



**Trinity  
College  
Dublin**

The University of Dublin

Phonetics & Speech Lab

School of Linguistic, Speech &  
Communication Sciences

## **ABAIR.ie:**

Irish Text-to-Speech Synthesis & the Wider Implications of Speech  
Technology for the Maintenance of Endangered Languages

**Ailbhe Ní Chasaide**

British-Irish Council Technology Conference

09/11/15

# The Voices

## Donegal (Gaoth Dobhair)

- Female; Unit-selection voice

Cá mé i mo shuí ó d'éirigh an ghealach aréir,  
a's cur tine síos san scíth is á fhadú go géar,  
cá bunú an tí ina luí is cá mise liom féin,  
cá na coiligh a's glaoch,  
is cá an saol mór ina chodladh ach mé.



Images by Liamfm. @ Flickr.com. Many thanks.

# TTS - Voices available at [www.abair.ie](http://www.abair.ie)

ABAIR = 'say/speak'

**abair.ie**

An tSaotharlann Foghraíochta agus Urlabhra  
Scoil na nEolaíochtaí Teangeolaíochta, Urlabhra agus Cumarsáide  
Coláiste na Tríonóide

Gaeilge English

Baile Eolas Fúinn Sintéis Áiseanna Teagmháil Rochtain Breiseán NVDA

**Fáilte go abair.ie – An Sintéiseoir Gaeilge**  
*An Focal Scríofa go Caint Bheo!*

Gaoth Dobhair Conamara Conamara HTS Corca Dhuibhne HTS Eolas

éist  
íoslódáil  
fogharscríobh

Maoinithe ag  
An Roinn Ealaíon,  
Oidhreacht agus Gaeltachta

Cuir téacs isteach anseo...

Déan sintéis

Dubh ina bhán

Luas Gnáthluas

Uasmhéid na gcarachtar: 2000. Méid carachtar fágtha: 2000

Clliceáil anseo le síneadh fada a chur leis.

# The Team

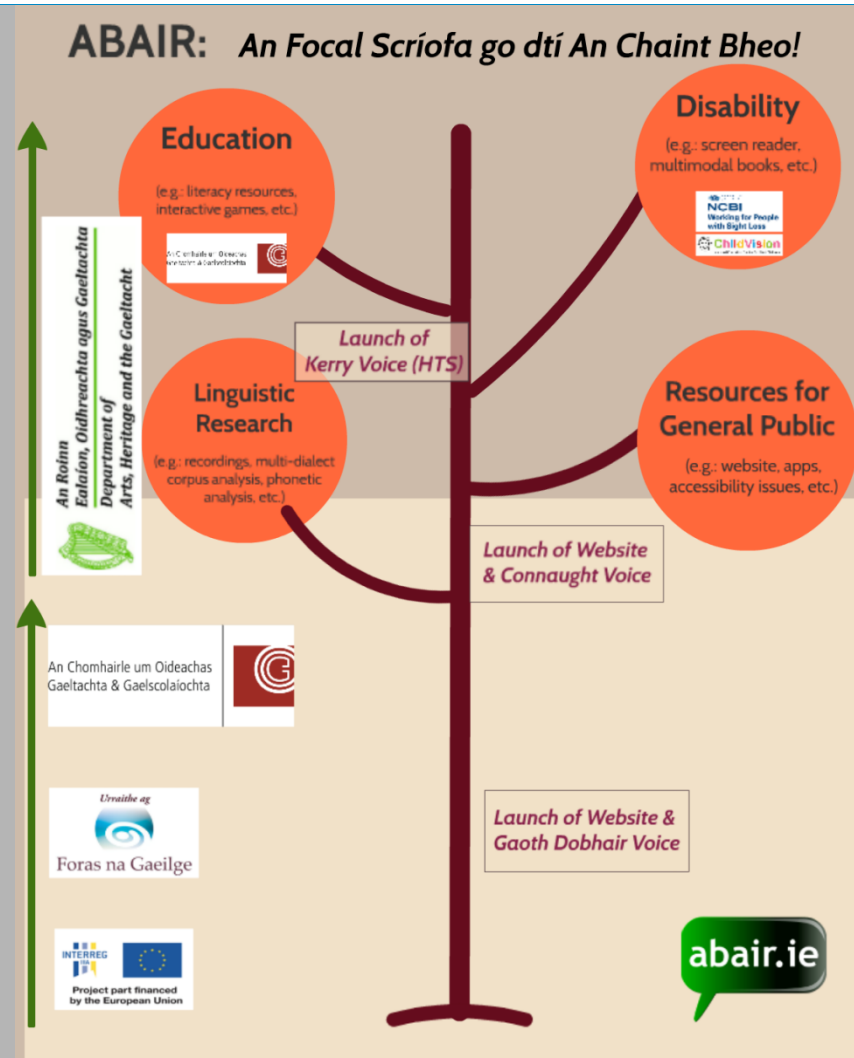
The Phonetics and Speech Lab, TCD





# Background of ABAIR Initiative

## Funding



# The ABAIR Initiative: 3 types of research activity

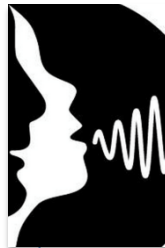
([www.abair.ie](http://www.abair.ie))

## Documentation



**(1) Building resources:**  
the phonetic-linguistic  
components

## Preservation



**(2) Core technology -**  
- the TTS system

## Revitalisation



**(3) Applications**

# Speech Technology - Endangered Languages

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*Technology → Globalisation of Culture → Language Loss*

*..but, properly harnessed, also huge potential for*

*→ Documenting → Preserving → Revitalising*

# Speech Technology - Endangered Languages

## *Requires*

### Cooperation of phonetician-linguist & technologist

### Understanding of minority language, its context and needs

- **very specific challenges** for technology development
- **different priorities** from the typically commercial concerns that drive development in the major languages
- **Non-mainstream '*solutions*'** often best meet the challenges/priorities

### Vision of where it can impact

- areas of impact/benefits - not same as in major languages
- envisaged uses (users) should drive priorities in development



