mushroom		/1	*Spoon		/1
Stairs		/2	*Class		/1
Leash		/1	Passing		/1
*Sham		/1	Sea		/1
Jazz		/1	Smell		/1
Mash		/1	Puss		/1
*Grassy		/1	*Keys		/1
Sock		/1	Sack		/1
*Sheet		/1	*Zip		/1
*Cash		/1	*Sue		/1
Bees		/1	Pass		/1
			*Quiche		/1
			Crashing		/1
			*Show		/1
	Subtotal	/34	Subtotal		/35
			Total Targets Correct		/69
			Percent Targets Correct		

Blue = target sound

Asterisk and Italics = suggested treated words

Sibilant distortions (affricates)

Word	Transcription	Score	Word	Transcription	Score
*Charm		/1	Chore		/1
Juice		/1	Jam		/1
Badger		/1	Badge		/1
Chop		/1	*Match		/1
*Chance		/1	*Peach		/1
*Fudge		/1	Watching		/1
*Catching		/1	*Jar		/1
Chart		/1			
Jeep		/1	Chew		/1
*Chalk		/1	*Cheap		/1
*Chain		/1	Coach		/1
*Poach		/1			
*G		/1	Cheer		/1
Patch		/1	Jog		/1
Angel		/1	Beach		/1
Chair		/1			
Chap		/1			
*Choke		/1			
*Tune		/1			
Jaw		/1			
	Subtotal	/20	Subtotal		/13
			Total Targets Correct		/33
			Percent Targets Correct		

Blue = target sound

**Asterisk and Italics = suggested treated words*

/s/ Cluster Reduction

Word	Transcription	Score	Word	Transcription	Score
Spot		/1	*Stomp		/1
Smoke		/1	Treat		
Nail			Nail		
*Screw		/1	*Smash		/1
Strong		/1	Stop		/1
Slope		/1	Ski		/1
Star		/1	Nap		
School		/1	Scar		/1
Lap			Scone		/1
Scream		/1	Key		
Cam			Small		/1
Sneeze		/1	Tears		
Snore		/1	Snap		/1
Cot			Scram		/1
Car			Knees		
Stairs		/1	Pot		
Stack		/1	*Stamp		/1
Sleep		/1	Tack		
Crew			Smartie		/1
Stone		/1	Tar		
Spade		/1	Pain		
Mash			*Scoop		/1
Coop			Gone		
Street		/1	*Straw		/1
Scroll		/1	Paid		
Cram			*Spoon		/1
Slim		/1	Top		
Skate		/1	*Scam		/1
Toll			Cream		
*Scott		/1	Tone		
Leap			*Stole		/1
Snow		/1	Kate		
Slap		/1	The slow snail was skipping down the stairs		
No					
*Spain		/1			
Cool					
	Subtotal	/23	Subtotal		/16
			Total Targets Correct		/39
			Percent Targets Correct		

Blue = target sound

Asterisk and Italics = suggested treated words

Stopping of /s/ and /ʃ/

Word	Transcription	Score	Word	Transcription	Score
Sock		/1	Tape		
*Shape		/1	Shock		/1
Jazz		/1	Leash		/1
*Quiche		/1	*Class		/1
Sharp		/1	Mash		/1
*Sew		/1	Put		
Passing		/1	Bead		
Zoo		/1	*Grassy		/1
*Zoom		/1	*Zip		/1
Tail			Shack		/1
Shoes		/2	Pass		/1
Piece		/1	Crashing		/1
*Show		/1	*Sail		/1
Save		/1	*Sheet		/1
*Moose		/1	Lose		/1
*Shark		/1	Mat		
*Mashing		/1	*Seat		/1
Sack		/1	Patting		
*Police		/1	Sea		/1
Matting			*Shop		/1
*Shoe		/1	Tack		
Shrink		/1	She		/1
Bees		/1	Zap		/1
Cat			Tore		
Shoot		/1	Sore		/1
Mushroom		/1	Top		
*Sam		/1	*Cash		/1
Toot			Puss		/1
Suit		/1	*Sue		/1
Buzzing		/1	Treasure		/1
Shave		/1	Pat		
2			Tea		
Toe			*Sham		/1
*Sob		/1	Push		/1
Doom			*Bush		/1
Shore		/1	*Keys		/1
			Dip		
	Subtotal	/30	Subtotal		/26
Blue = target sound			Total Targets Correct		/56
*Asterisk and Italics = suggested treated words			Percent Targets Correct		

Appendix C: Target Specific Treatment Wordlists

Velar Fronting

	vowel context	treated	minimal pair
/k/ WI	i	key	tea
	e	K	
	a	cap	tap
	ɔ	Call	tall
	o	cone	
	u	cook	
/k/ WF	i	peak	
	a	back	
	u	book	
/k/ WM		poking	
/g/ WI	ɔ	got	dot
	o	ghost	
	u	goo	do

Alveolar backing

	Vowel context	treated	Minimal pair
/t/ WI	i	tea	key
		tail	
	a	tap	cap
	ɔ	tall	call
	o	toe	
	u	Toot	
/d/ WF	I	bead	
	a	mat	
	u	boot	
/d/ WM	o	loading	

Labialised /r/

	treated	Minimal pair
/r/ WI	Reel	wheel
	Rail	whale
	rat	
	rug	
	rock	wok
	rope	
	Rude	wood
/r/ WF	pier	
	car	
	pour	
/r/ WM	scary	
	Soaring	sewing

Post-alveolar fronting

	vowel context	treated	Minimal pair
/ʃ/ WI	i	sheet	Seat
	e	shape	
	a	sham	Sam
	ɑr	shark	
	ɔ	shop	
	o	show	Sew
	u	shoe	Sue
/ʃ/ WF	i	quiche	
	a	cash	
	u	bush	
/ʃ/ WM		mashing	

Stopping of affricates

	vowel context	treated	Minimal pair
/ʧ/ WI	i	cheap	tea
	e	chain	
	a	chance	
	ɑr	charm	
	ɔ	chalk	talk
	o	choke	
	u	tune	
/ʧ/ WF	i	peach	
	a	patch	pat
	o	poach	
/ʧ/ WM	a	catching	
/ʤ/ WI	i	G	D
	a	Jar	
/ʤ/ WF		fudge	

Deaffrication

	vowel context	treated	Minimal pair
/ch/ WI	i	cheap	sheep
	e	chain	Shane
	a	chance	
	ɑr	charm	
	ɔ	chalk	
	o	choke	
	u	choose	shoes
		chip	ship
/ch/ WF	i	peach	
	a	catch	cash
	o	poach	
/ch/ WM		catching	cashing

Sibilant Distortions (fricatives and affricates)

Fricatives		
	vowel context	Treated
/ʃ/ WI	i	sheet
	e	shape
	a	sham
	ɑr	shark
	ɔ	shop
	o	show
	u	shoe
/ʃ/ WF	i	quiche
	a	Cash
	u	Bush
/ʃ/ WM	a	Mashing
/s/ WI	i	Seat
	e	Sail
	a	Sam
	ɔ	Sob
	o	Sew
	u	Sue
/s/ WF	i	Police
	a	Class
	u	Moose
/s/ WM		Grassy
/z/ WI		Zip
		Zoom
/z/ WF	i	Keys
	u	Shoes
Clusters		Screw
		Straw
		Spoon
		Stamp
		Smoke
		Snow

Affricates		
	Vowel context	Treated
/ʧ/ WI	i	cheap
	e	Chain
	a	Chance
	ɑr	Charm
	ɔ	Chalk
	o	Choke
	u	Tune
/ʧ/ WF	i	Peach
	a	Match
	o	Poach
/ʧ WM		Catching
/ʤ/ WI	i	G
	a	jar
/ʤ/ WF		fudge

/s/ cluster reduction

	vowel context	treated	Minimal pair
/skr/ WI	U	screw	crew
/str/ WI	ɔ	straw	
/sp/ WI	E	spain	pain
	U	spoon	
/st/ WI	A	stamp	
	ɔ	stomp	
	O	stole	toll
/sk/ WI	ɑr	scam	cam
	ɔ	Scott	cot
	U	scoop	coop
/sm/ WI	A	smash	mash
	O	smoke	
/sn/ WI	A	snap	nap
	o	snow	no
sl	i	slim	
	a	slap	lap

Stopping of /s/ and /ʃ

treated	Minimal pair
sheet	
shape	tape
sham	
shark	
shop	top
show	toe
Shoe	2
quiche	
Cash	cat
Bush	
mashing	matting
Seat	
Sail	tail
Sam	
Sob	
Sew	
Sue	
police	
Class	
moose	
grassy	
Zip	dip
Zoom	doom
Keys	
shoes	

Appendix D: Printable Worksheets for Intervention

(Provided Separately)

Qualitative Ultrasound Analysis Form. Participant ID_____ Date_____ Assessor_____ LIVE, OFFLINE REAL TIME, 2x Slower, 4 times slower

Appendix E: Qualitative Ultrasound Analysis Form

Instructions (for further information see the section on error types)

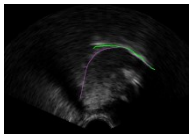
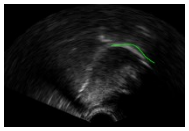
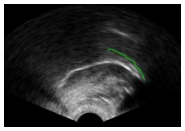
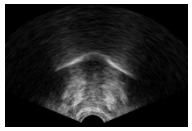
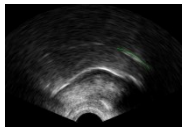
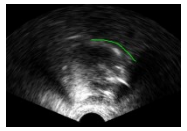
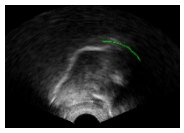
1. Add Participant name/number, date, and the name of the assessor to each form.
2. Indicate whether you completed the form:
    a. live- as the child was producing the words
    b. offline real-time, after the recording session but by playing the recordings back at normal speed
    c. offline, after the recording session but by playing the recordings back at 2x slower speed
    d. offline, after the recording session but by playing the recordings back at 4x slower speed
3. Using the General Assessment Wordlist for the /aCa/ sequences in the mid-sagittal view note down on the form whether the productions were:
    a. Typical production: similar to that of a typically developing child. Tick or transcribe
    b. Increased contact: between the tongue and the hard palate. Indicate degree of increased contact using the visual analogue scale from ○ none to complete ●.
    c. Retracted to a velar (V) or palatal (P) place of articulation
    d. Fronted
    e. Open pattern: produced with no/reduced tongue to palate contact using the visual analogue scale from ○ reduced contact to no contact ●.
    f. Double Articulations: evidence of closure at more than one place of articulation- transcribe, for example [t͡k]
    g. Retroflex: retroflexion of the tongue tip
    h. Increased variability: subphonemic variability between productions in place of articulation
    i. Silent groping

    In the coronal view for the sibilants:

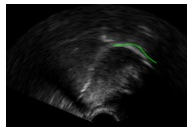
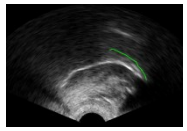
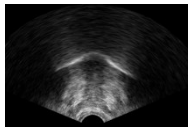
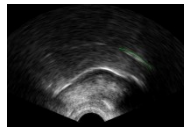
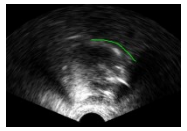
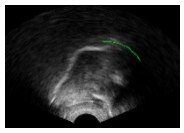
    j. Increased contact: between the tongue and the hard palate. Indicate degree of increased contact using the visual analogue scale from ○ none to complete ●.
    k. Complete closure: no groove evident.