# Irish: a Celtic Language

## Q-Celtic

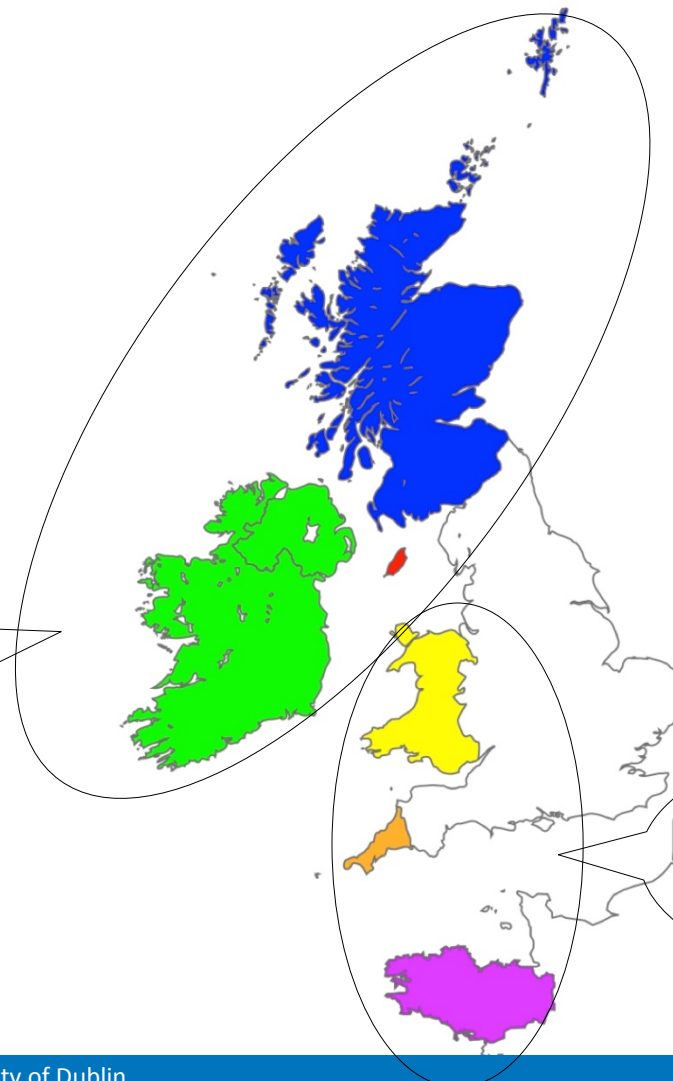
*Irish*  
*Scots Gaelic*  
*Manx*

*“ceann”*

## P-Celtic

*Welsh*  
*Breton*  
*Cornish*

*“penn”*

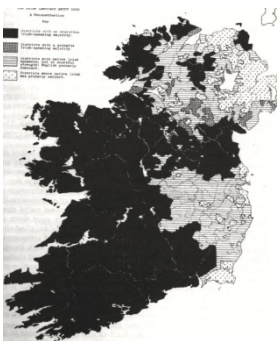


# The Irish Context

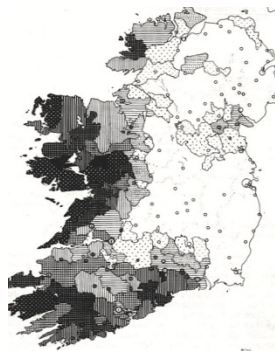
1800 -> 1956

- Endangered
- Decline – especially in last 150 years

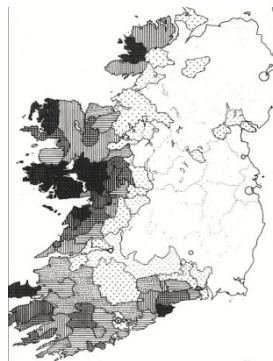
1800



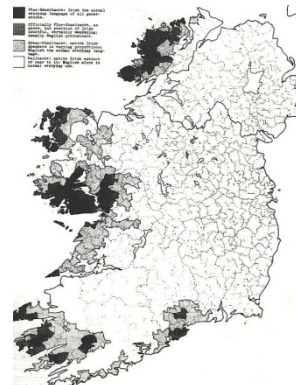
1851



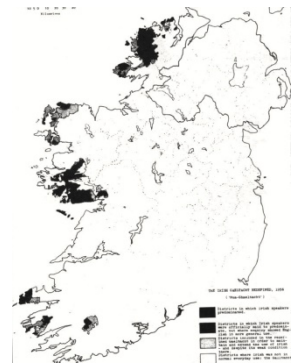
1891



1926



1956



# The Irish Context

## The Present Situation

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### Endangered: **\*Problem of Transmission\***

- A community language only in '*Gaeltacht*' areas
  - Even there, only c. 24% of population are regular speakers
  
- Scattered: 3 major dialects
  - Geographically separated
  - Often large phonological, morphological & syntactic differences
  - No spoken standard variety

# The Irish Context

## The Present Situation

---

### However, on the positive side:

- First official language (State support): school subject -> age 18
  - Irish language education → many challenges
- Many speakers outside the *Gaeltacht*
- Irish medium schools increasingly popular
- Education – critical to survival



# ABAIR: building synthetic voices: 3 activities

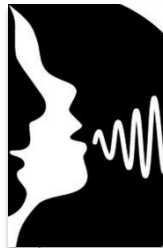
## 1. Building Resources/Components of TTS -> Documentation

### Documentation



(1) Building the phonetic-linguistic components

### Preservation



(2) Core technology -  
- the TTS system

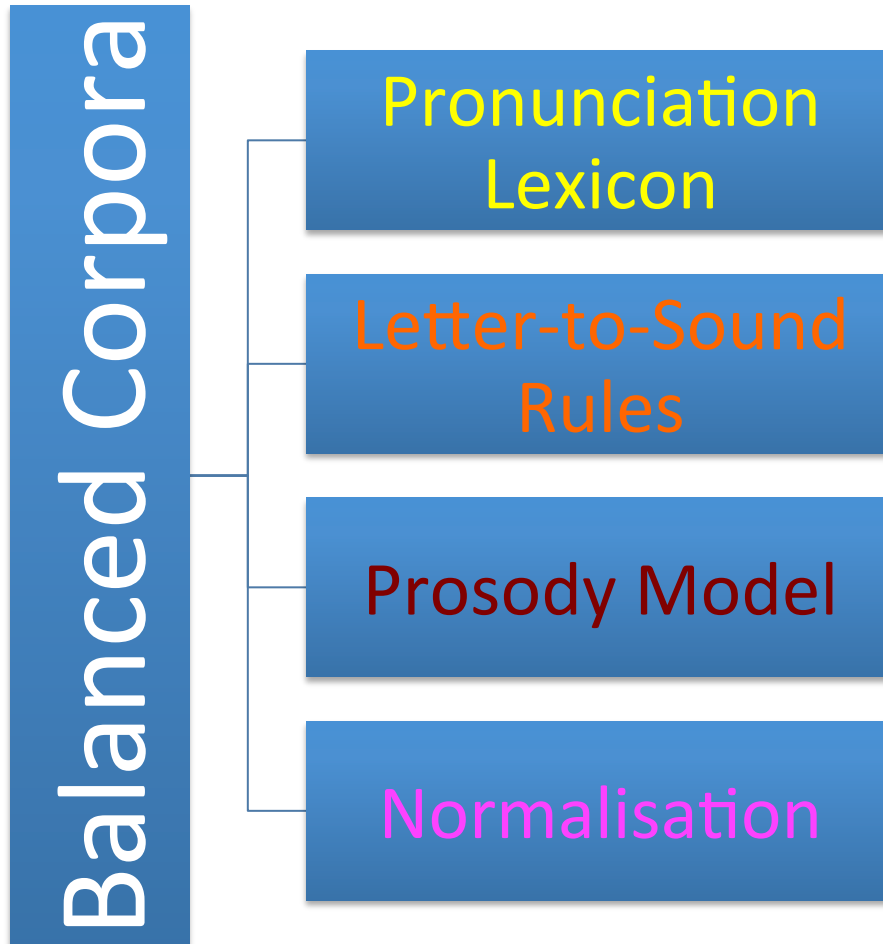
### Revitalisation



(3) Applications

# Building the Text-to-Speech system

## 1. Building Resources/Components of TTS -> Documentation



- many resources not available (or not fit-for-purpose)
- important documentation of language structure

# Pronunciation Lexicon

- **No standard spoken variety:** 3 main dialects
  - So, multidialect TTS planned from outset
- **No dialect-specific pronunciation dictionary**
  - the pocket lexicon, *An Foclóir Póca*
    - proposes ‘standard’, (*Lárchanúint* - *Middledialect*) forms compromise – using bits of all dialects
    - not fit-for-purpose
    - no native speakers of *Lárchanúint*
    - no possible corpus

# Pronunciation Lexicon

Headwords = root forms

other inflected forms?

Mutations: initial consonants inflect [k] → [x] → [g]

e.g., verbs mutate in question and negative forms

**Cuir** 'put' initial [k]; **Druid**, 'close' [d̪]; **Glac**, 'take' [g]

Positive	Negative	Question
[k] <b>C</b> uireann sí. 'She puts'	[x] Ní <b>ch</b> uireann sí. 'She does not put'	[g] An <b>g</b> uireann sí? 'Does she put?'
[d̪] <b>D</b> ruideann sí. 'She closes'	[ɣ] Ní <b>dh</b> ruideann sí. 'She does not close'	[n̪] An <b>nd</b> ruideann sí? 'Does she close?'
[g] <b>G</b> lacann sí. 'She takes'	[ɣ] Ní <b>gh</b> lacann sí. 'She does not take'	[ŋ] An <b>ng</b> lacann sí? 'Does she take?'

14 inflected versions of verbs



# Pronunciation Lexicon

- **Built own dialect-appropriate versions**
- **Hand written approach**
  - machine learning (mainstream option) here unsuccessful

# Letter-to-Sound Rules

## Rich consonantal System

Contrasts pairs of **velarised (broad)** & **palatalised (slender)** consonants:

**/d<sup>ˠ</sup>/** **/d<sup>j</sup>/**

**/m<sup>ˠ</sup>/** **/m<sup>j</sup>/**

**/l<sup>ˠ</sup>/** **/l<sup>j</sup>/**

	LABIAL	DENTAL	ALVEOLAR	ALVEOLO-PALATAL	PALATAL	VELAR	GLOTTAL
PLOSIVE	p <sup>ˠ</sup> b <sup>ˠ</sup> p <sup>j</sup> p <sup>j</sup>	t <sup>ˠ</sup> d <sup>ˠ</sup>		t <sup>j</sup> d <sup>j</sup>	c    ɟ	k    g	
FRICATIVE/ APPROXIMANT	f <sup>ˠ</sup> w f <sup>j</sup> v <sup>j</sup>		s <sup>ˠ</sup>	ɸ	ç    j	x    ɣ	h
NASAL	m <sup>ˠ</sup> m <sup>j</sup>	n <sup>ˠ</sup>	n	n <sup>j</sup>	ɲ	ŋ	
TAP			r <sup>ˠ</sup> r <sup>j</sup>				
LATERAL APPROXIMANT		l <sup>ˠ</sup>	l	l <sup>j</sup>			

# Letter-to-Sound Rules

Contrast important to grammar

/ b<sup>y</sup>ad<sup>y</sup>/ vs. / b<sup>y</sup>ad<sup>j</sup>/

bád vs. báid ('boat' sing – plur)

	LABIAL	DENTAL	ALVEOLAR	ALVEOLO-PALATAL	PALATAL	VELAR	GLOTTAL
PLOSIVE	p <sup>y</sup> b <sup>y</sup> p <sup>j</sup> p <sup>j</sup>	t̪ <sup>y</sup> d̪ <sup>y</sup>		t̪ <sup>j</sup> d̪ <sup>j</sup>	c    ɟ	k    g	
FRICATIVE/ APPROXIMANT	f <sup>y</sup> w f <sup>j</sup> v <sup>j</sup>		s <sup>y</sup>	ɕ	ç    j	x    ɣ	h
NASAL	m <sup>y</sup> m <sup>j</sup>	n̪ <sup>y</sup>	n	n̪ <sup>j</sup>	ɲ	ŋ	
TAP			r <sup>y</sup> r <sup>j</sup>				
LATERAL APPROXIMANT		l̪ <sup>y</sup>	l	l̪ <sup>j</sup>			

# Letter-to-Sound Rules

Complex writing system

35 consonants → 13 Consonant letters in the Irish alphabet

	LABIAL	DENTAL	ALVEOLAR	ALVEOLO-PALATAL	PALATAL	VELAR	GLOTTAL
PLOSIVE	p <sup>y</sup> b <sup>y</sup> p <sup>j</sup> p <sup>j</sup>	t <sup>y</sup> d <sup>y</sup>		t <sup>j</sup> d <sup>j</sup>	c    ɟ	k    g	
FRICATIVE/ APPROXIMANT	f <sup>y</sup> w f <sup>j</sup> v <sup>j</sup>		s <sup>y</sup>	ç	ç    j	x    ɣ	h
NASAL	m <sup>y</sup> m <sup>j</sup>	n <sup>y</sup>	n	n <sup>j</sup>	ɲ	ŋ	
TAP			r <sup>y</sup> r <sup>j</sup>				
LATERAL APPROXIMANT		l <sup>y</sup>	l	l <sup>j</sup>			



# Letter-to-Sound Rules

## Complex writing System

### Consonant quality shown by sequences of vowel letters

palatalised **C** ← **e i**

velarised **C** ← **a o u**

So, a single vowel → appears to have many written forms

/i:/	í
	uí
	aí
	oí
	aoi
	íó
	aíó
	uíó

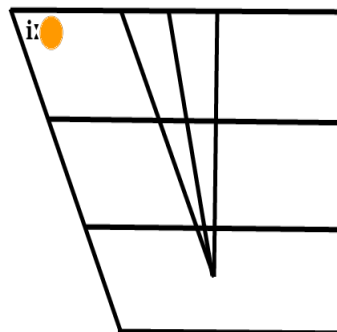
# Letter-to-Sound Rules

## Complex writing System

/i:/	í	sí
	uí	suí
	aí	claí
	oí	cloí
	aoi	caoi
	íó	díol
	aíó	maíomh
	uío	bruíon

/i:/

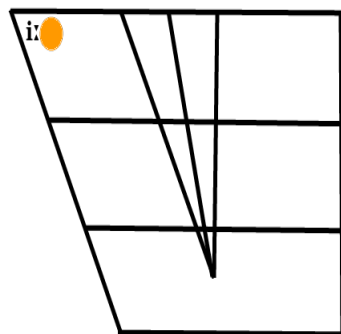
Cj-



í	sí	/sʲi:/
---	----	--------

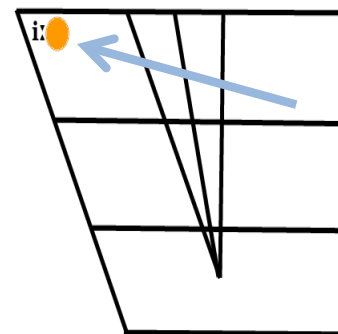
/i:/

Cj-



í	sí	/sʲi:/
---	----	--------

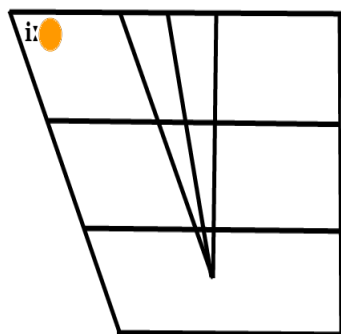
Cʲ-



uí	suí	/sʲi:/
aí	caí	/kʲi:/
oí	cloí	/klʲi:/
aoi	caoi	/kʲi:/

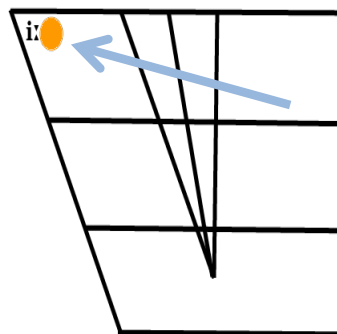
/i:/

Cj-



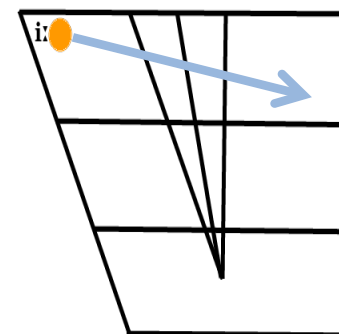
í	sí	/sʲi:/
---	----	--------

Cʲ-



uí	suí	/sʲi:/
aí	caí	/kʲi:/
oí	cloí	/klʲi:/
aoí	caoi	/kʲi:/

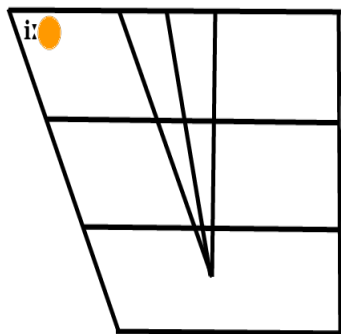
Cj-Cʲ



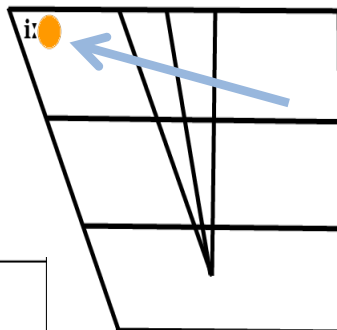
íó	díol	/dʲi:lʲ/
----	------	----------

/i:/

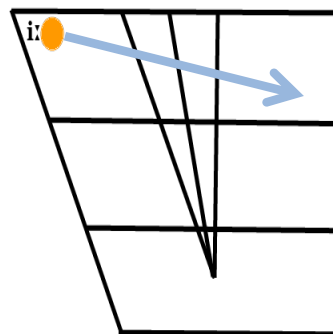
C<sup>j</sup>-



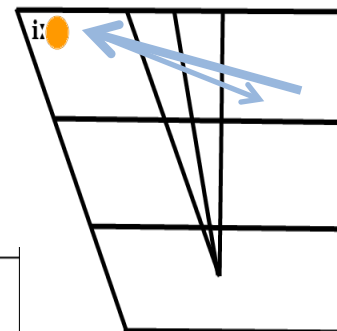
C<sup>ʲ</sup>-



C<sup>j</sup>-C<sup>ʲ</sup>



C<sup>ʲ</sup>-C<sup>ʲ</sup>



í

sí

/sʲi:/

íó

díol

/dʲi:lʲ/

uí

suí

/sʲi:/

aí

caí

/kʲi:/

oí

cloí

/klʲi:/

aoi

caoi

/kʲi:/

aíó

maíomh

/mʲi:wʲ/

uío

bruíon

/brʲi:nʲ/

# Letter-to-Sound Rules

## Archaic writing system

Written forms – often fossilised – bear witness to centuries of sound changes

(e.g. future negative form of verb ‘faigh’ *to get*)

Ní **bhfaighfidh** -> ‘*not get*’ (future.)