Qualitative Ultrasound Analysis Form. Participant ID_____ Date_____ Assessor_____ LIVE, OFFLINE REAL TIME, 2x Slower, 4 times slower

Sagittal view

	Typical production	Increased contact	Retraction to Velar or Palatal Placement	Fronted Placement	Complete Closure (Loss of Groove)	Open Pattern	Double Articulations	Retroflex	Increased Variability (dynamic)	Silent Groping
									*(sub-phonemic variability)*	*(silent misdirected movements)*
ata		○—●	V / P			○—●				
ana		○—●	V / P			○—●				
ara		○—●	V / P			○—●				
atha		○—●	V / P			○—●				
asa		○—●	V / P			○—●				
asha		○—●	V / P			○—●				
ala		○—●	V / P			○—●				
aya		○—●	V / P			○—●				
aka		○—●	V / P			○—●				
acha		○—●	V / P			○—●				
bang		○—●	V / P			○—●				
apa		○—●	V / P			○—●				

Qualitative Ultrasound Analysis Form. Participant ID_____ Date_____ Assessor_____ LIVE, OFFLINE REAL TIME, 2x Slower, 4 times slower

		Typical production	Increased contact	Retraction to Velar or Palatal Placement	Fronted Placement	Complete Closure (Loss of Groove)	Open Pattern	Double Articulations	Retroflex	Increased Variability (dynamic)	Silent Groping
										*(sub-phonemic variability)*	*(silent misdirected movements)*
Sagittal view	ama		○—●	V / P			○—●				
	afa		○—●	V / P			○—●				
	awa		○—●	V / P			○—●				
	iki		○—●	V / P			○—●				
	oko		○—●	V / P			○—●				
	iti		○—●	V / P			○—●				
	oto		○—●	V / P			○—●				
Coronal view	asa		○—●				○—●				
	asha		○—●				○—●				
	acha		○—●				○—●				

SonoSpeech™ User Guide

Version 2.17.04

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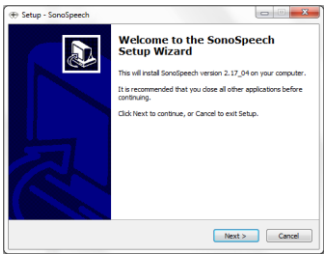
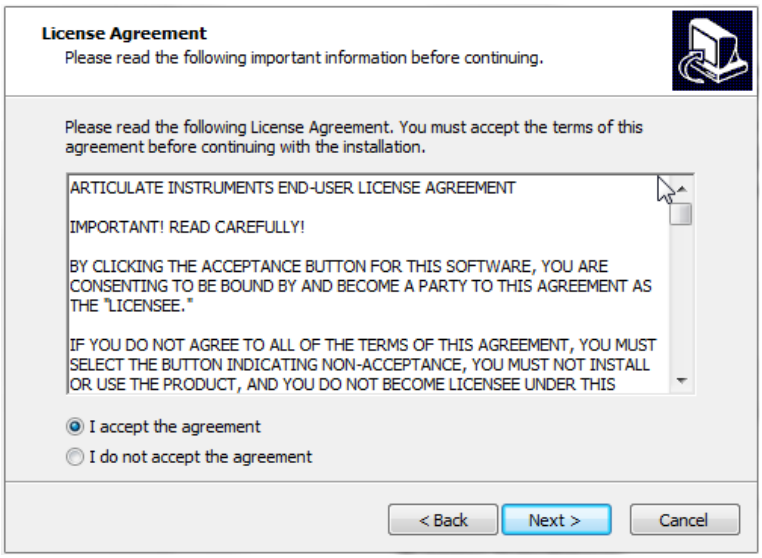
1 INSTALLING THE SONOSPEECH™ APPLICATION

To install the software, either:

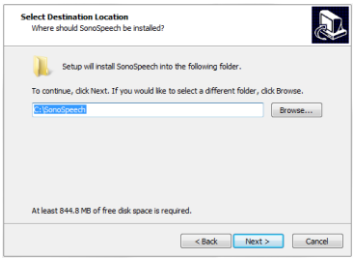
- Download and run Setup_SonoSpeech.exe from www.articulateinstruments.com/downloads/
- Run setup_SonoSpeech.exe from the Articulate Instruments flash drive supplied with Micro system



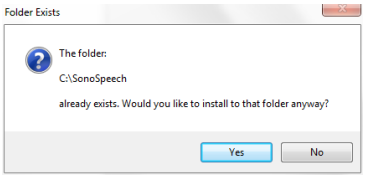
Click Next



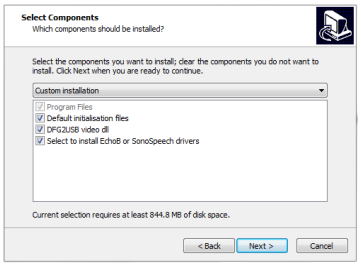
Read and accept the license agreement. Then click Next.



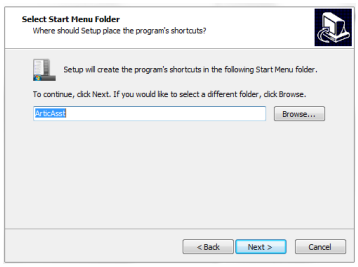
Click Next.



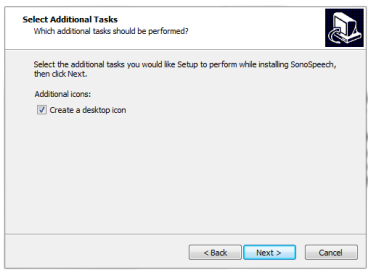
If the software is already installed, a warning will appear. To upgrade, click Yes.



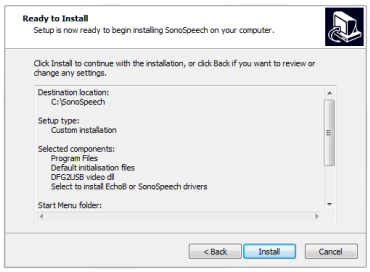
Click Next.



Click Next.

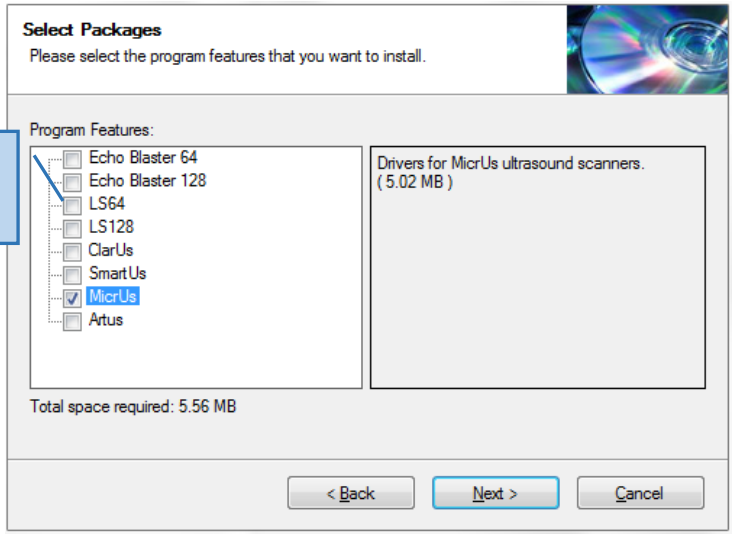


Click Next.



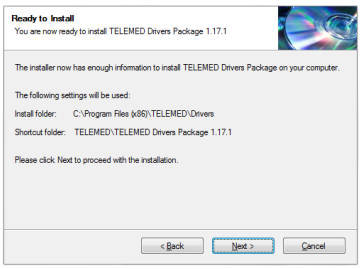
Click Install.

Click Next to install ultrasound hardware drivers.

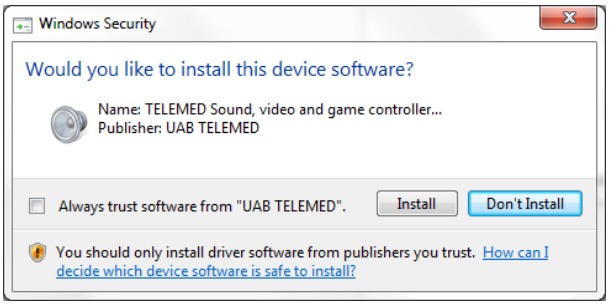


Uncheck these

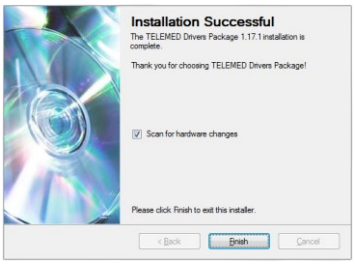
Leave MicrUS checked and **uncheck all the rest to save time** then click Next.



Click Next.

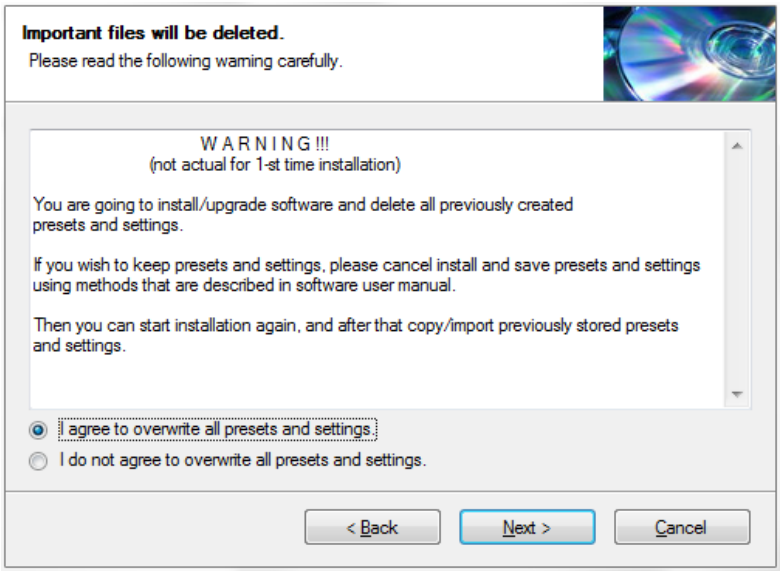


This message will appear three times. Click Install each time.

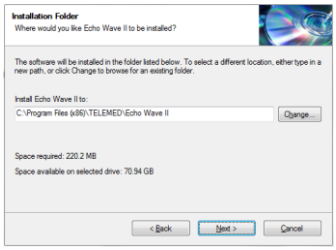


Click Finish.