/n i: w i: /

(2 sounds – 11 letters)

# Letter-to-Sound Rules

# Pronunciation Lexicon

## Challenges, e.g.,

- Cross-dialect differences & no standard spoken variety
- Archaic & Complex writing system

## Non- mainstream approach

- Multi dialect synthesis
- Hand written rules/lexica etc. (Machine learning (mainstream) - poor results)

## Downstream benefits

- Modular dialect-by dialect development
- Exploited in downstream applications (educational – see below)
- Goldmine for research



## 2. Building a TTS system/Core technology -> Preservation

### Documentation



**(1)** Building the phonetic-linguistic components

### Preservation



**(2)** Core technology -  
- the TTS system

### Revitalisation



**(3)** Applications

# Voices available at [www.abair.ie](http://www.abair.ie)



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éist  
íoslódáil  
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Maoinithe ag  
An Roinn  
Ealaíon,  
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Gaeilteachta





Cuir téacs isteach anseo...

Déan sintéis

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Uasmhéid na gcarachtar: 2000. Méid carachtar fágtha: 2000

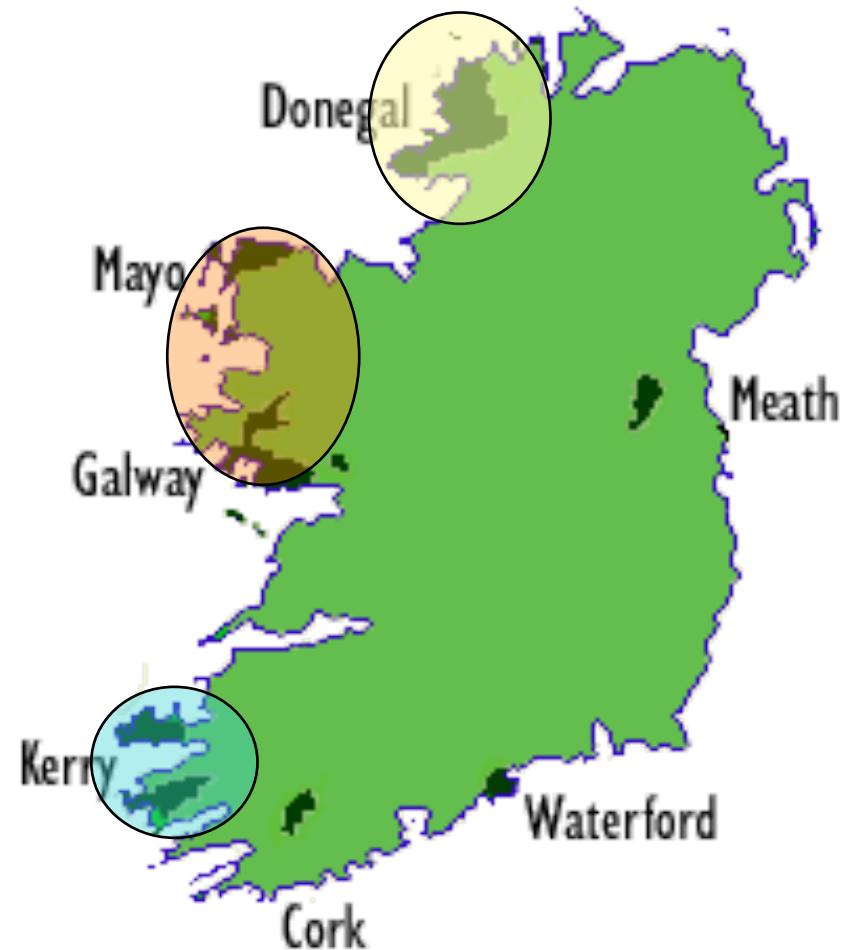
Clliceáil anseo le síneadh fada a chur leis.

# 3 main dialects

Ulster (Donegal)

Connaught

Munster (Kerry)



# The Voices

## Donegal (Gaoth Dobhair)

- Female; Unit-selection voice

Cá mé i mo shuí ó d'éirigh an ghealach aréir,  
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cá na coiligh as glaoch,  
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Images by Liamfm. @ Flickr.com. Many thanks.

# The Voices

## Connaught (Ráth Chairn)

- Male; unit-selection voice



I gCinn Mhara bhíos nuair a chuireas aithne ar m'asal beag dubh i dtosach. Lá aonaigh a bhí ann, agus bhí sé in a sheasamh ansin cois claí agus a thóin le gaoith, gan aird aige ar an saol ná a g saol air.

**Pádraic Ó Conaire**



**Dáta breithe** 20 Feabhra, 1882  
Contae na Gaillimhe

**Dáta báis** 6 Deireadh Fómhair, 1928  
Baile Átha Cliath

**Náisiúntacht** Éireannach

**Gairm** Úrscéalaí, gearrscéalaí

**Seánra** Ficsean

# The Voices

## Connaught (Ráth Chairn)

- Male; HTS voice



# The Voices

## Munster (Corca Dhuibhne)

- Female; HTS voice

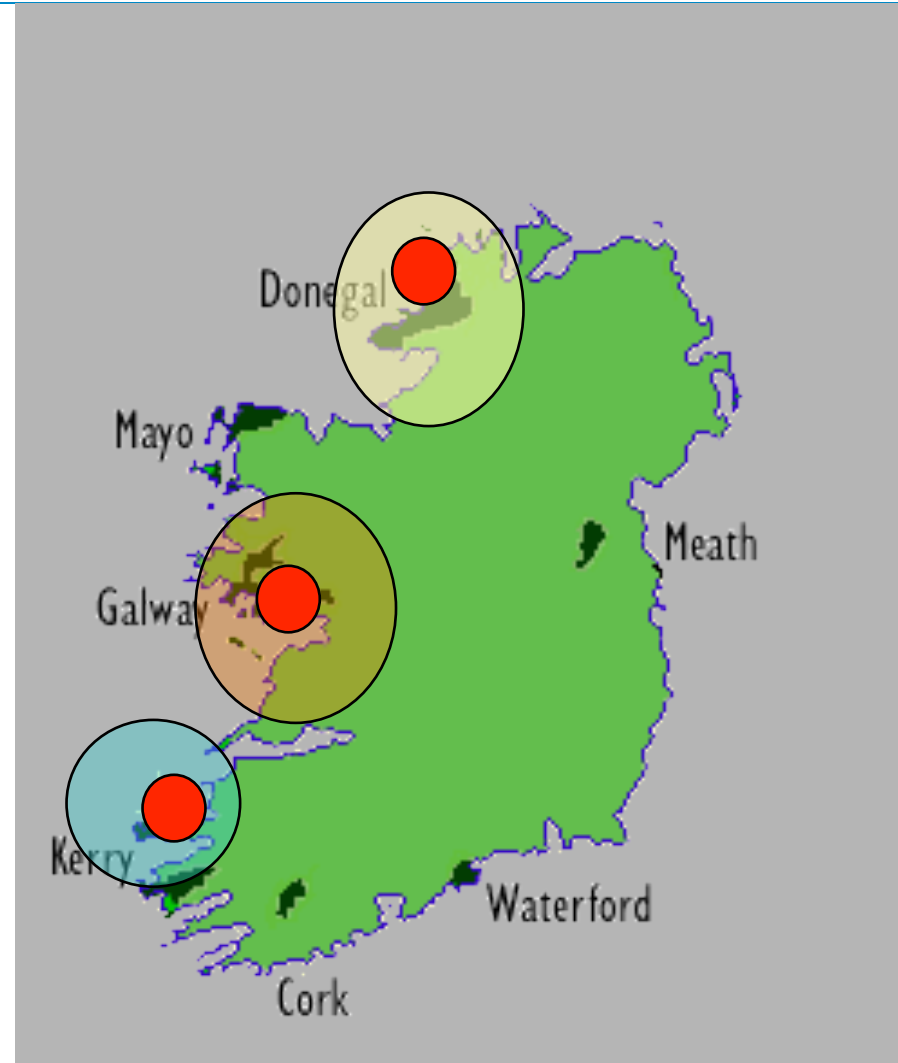


# 3 main dialects

Ulster (Donegal)