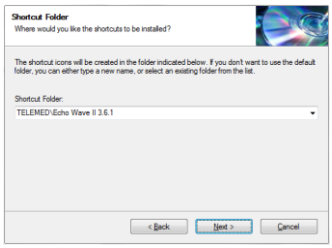
Click Next to install the default software that comes with the Micro system.



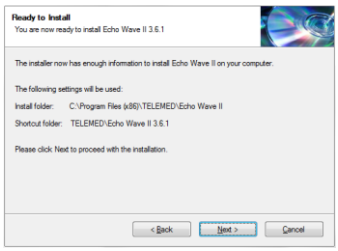
Agree to overwrite all presets and settings and click Next.



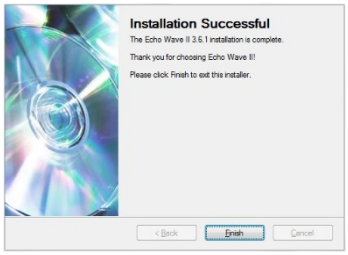
Click Next.



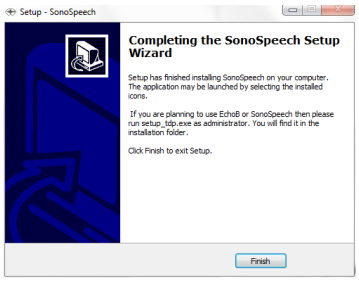
Click Next.



Click Next.



Click Finish.



Click Finish

2 GETTING STARTED

RUNNING SONOSPEECH

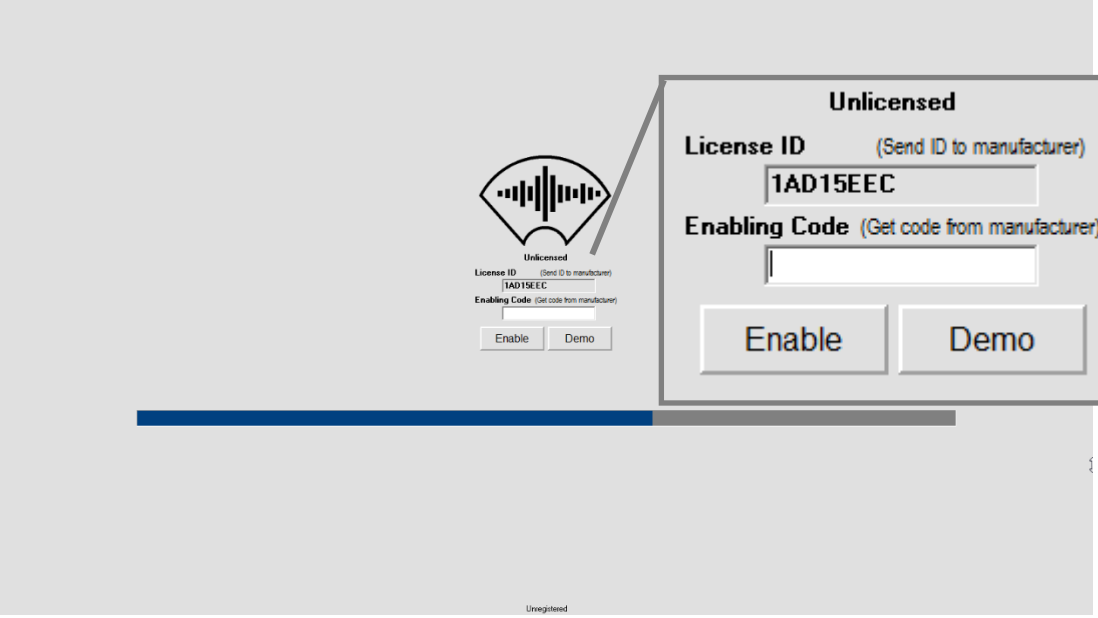
After installation the SonoSpeech™ application will be in the 'C:\SonoSpeech\' folder. The program can be run from the Windows Taskbar Start Menu ('**Start:Programs:ArticAsst:SonoSpeech**) or from a desktop icon.

REGISTERING SONOSPEECH (ACTIVATING THE LICENSE)

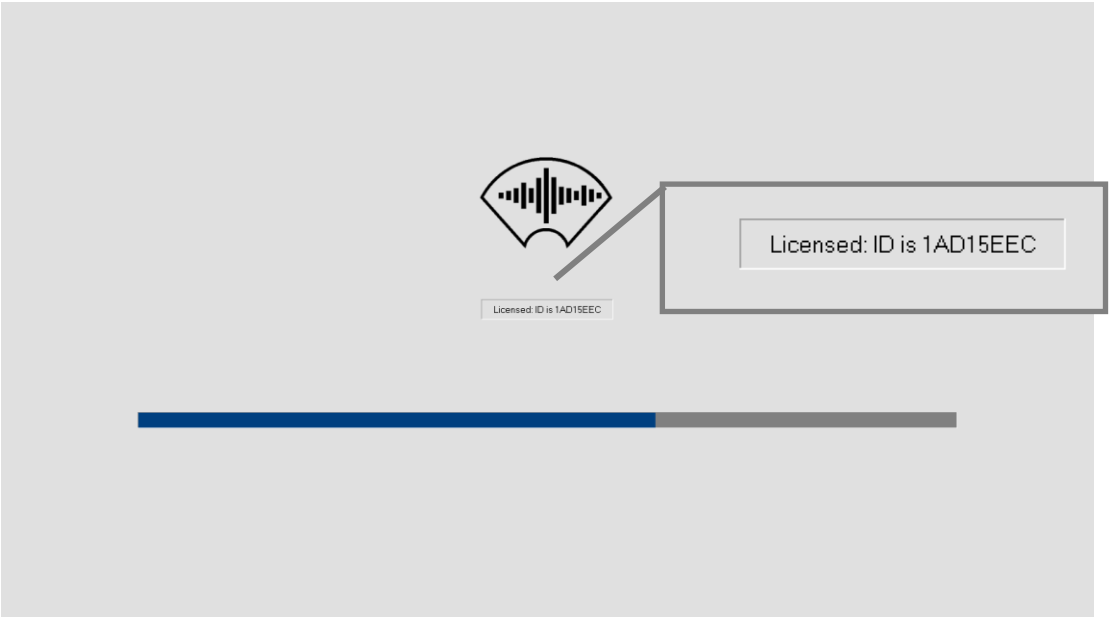
When SonoSpeech is run for the first time the startup screen will prompt for a registration code. If a license has been purchased then email the License ID to awrench@articulateinstruments.com. An enabling code will be sent by return email. Enter that code and click the Enable button. It is only necessary to do this once.

> **NB.** The License is locked to the computer that it is installed on. To install the application on a different computer will require purchase of another license.

Otherwise select the Demo button to continue in demonstration mode. It is not possible to see live ultrasound data in this mode but pre-recorded data can be viewed.



After registration is complete the SonoSpeech application must be restarted. The startup screen will then show the License ID. This is confirmation that the application is fully functional.



3 USING THE SONOSPEECH™ APPLICATION

SOFTWARE FEATURES

- **Simple data management**. The software automatically manages files, grouping files according to client and session without the need to open, save or name individual files.
- **Client-based**. Each client's data is stored in an individual folder in an encrypted form.
- **Easy to use.** The software comes with an intuitive interface designed to be easy to operate for non-technical users. (But we are always open to suggestions to make it even easier)
- **Flexible**. The display can be configured to include only the windows that are needed for the task in hand.
- **Encouraging.** Best attempts in a previous session can be labelled and recalled to give client the confidence that the target sound is achievable. Rewarding animations can be played after successful attempts. Symbols and colours can be chosen to mark target positions for the tongue.
- **Compatible.** Data recorded using SonoSpeech can be read by AAA software that researchers can use to study speech in more detail.

OVERVIEW

SonoSpeech™ is a full-featured interface for the Micro or EchoB ultrasound systems running on Windows 7/8/10. SonoSpeech™ is designed to allow Speech & Language Therapists to record, review and assess ultrasound images produced by their clients.

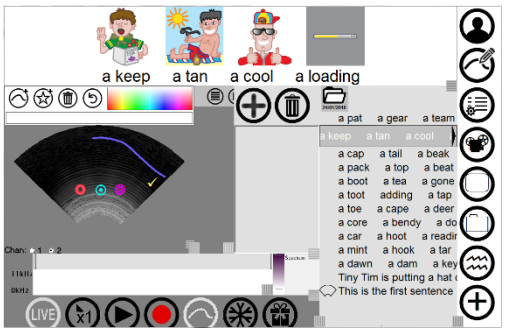
Sonospeech™ also has features which may be helpful when using the live visual display for clinical intervention including the following:

- Overlays showing palate position and markers for where the tongue should be placed (and not placed)
- Pre-recorded template videos of key target sounds which may be played to demonstrate typical tongue position and movement for the target sound being treated.
- The ability to save and recall the client's own best effort from the current or previous session.
- A reward animation which can be played to encourage the client

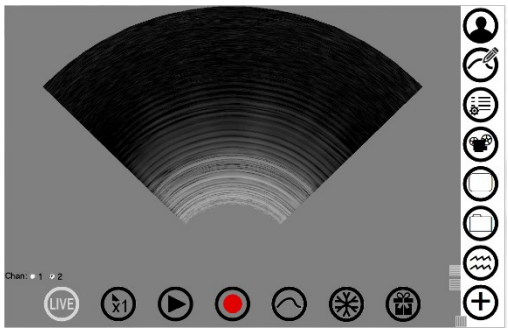
Sonospeech™ may be operated by a touch screen or a mouse whichever is most convenient.

Managing the appearance of the application

The buttons down the right side of the application allow all windows (apart from the ultrasound display) to be hidden, simplifying the display.



All windows showing



All windows hidden

Clicking one of these buttons toggles between showing and hiding the corresponding display.