Connaught

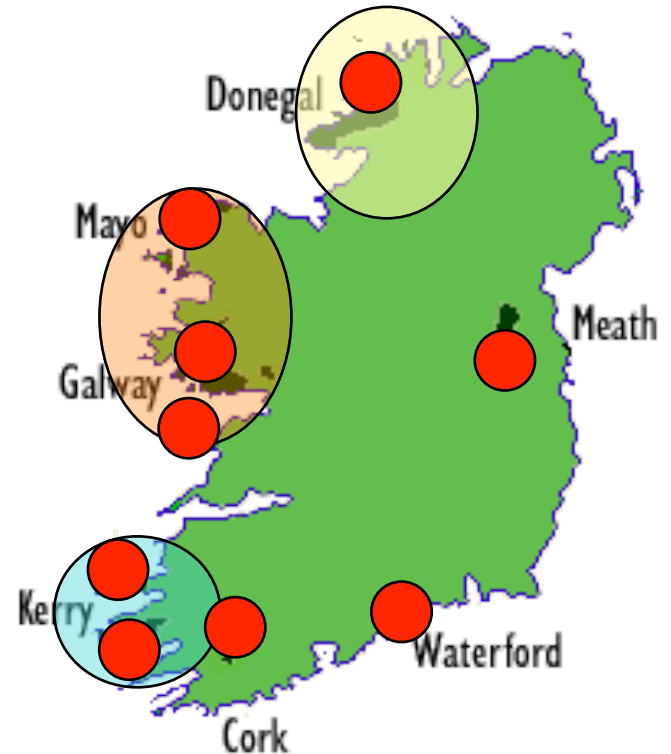
Munster (Kerry)





# More dialects.....Preserving ‘virtual speakers’

- Extension to most threatened dialects  
(Mayo, Múscaí, Aran Islands, An Rinn)
- Potential: extension to Scottish dialects...
- Potential: resurrect virtual speaker of Manx?



# Website - access to resources, TTS innards

- Phonetisation
- Text Normalisation
- Part-of-Speech Tagging

Also, see below,

- Learning Resources
- Screenreader
- etc.

## Facilities available on [www.abair.ie](http://www.abair.ie)

### Phonetisation

Converts words into a phonetic spelling:

Fáilte go [abair.ie](http://www.abair.ie) -> sil # f a: ll' t' @ # g @ # a b @ r' # p o N k # ai\_e  
ii\_e # sil # (X-SAMPA)

### Text Normalisation, Expansion of Numerals

Converts numbers and symbols into words:

Tús maith 1/2 na hoibre. -> tús maith leath na hoibre.

### Part of Speech Tagging

Assigns a part of speech to each word:

Slán Leat -> **Part-of-Speech** for [Slán](#) slán+Noun+Masc+Com+Sg;  
**Part-of-Speech** for [Leat](#) le+Pron+Prep+2P+Sg+<<<

### Learning Resource

Intended down the road as an open facility to which teachers and learners can contribute.

### Search Engine integration into Web Browsers

Use the search add-on for *Firefox*. It allows you to synthesise a word or phrase while reading any Irish-language web page.



# **Web availability -> a global community**

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## **A large, unexpected global community of users**

- Very large numbers in North America, Britain
- hits from virtually every corner of globe
- can 'finally' hear how written text is pronounced!

## **In Ireland: parents helping schoolchildren with homework**

- increases exposure to native-like language
- hugely helpful in early reading

### 3. Applications

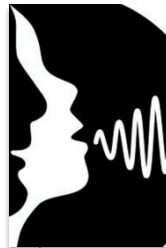
→ Maintenance/Revitalisation

#### Documentation



(1) Building the phonetic-linguistic components

#### Preservation



(2) Core technology -  
- the TTS system

#### Revitalisation



(3) Applications

### 3. Applications

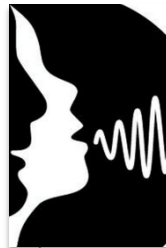
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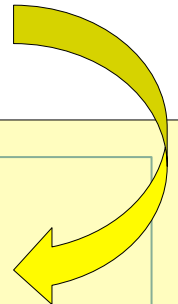


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#### Revitalisation



(3) Applications



### 3. Applications

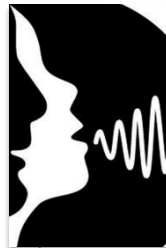
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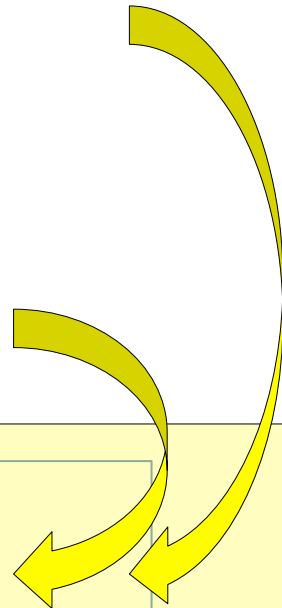


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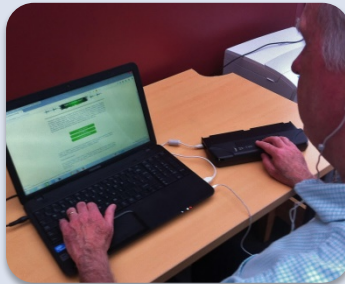