Adjusting the size of windows

Click and drag a grabhandle  with horizontal stripes to change the height of a window

Click and drag a grabhandle  with vertical stripes to change the width of a window

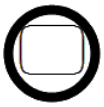
What the buttons do

Show client selection display


Show palate and marker overlay editor


Show word list editor


Show exemplar display


Show prompt display


Show currently loaded wordlist


Show spectrogram


Show additional buttons


Close application (Only on Client window, click  first)

THE BASICS

Loading a Client

The first thing to do when the program is started up is to select an existing client or create a new one. Each new client is given a code number automatically. A client name is added by the clinician and displayed beneath the code number (**Error! Reference source not ound.C**). The first time the program is started, only the demo client 'Ultrax_02TD1M' is

visible. If a new client is to be recorded then the '**Add new client**' button ⊕ must be clicked (**Error! Reference source not found.C**)

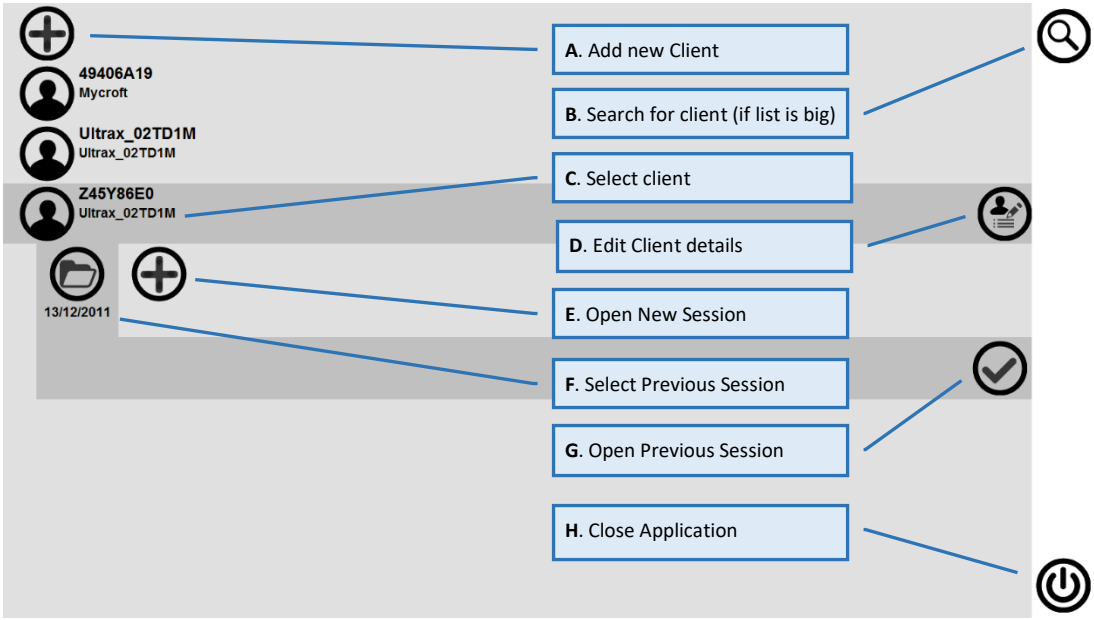


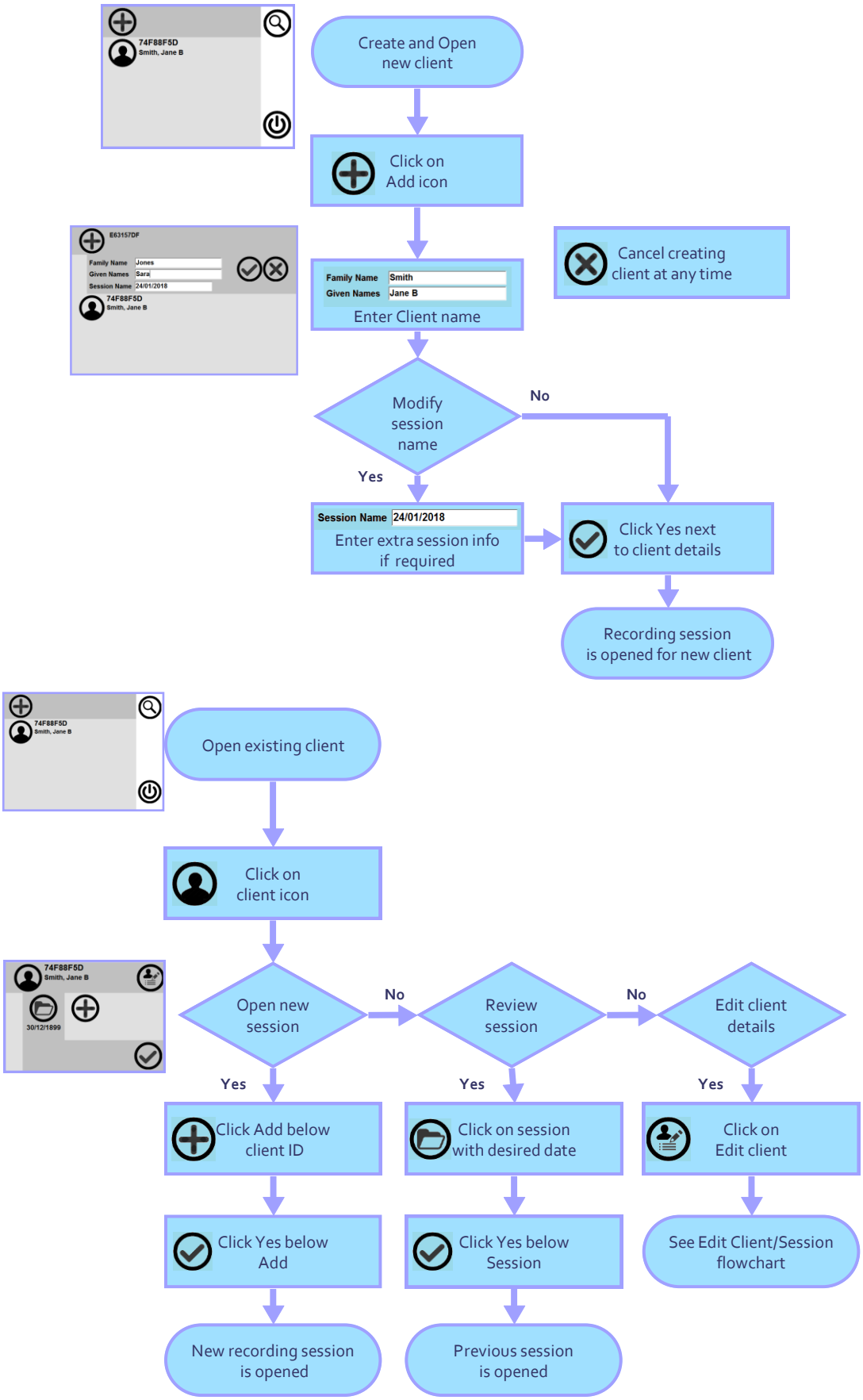
Figure 1 Client window: Create and open client sessions

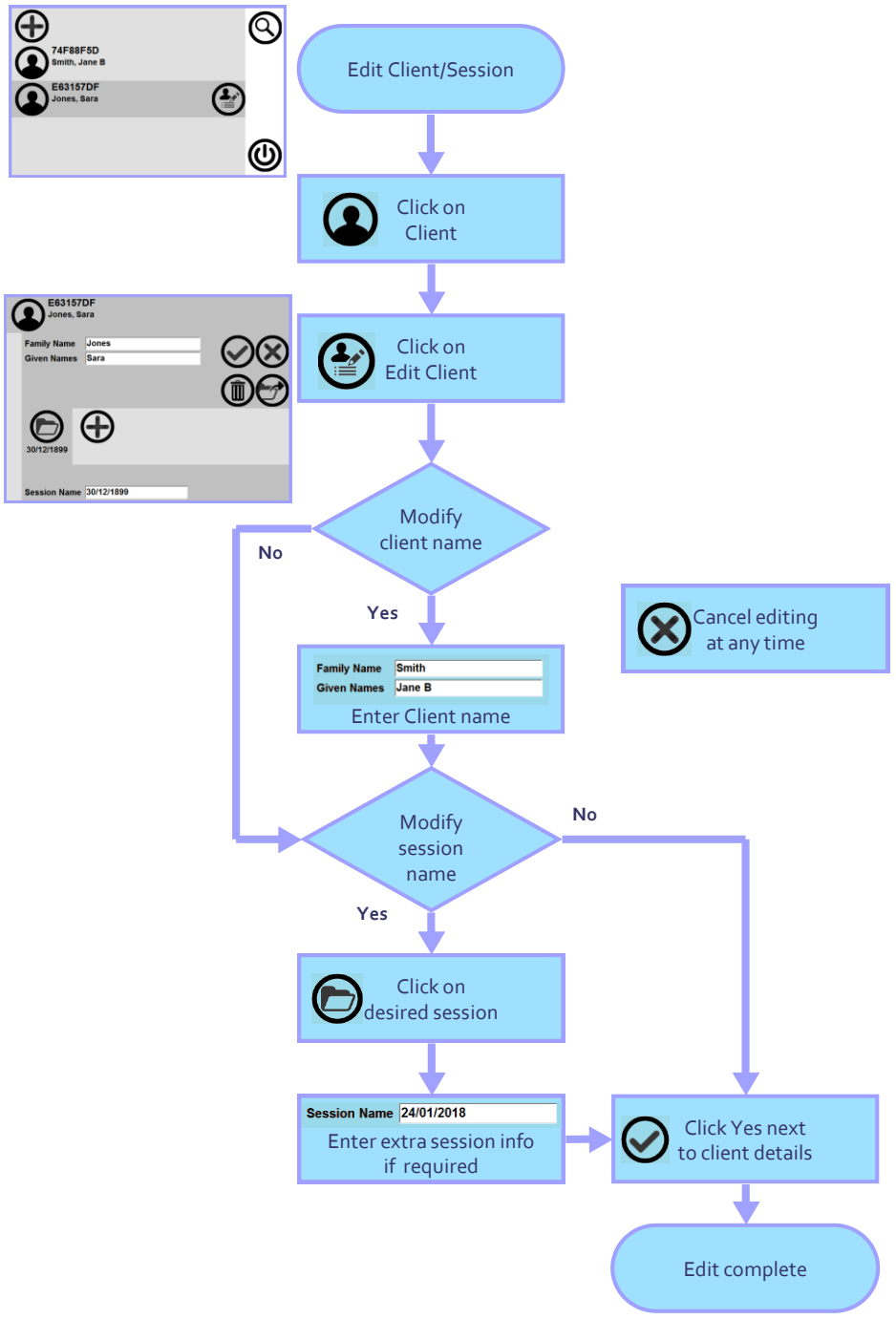
and their details typed into the client editor. The client name can be edited at any time using the '**Edit Client Details**' button .

Refer to the following flowcharts to:

- Create a new client
- Open an existing client to review a past session or record a new session
- Edit the Client name or session name

> **NB.** The date of the recording is automatically provided as the session name. It is advisable to retain the date if the session details are revised. E.g. 13/12/2011 Pre-therapy 1

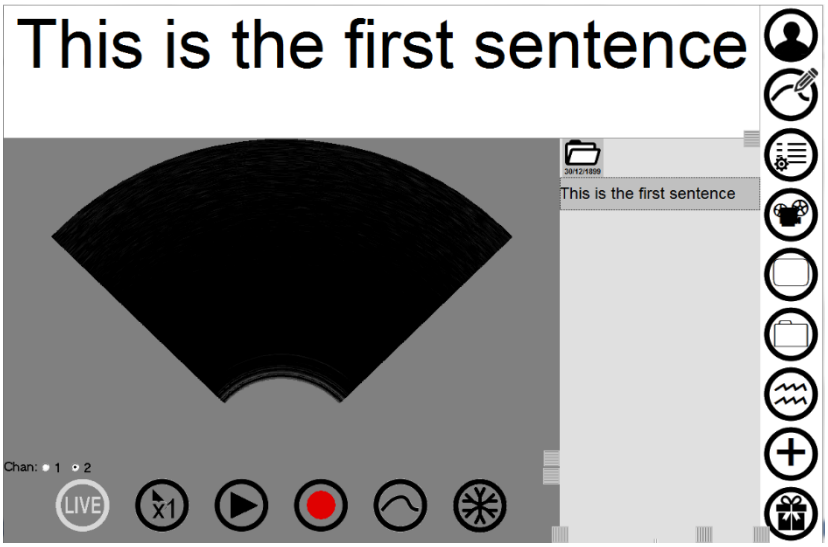

74F88F5D
Smith, Jane B
Create and Open new client
Click on Add icon
E63157DF
Family Name Jones
Given Names Sara
Session Name 24/01/2018
74F88F5D
Smith, Jane B
Family Name Smith
Given Names Jane B
Enter Client name
Cancel creating client at any time
Modify session name
No
Yes
Session Name 24/01/2018
Enter extra session info if required
Click Yes next to client details
Recording session is opened for new client
74F88F5D
Smith, Jane B
Open existing client
Click on client icon
74F88F5D
Smith, Jane B
30/12/1899
Open new session
No
Review session
No
Edit client details
Yes
Yes
Yes
Click Add below client ID
Click on session with desired date
Click on Edit client
Click Yes below Add
Click Yes below Session
See Edit Client/Session flowchart
New recording session is opened
Previous session is opened



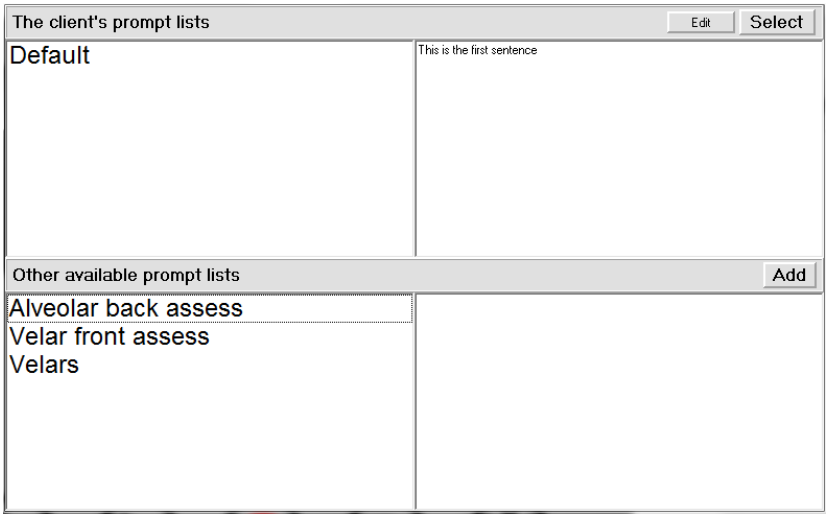
NB. All the client details and data files created in 'SonoSpeech™' are automatically saved.

Loading a wordlist

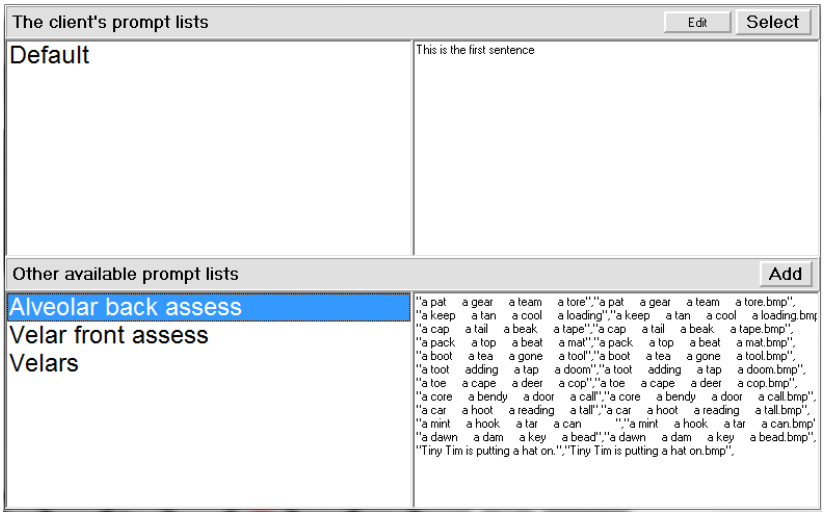
To record a client, an appropriate wordlist should be loaded.



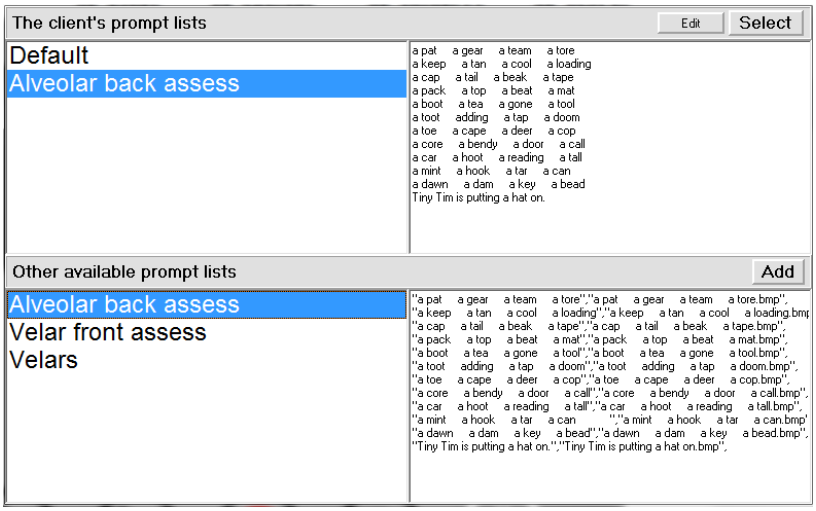
Click the Edit/Load prompts icon  to open the wordlist dialogue.



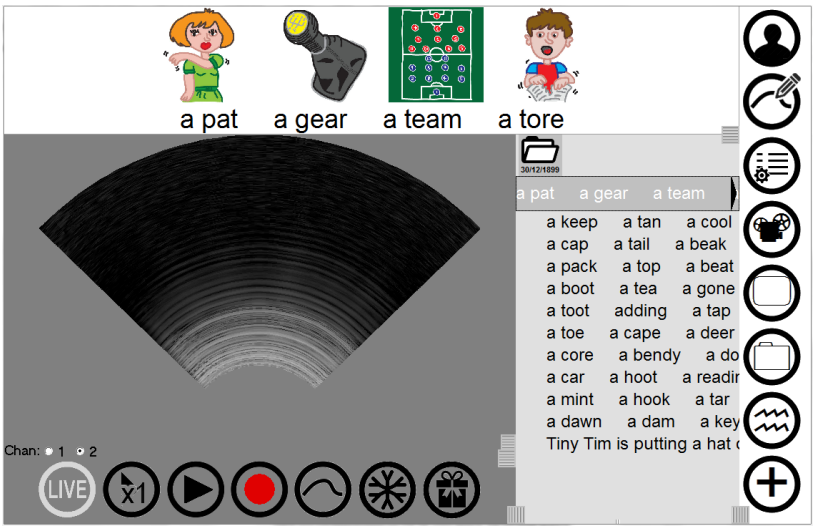
If the desired wordlist is not in the top left panel click on one of the available word lists in the bottom left panel and click Add



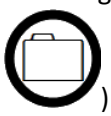
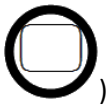
Then select the wordlist in the top left panel and click 



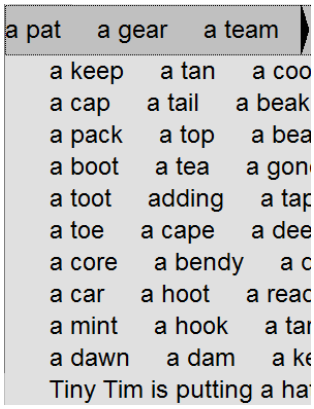
The wordlist editor will disappear and the selected wordlist will be available to start recording.



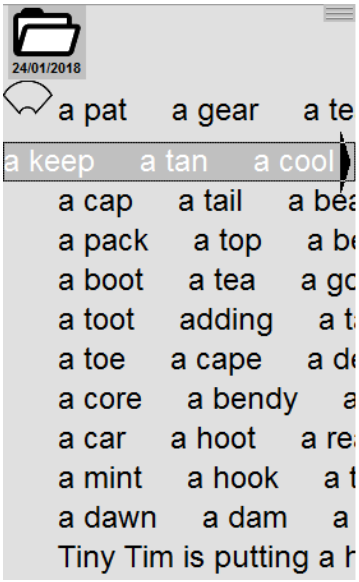
Recording a wordlist

Making a recording is easy. Configure the display so that the word list is visible on the right side (click ) and the prompt screen is visible at the top (click ).

Select the prompt that you want the client to read by clicking on the appropriate line in the list of prompts.



Once the correct prompt is showing click record  to start recording and stop  to stop recording. Nothing else to do. The recording is automatically saved and shows up as an  icon at the start of the line in the prompt list.



NB. Start with the first prompt in the list and the application will automatically move on to the next prompt after stopping the recording.

Playing back a recording

Recordings can be reviewed by clicking on the  icon next to the prompt to load that recording. The icon turns white  to indicate that it is selected. The recording can then be played by clicking the play  button.

Playing back more slowly

Click the 

button once to change icon to 

and set playback speed to half.

Click a second time to change icon to 

and set playback speed to a quarter. Click a third time to reset back to normal playback speed (icon resets to 

).

After setting the playback speed simply click the play button to play back at the selected speed.

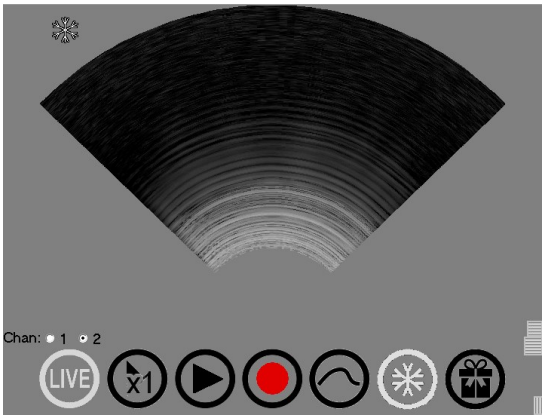
Using the live feedback display (freezing)

When a client is loaded and if the ultrasound is connected then the ultrasound display will show a live image when the probe is in position. The live button 

will be light grey to indicate the display image is live. If the ultrasound is disconnected then the image should appear shortly after connecting.

> **NB.** It is OK to connect the system or change probes while SonoSpeech is running.

To freeze the image, click the freeze 
button. The button will turn light grey 
and a freeze symbol will appear at the top left corner of the ultrasound image.



Click the freeze 
button to unfreeze the display.

If a recording is loaded, the display will not respond to the probe and the live image button will be black 

rather than light grey. To return to a live image display simply click the Live button.