### 3. Applications

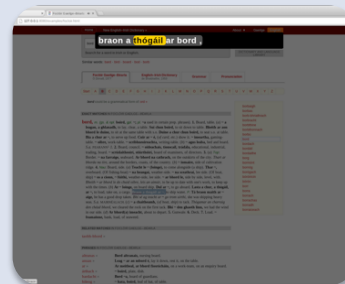
Education



Disability



Public Use



Commercial



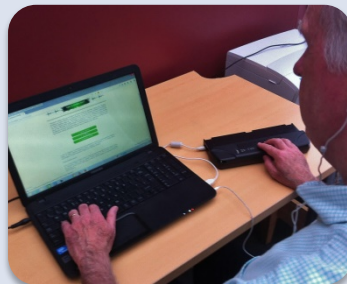
### 3. Applications

Education

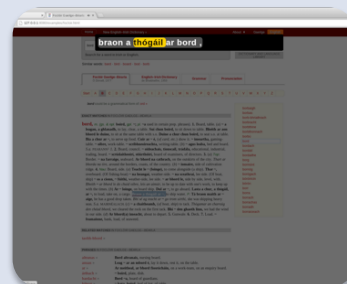
Educational  
Games



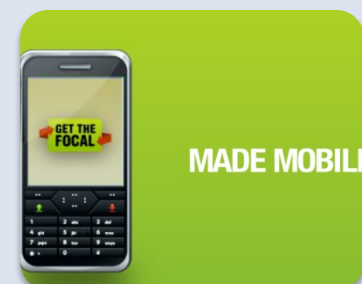
Disability



Public Use



Commercial





### 3. Applications

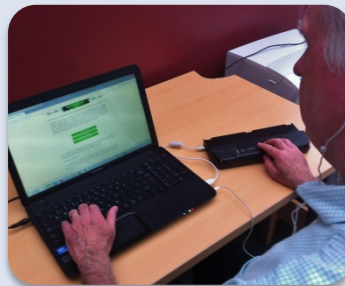
Education

Educational  
Games

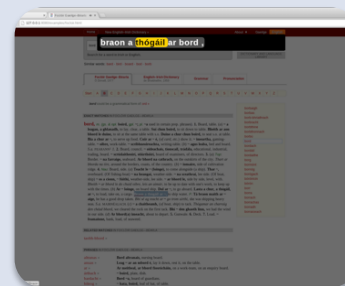


Disability

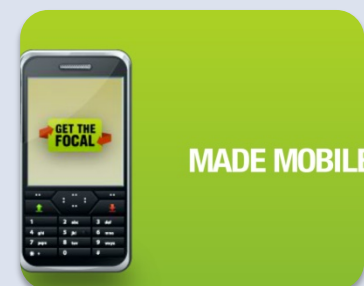
Screenreader



Public Use



Commercial



### 3. Applications

Education

Educational  
Games



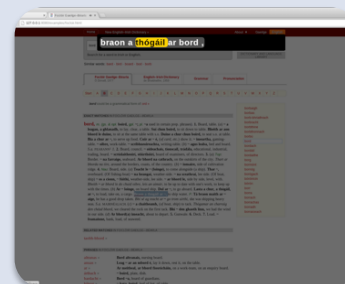
Disability

Screenreader



Public Use

Webbrowser



Commercial



### 3. Applications

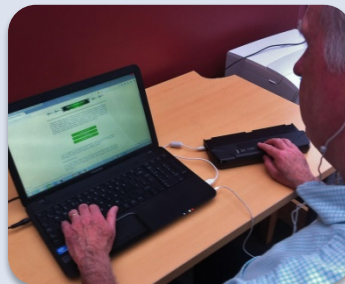
#### Education

Educational  
Games



#### Disability

Screenreader



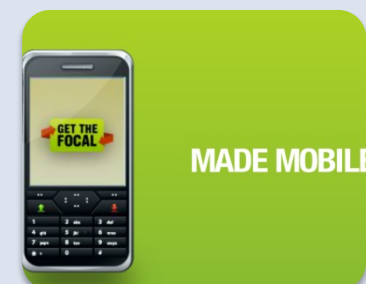
#### Public Use

Webbrowser



#### Commercial

Mobile Eng-  
Irish talking  
dictionary



**Web Browser ..... in testing phase**  
**to read out online dictionaries, newspapers...**



# Disability & Access

## Screen Reader for the visually impaired

---

Hitherto:

- Irish text read thru English TTS → like learning a new language
  - » Very few books in Braille
- Excluded from Irish language networks, education etc..

Development

- **Collaboration with NCBI (National Council for the Blind of Ireland)**
- Entailed redeveloping synthesis, using a different engineering engine to allow very rapid response time needed

# Disability & Access

## Screen Reader : with speech & Braille output

Launched last week





## multimodal speaking textbooks: active pipeline of production Collaboration with ChildVision Ireland

AN DTUIGEANN TÚ ANOIS É 2 PAGES 1 TO 11

Well, in Irish, all question words start with "C". For example:

**Cé?**

**Cad?** (or **Céard?**)

**Cá?**

**Cathain?**

**Cén fáth?**

**Conas?**



Cé hé sin?

**Cad is ainm duit?**

Conas tá tú

Deirdre is ainm dom.

Tá mé go maith, go raibh maith agat.

How do you tell them apart? Well, if you recognise the following phrases, you have already heard at least four.

**Conastá tú?** (**How** are you?)

**Cé tusa?** (**Who** are you?)

**Cad is ainm duit?** (**What** is your name?)

**Cá bhfuil tú i do chónaí?** (**Where** do you live?)

Look at the above phrases again.

What does **Conas?** mean?

What does **Cé?** mean?

What does **Cad?** mean?

What does **Cá?** mean?



Cá bhfuil tú i do chónaí?

Mars

## P5

Here's one more:

**Cathain?**

The word **Cathain** means **When**? Do you notice anything that the English and Irish words for "When?" have in common? Look at the **last letter** of each word. Bingo! Both words end in "n". Use that to help you remember what the word "Cathain" means.

Here's a little rhyme to help you:

**Cathain? and When?** both end in "n"

(OK, it won't win prizes for poetry, but it works!). Time for one more question word.

**Cén fáth?** means **Why?**

If you ever spend time in the Gaeltacht in a house with a young child, you will get to know this word very well. Young Irish speaking children ask the question **Cén fáth?** about fifty times a day.

# Education

*CabairE*: web application – ABAIR voices in the classroom

Funded by COGG



An Chomhairle um Oideachas  
Gaeltachta & Gaelscolaíochta



Baile Eolas Scéalta Cabhair Teagmháil abair.ieGaeilge English

## Áis Litearthachta don Ghaeilge!

Eagarthóir ▲SintéiseoirSocrulthe téacs

Glór: Corca Dhuibhne ▾■ Rialtáin Fualme☒ Seinn go huatholbríoch

Cuir téacs isteach anseo...

Abair é!

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Coláiste na Tríonóide, Baile Átha Cliath, Éire



*A 'talking blackboard'*



Teachers creating teaching/learning materials within CabairE



An Chomhairle um Oideachas  
Gaeltachta & Gaelscolaíochta



**Funded by COGG:**

**Teachers can create content, using speech and visual feedback:**

- **highlighting:** word/phrase, of letter sequences corresponding to sounds
  - pronunciation training
  - Reading, writing (especially important for dyslexics)
- **variable speed**
- **magnification**
- **choice of dialects**

## Future: *CabairE* as a virtual resource centre



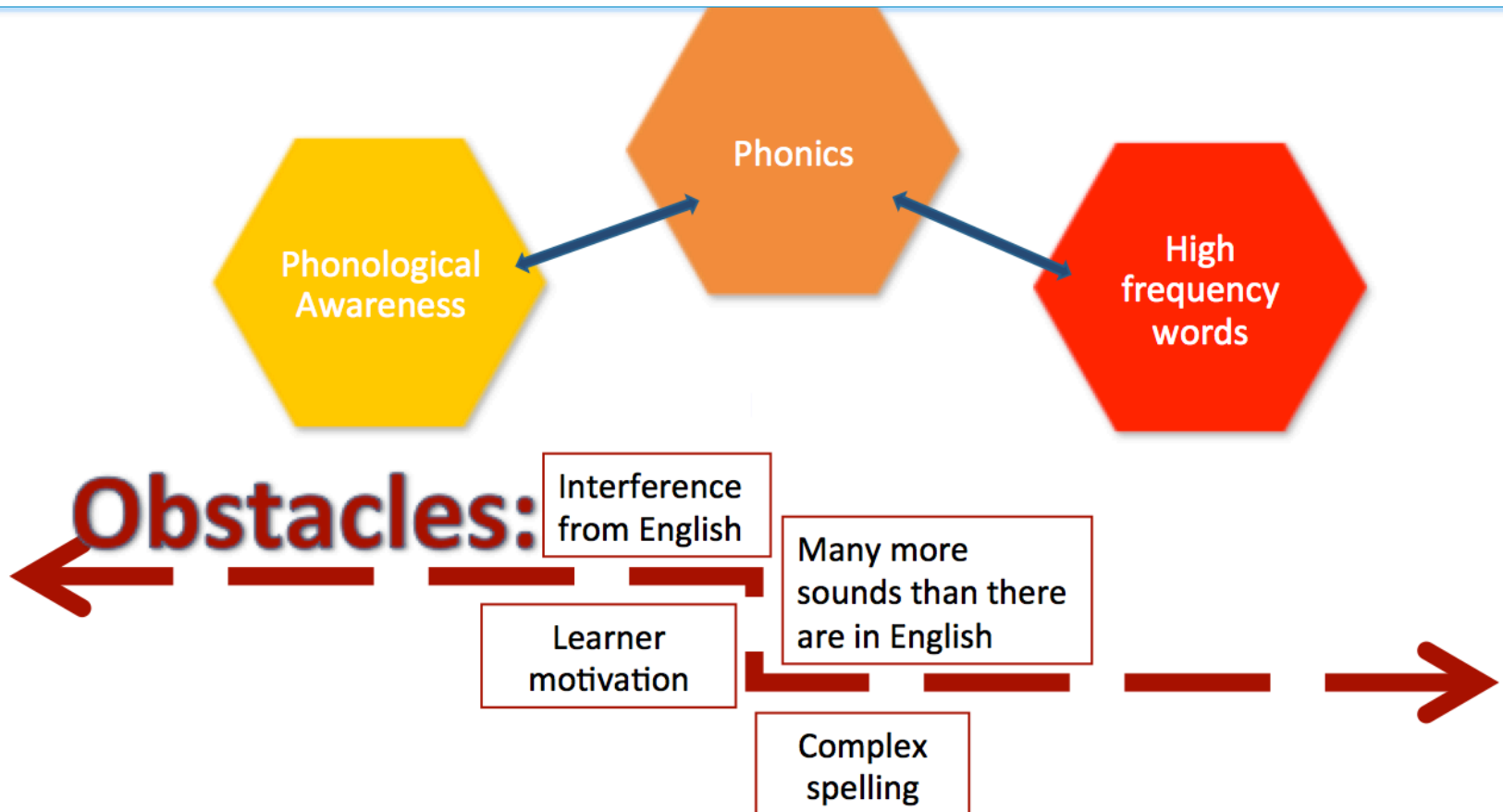
Teachers creating materials within CabairE