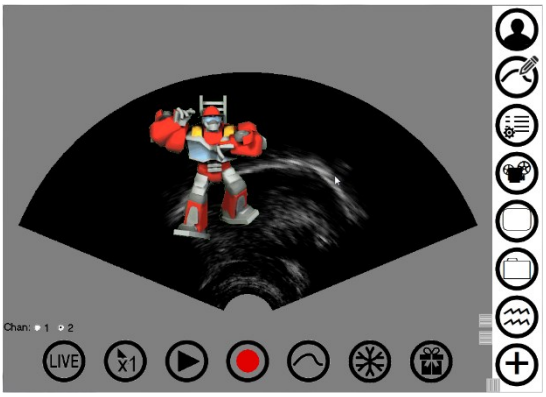
Playing a reward animation

Click the reward  button to start playing an animated gif on top of the ultrasound display after a successful attempt or when the client needs encouragement.

Click the reward  button to stop playing the animated gif

A random gif is played each time.

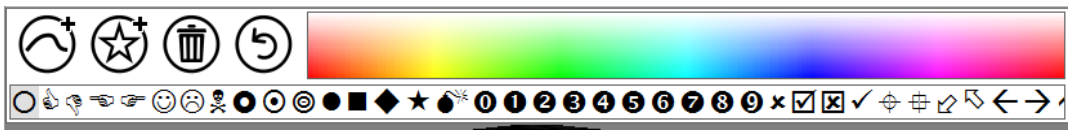
A number of animated gifs with transparent backgrounds are stored in the C:\SonoSpeech\GIFS\ folder. Gifs in this folder can be deleted or new transparent animated gifs can be added by the clinician as judged appropriate.



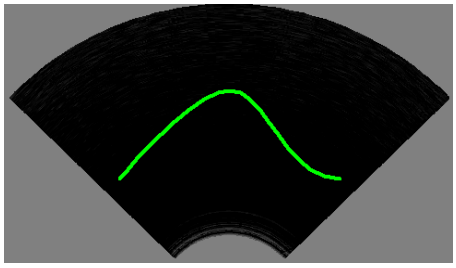
ULTRASOUND DISPLAY OVERLAYS

Creating a palate trace

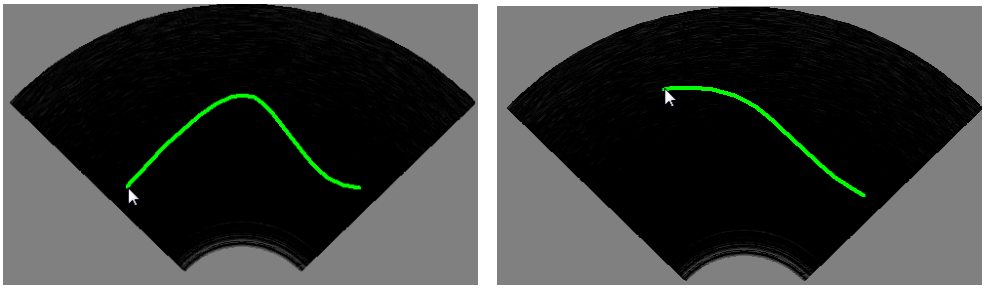
To add or delete markers and palate traces, click the marker editor  button. The marker editor dialogue will appear as a strip across the top of the ultrasound display.



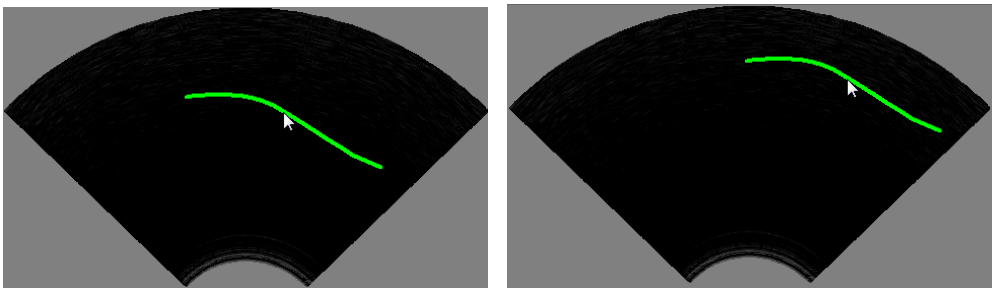
Click the add palate button  in the marker dialogue to add a palate.



Click and drag the ends and the middle of the palate curve in order to change the shape.

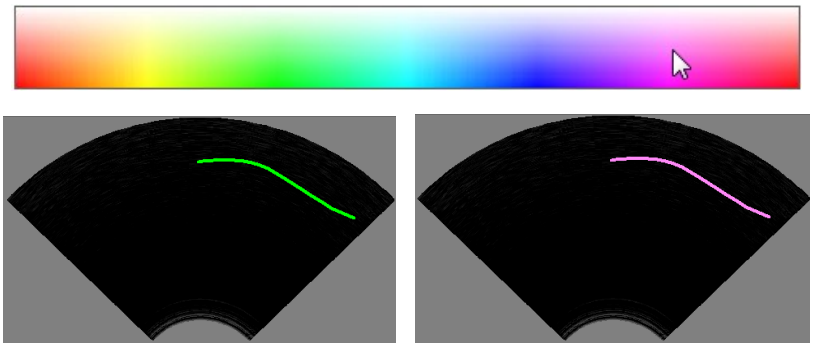


Right-click and drag to move the palate without changing the shape. Tap and hold then drag on a touch screen.

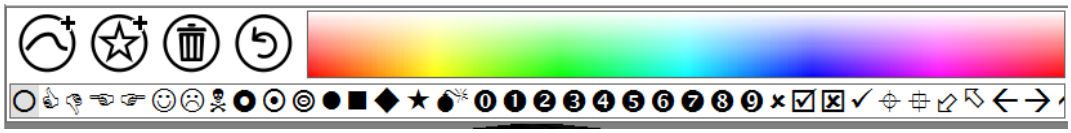


Change palate or marker colour

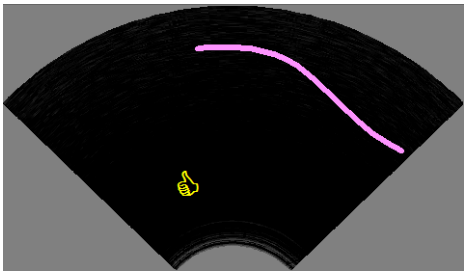
To change the colour of a palate or marker, select the palate or marker and then click on the colour chart.



Creating a marker



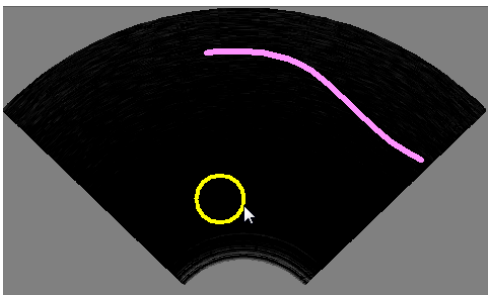
Click the add marker button  in the marker dialogue to add a marker symbol.

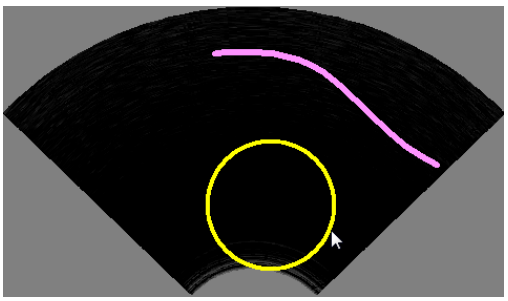


Click and drag to move the marker to the desired location.

To change symbol, select the marker and click on symbol in mrker dialogue.

The circle symbol (first symbol in dialogue) is special. The radius of the circle can be changed. **Click and drag** the edge of the circle to change the radius and move it.





Selecting a palate or marker

To select a marker to change its colour or symbol, click on it first then change the colour or symbol.

Deleting a palate or marker

To delete a palate or marker, select it and click the delete button  in the edit markers dialogue.

Saving a palate or marker (= closing the editor)

Click the marker editor button  to close the dialogue and save the changes.

NB. A unique set of markers is saved for each client.

Cancelling (undoing) changes to palate or markers

While in the editor it is possible to cancel all of the changes made during the current edit (i.e. before closing the editor). To cancel click the undo button.

Hiding/showing markers

Click the marker hide button below the ultrasound display to hide the palate and markers. Click the marker show button to show the palate and markers.

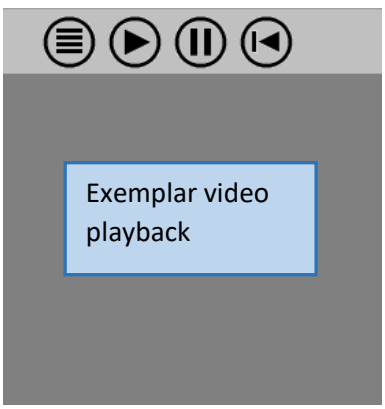
NB. If the hide/show button looks like this then the markers are active and if no markers are visible it is because they have not been created for that client.

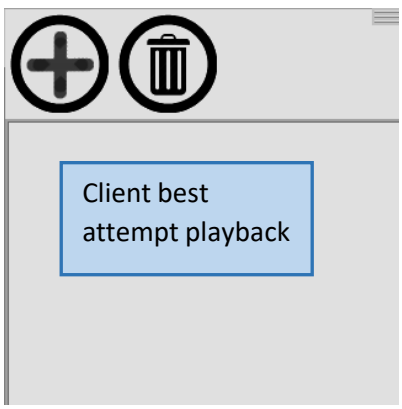
USING EXEMPLARS

Show/hide the exemplar window

The exemplar window can be shown and hidden using the exemplar button on the right side of the application. The exemplar window has two parts:

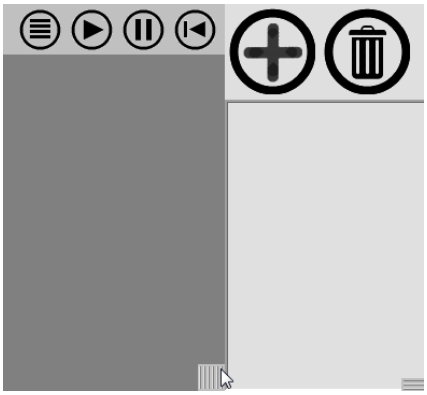
- A window for playing videos of typical productions.
- A window for selecting previous best attempts by the current client.