Upload & share: along with other educational resources



# Future: Exploiting phonetic-linguistic resources - pronunciation, & literacy training



# Phonological Awareness



Phonological  
Awareness

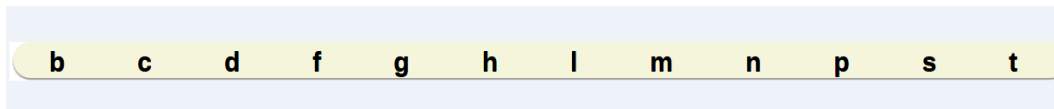
Distinguishing between the sounds of Irish

# Phonological Awareness

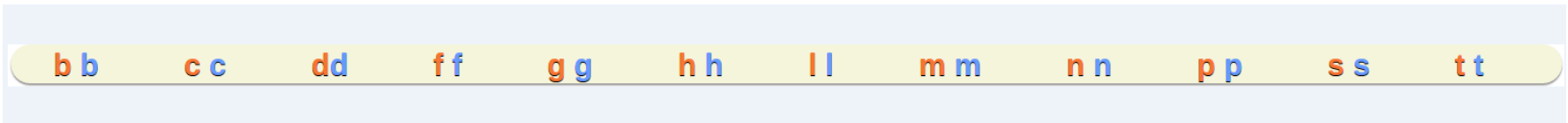
Colour coding contrast: speech & visual cues




## Alphabet: one set of consonants



Two sets of sounds: **Slender** and **Broad**




**b**




**b**eo

**b**



**b**ó

**n**



**n**igh

**n**

**9**

**n**aoi

# Phonological Awareness

Colour coding contrast: speech & visual cues





An Chomhairle um Oideachas  
Gaeltachta & Gaelscolaíochta



Baile Eolas Scéalta Cabhair Teagmháil abair.ie

Gaeilge English

## Áis Litearthachta don Ghaeilge!

L



Leon

L



Lón

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# Phonological Awareness

Colour coding contrast: speech & visual cues



 An Chomhairle um Oideachas  
Gaeltachta & Gaelscolaíochta 

Baile Eolas Scéalta Cabhair Teagmháil abair.ie Gaeilge English

**Áis Litearthachta don Ghaeilge!**

 **Leon**  **Lón**

D'ith an **L**eon mo **L**ón



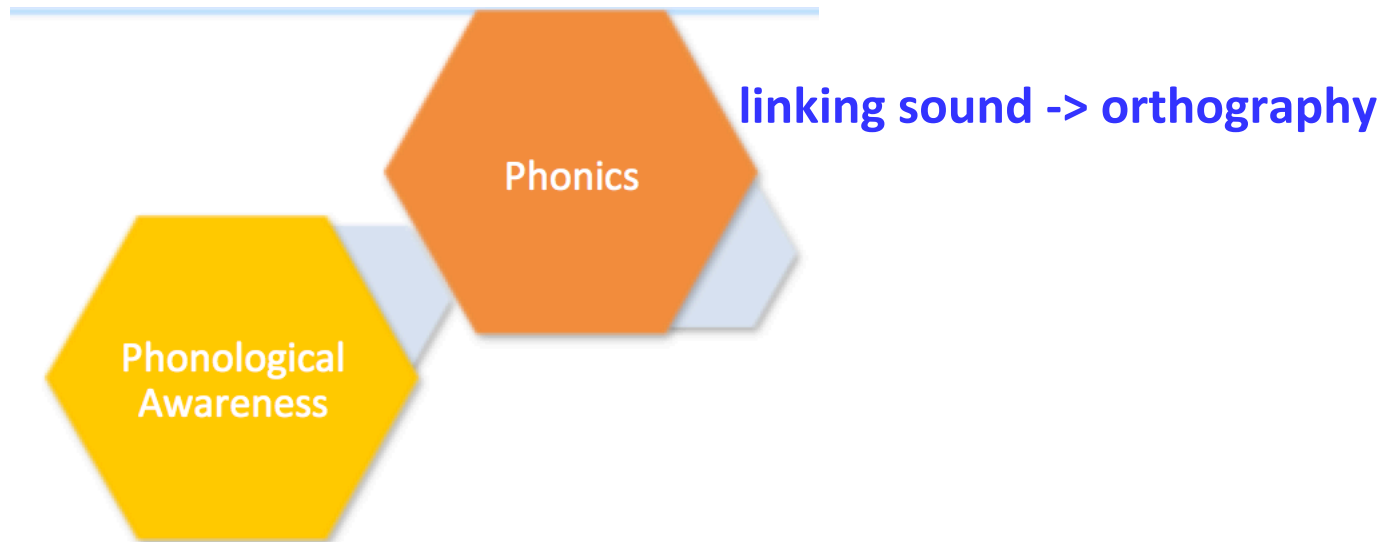
© 2015 An tSaotharlann Foghlaíochta agus Urlabhra, Scoil na nEolaíochtaí Teangeolaíochta, Urlabhra agus Cumarsáide, Coláiste na Tríonóide, Baile Átha Cliath, Éire

Translation:  
“The lion  
ate my  
lunch!”