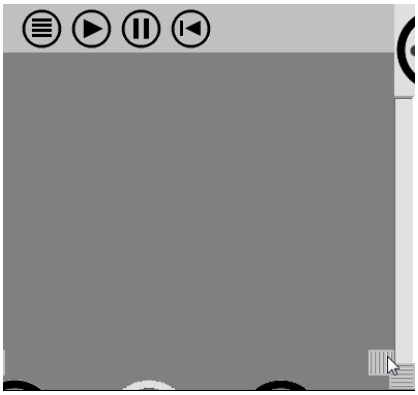




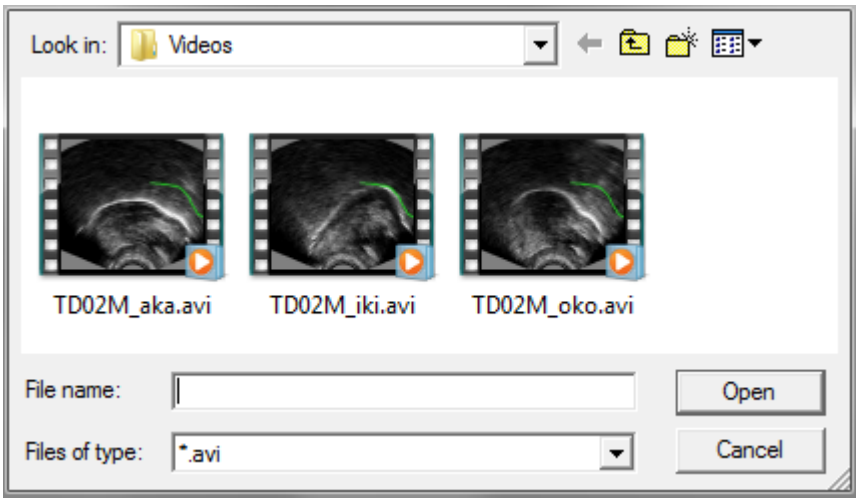
Loading and playing an exemplar video

First make the make the exemplar video window bigger. To do this click and drag the grabhandle  at the bottom centre of the exemplar window towards the right.

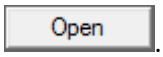




Click the open load  button.

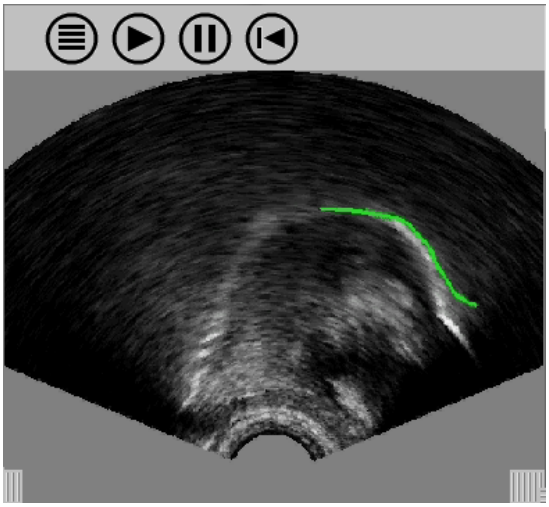


Exemplar videos are stored in the C:\SonoSpeech\Videos\ folder. New exemplar videos can be added there.

Select the desired exemplar video and click 

.

The selected video will appear in the window.



Click the play  button to play

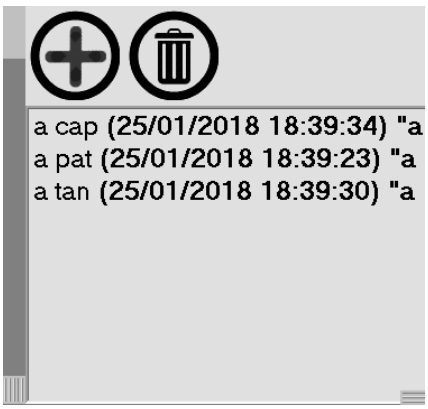
Click the pause  button to pause.

Click the rewind  button to rewind to start of video.

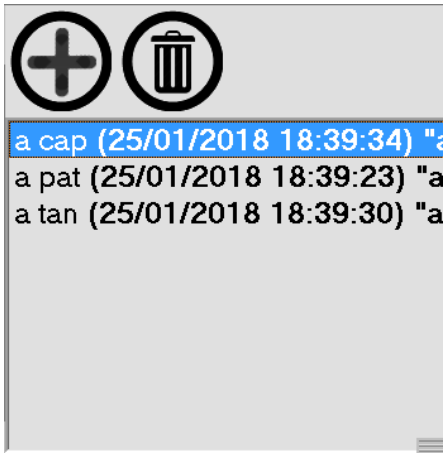
NB. With short exemplar videos it is usually only necessary to use the play button. The video will rewind automatically when it reaches the end.

Loading and playing client's best attempt

First make the make the clients best attempt window bigger. To do this click and drag the grabhandle  at the bottom centre of the exemplar window towards the left.



Select an attempt from the list.



This loads this previously annotated recording into the ultrasound display which then can be played with the play button beneath the ultrasound display (see Basics section).

See the Spectrogram section for how to add entries to this list with the add button.

Click the delete button to delete any entries that are no longer required.

CREATING EXEMPLARS - THE SPECTROGRAM WINDOW

Show/hide the spectrogram window

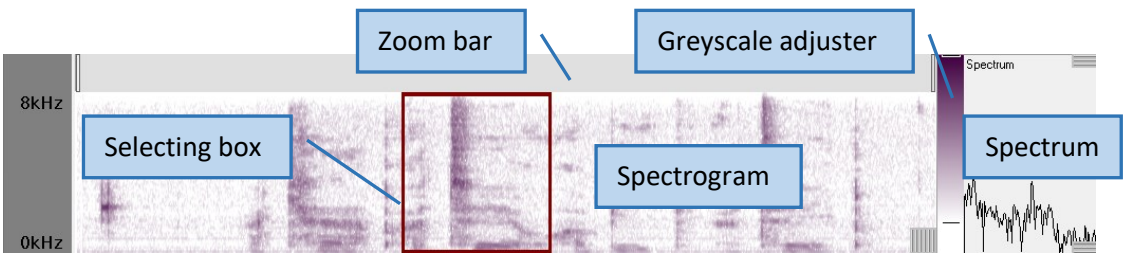
The spectrogram window can be shown and hidden using the spectrogram button on the right side of the application. The apectrogram window has one main function:

- Find and select part of a recording (e.g. a single word from a set of 4) so that it can be saved as a best attempt of the client.

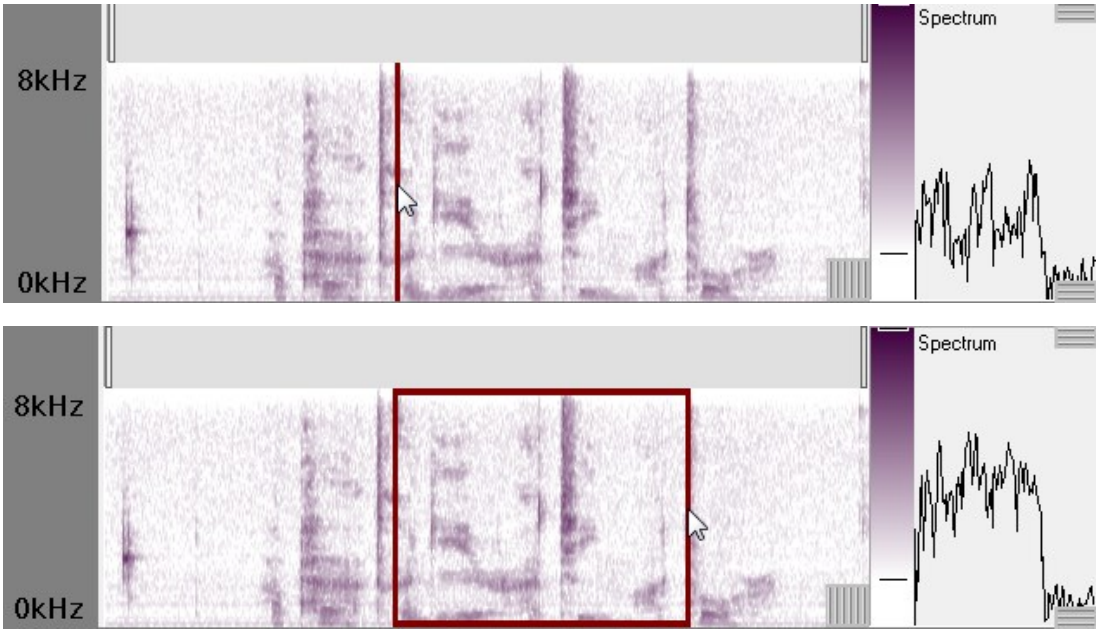
Selecting a region of the recording

The spectrogram window has:

- A spectrogram
- A zoom bar
- A selection box
- A spectrum
- A greyscale adjuster



Click on the spectrogram at the startpoint of the region to be selected and drag horizontally to the endpoint. This will create a red rectangle defining the selected region.

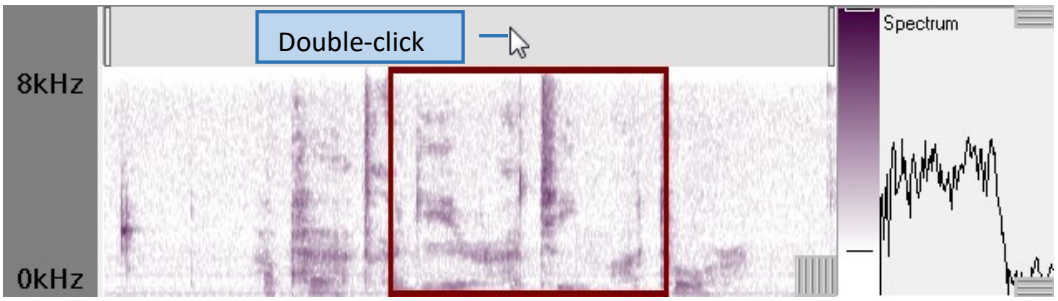


Click the play  button to listen to the selected region.

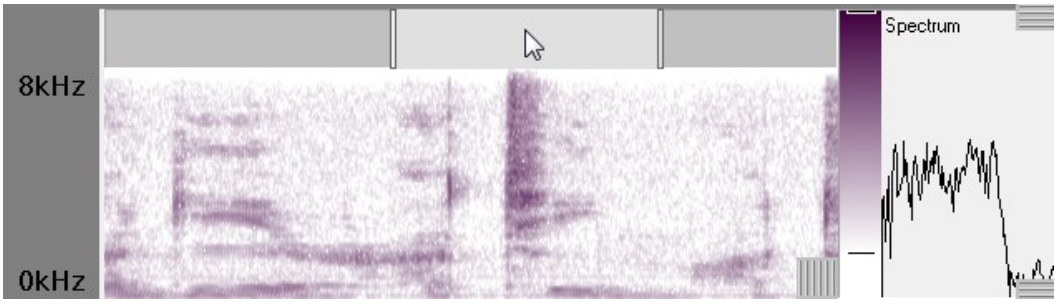
Tip. Select a wider region that should contain the word. Then zoom in to make it easier to select the word more accurately.

Zooming in

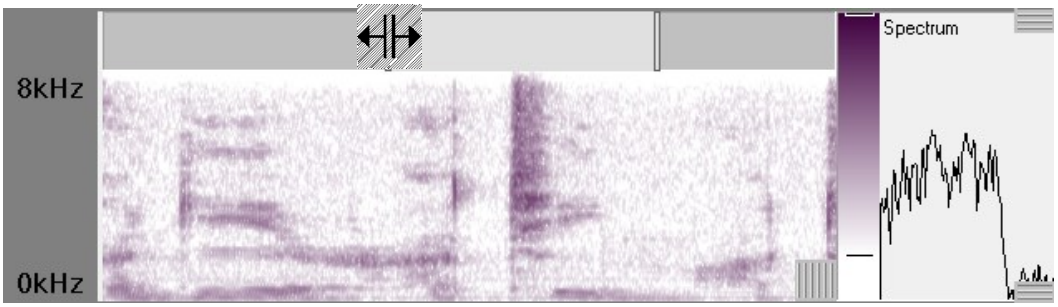
Select a region then double-click on the zoombar above the selected region.



Cursors on the zoombar will move to indicate the zoomed region and the spectrogram will show only the zoomed region.

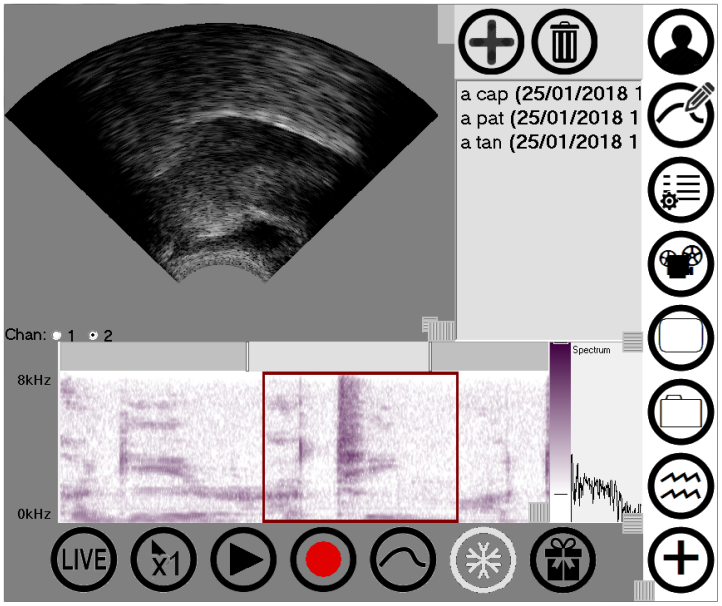


It is also possible to click and drag each cursor to adjust the zoomed region.



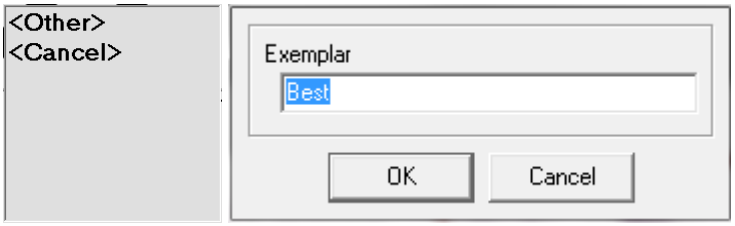
Creating a best attempt exemplar

Make sure the spectrogram window and the exemplar window are visible.

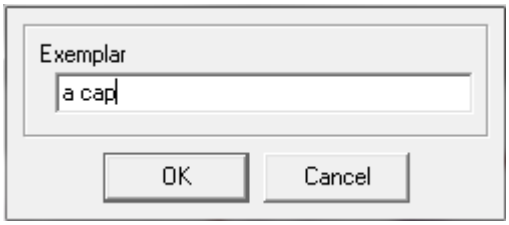


Select the word in the spectrogram and click on the add button in the exemplar window.

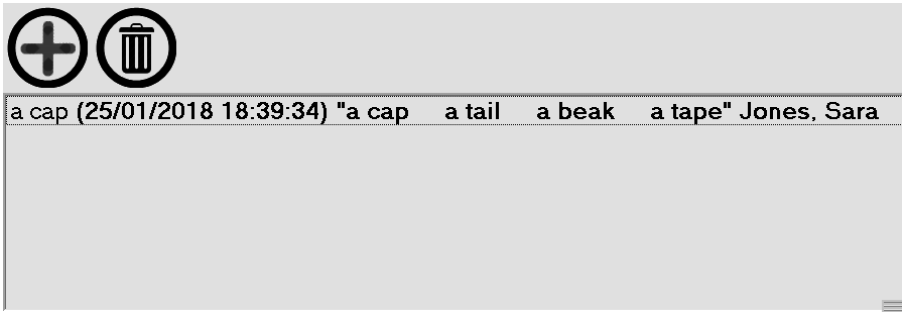
Click <Other>



Type in the word. This is the text that will appear in the list.



The new exemplar will appear in the list along with details of when it was recorded.



SETTINGS

Show the settings buttons

Click the Extra  button at the bottom right of the application to reveal an extra set of buttons. Click again to hide the extra buttons. The extra buttons are:

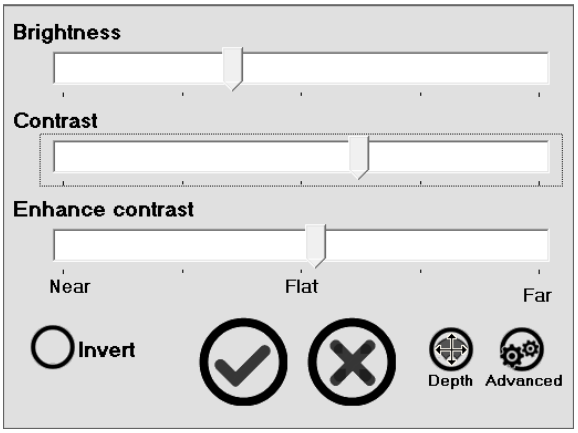
 Ultrasound display settings

 General settings

 Audio Settings

Set ultrasound brightness and contrast

Click on the ultrasound settings  button.



Use sliders to control brightness and contrast.

Brightness is typically set between ¼ and ½ full scale.

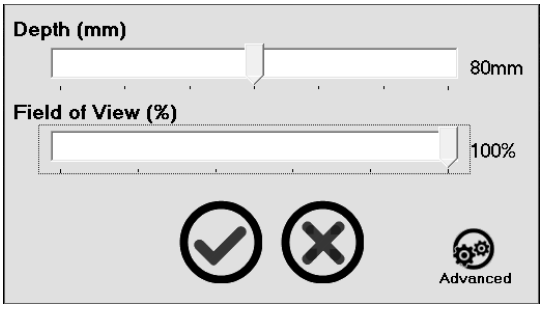
Contrast is typically set between ½ and ¾ full scale

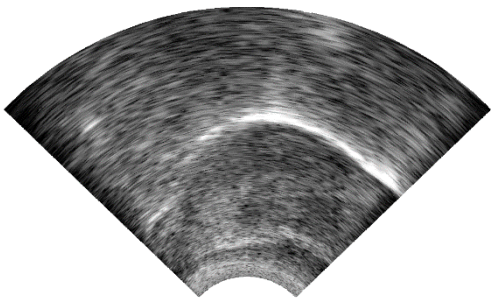
Enhance contrast accentuates the relative contrast near the probe or far from the probe. Typically this will be set flat or slightly towards the **Far** end.

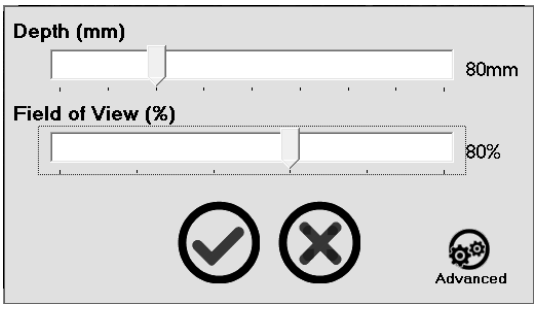
Change ultrasound depth and field of view

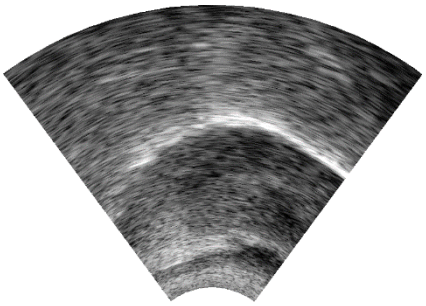
Click the depth  button to show the depth and field of view dialogue.

Field of view narrows or widens the angular extent of the image.

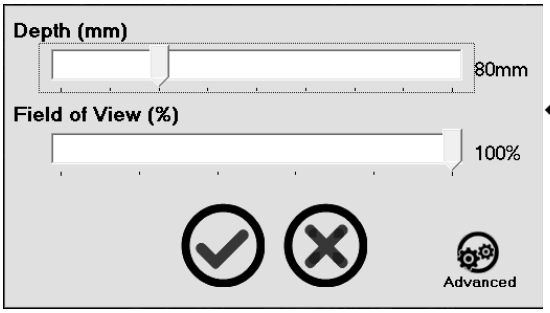


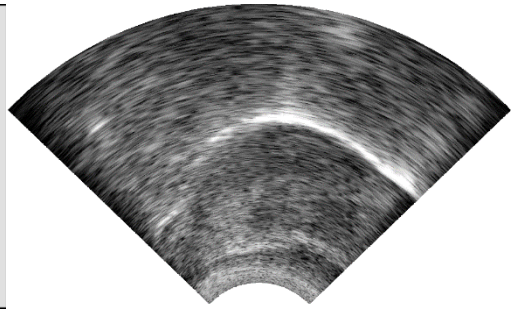


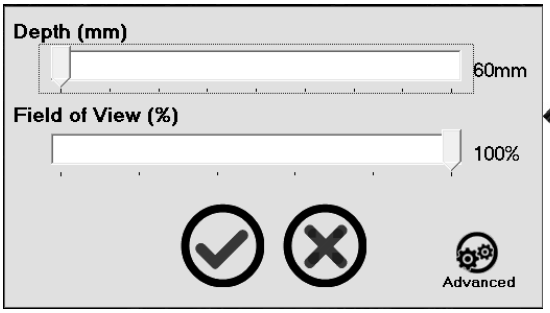


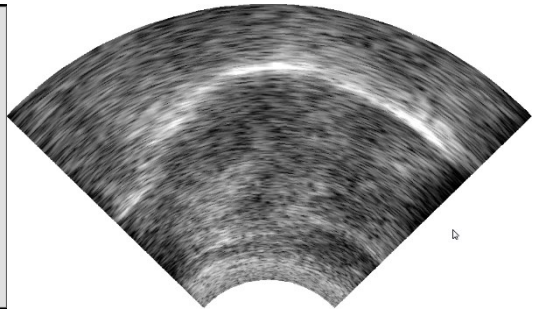


Depth alters the maximum displayed depth









Tip. Recommend Depth 80 and Field of view 100%

General settings

There is no need to change the general settings.

Audio settings

There is no need to change the audio settings.

4 TROUBLESHOOTING

To be updated in due course

INDEX