# Phonics: Linking sound -> orthography

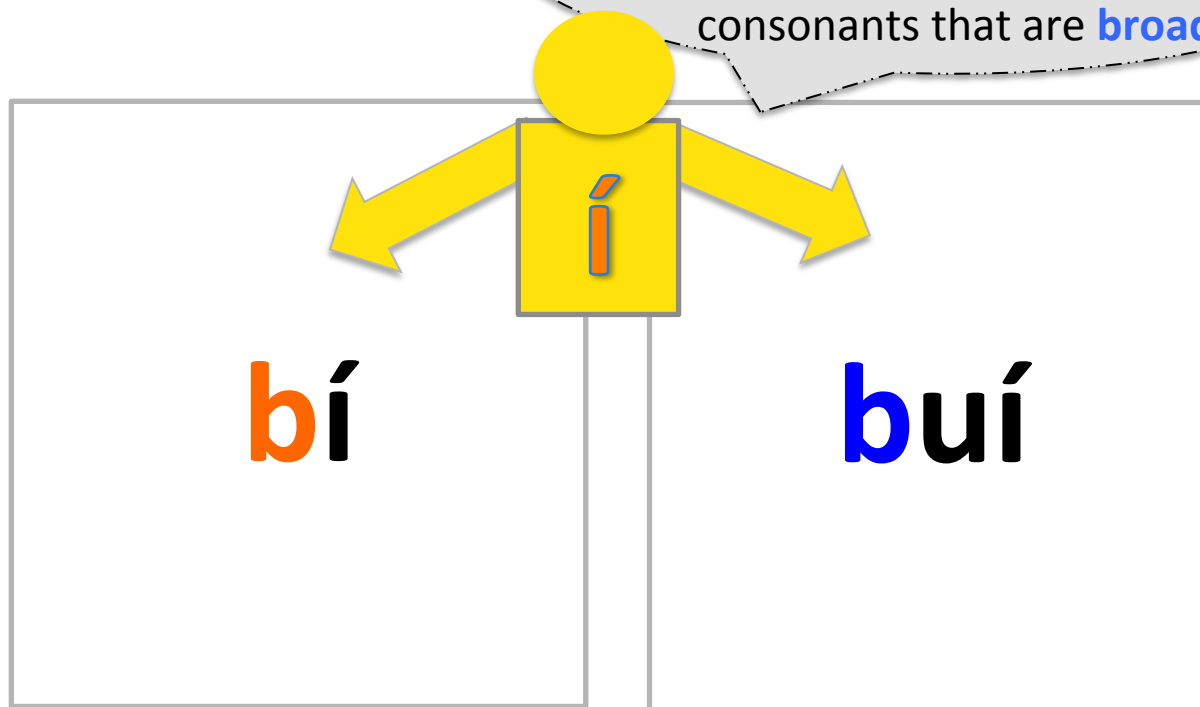
Using our letter-to-sound rules



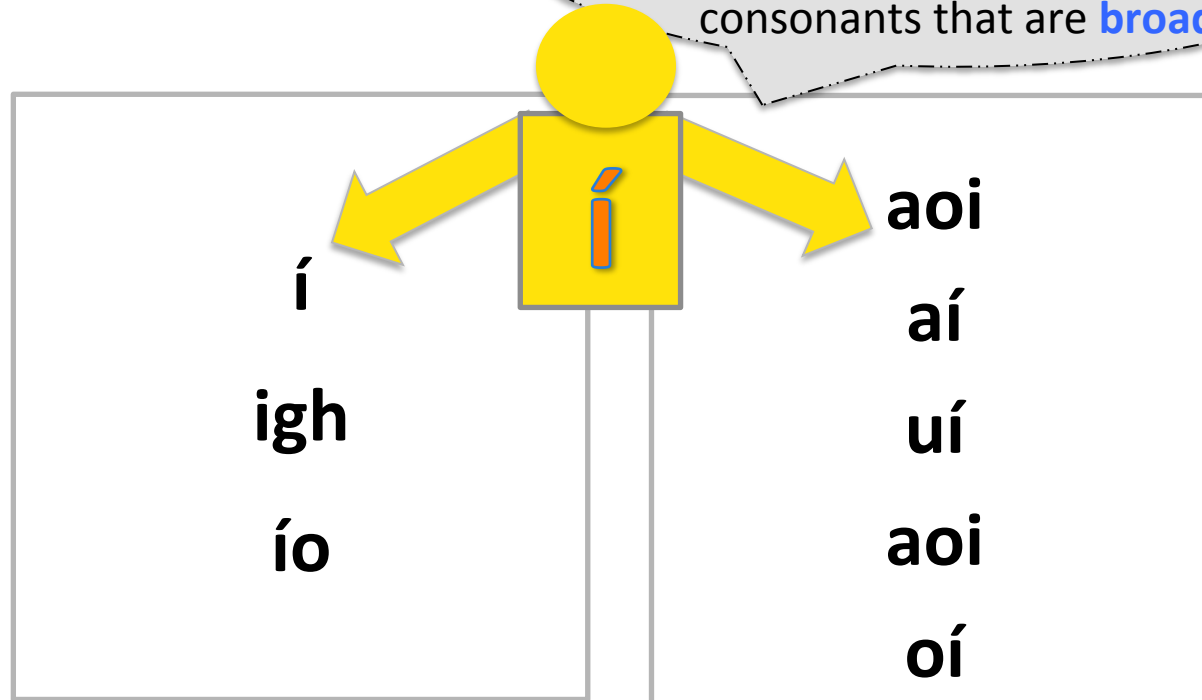
# Linking sound -> orthography



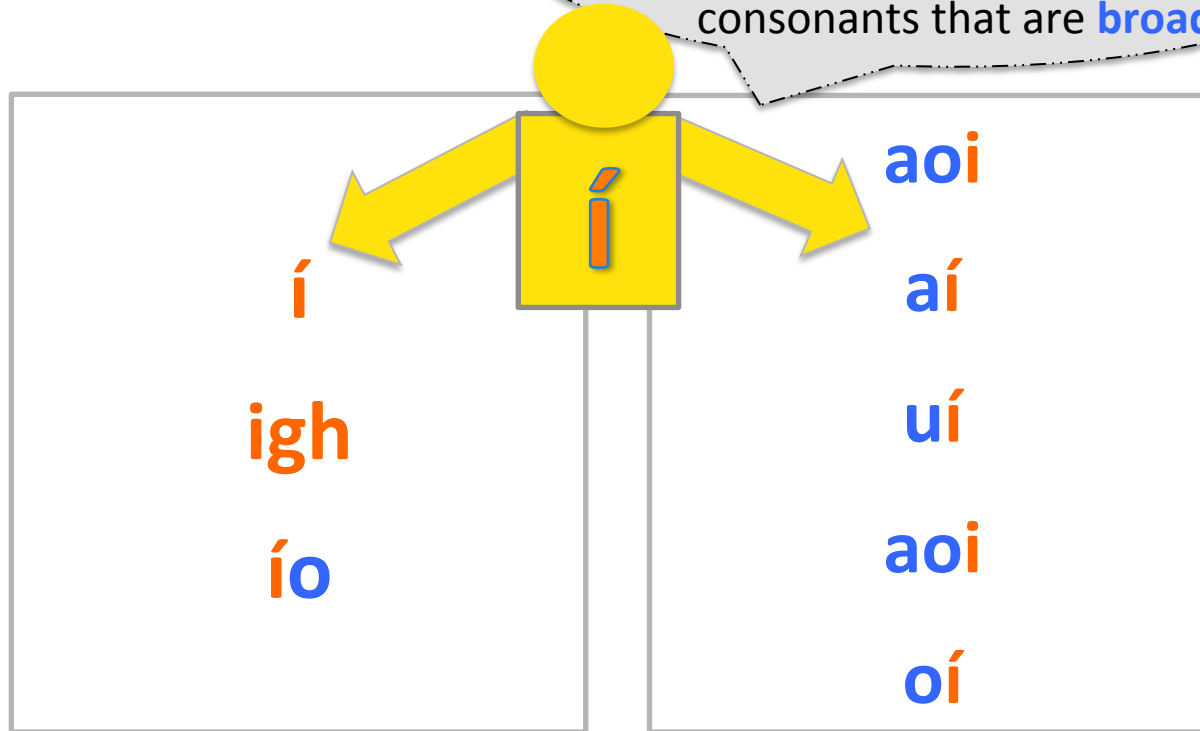
Spelling: the vowels denote the difference between consonants that are **slender** and consonants that are **broad**



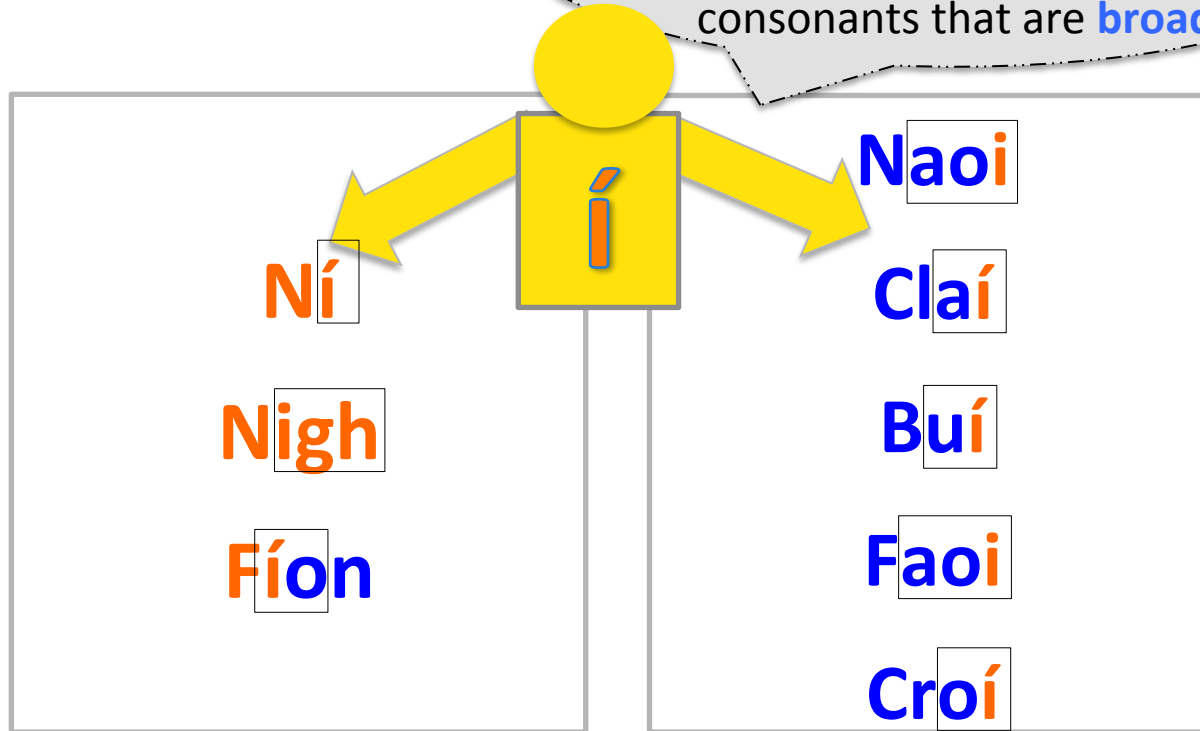
Spelling: the vowels denote the difference between consonants that are **slender** and consonants that are **broad**



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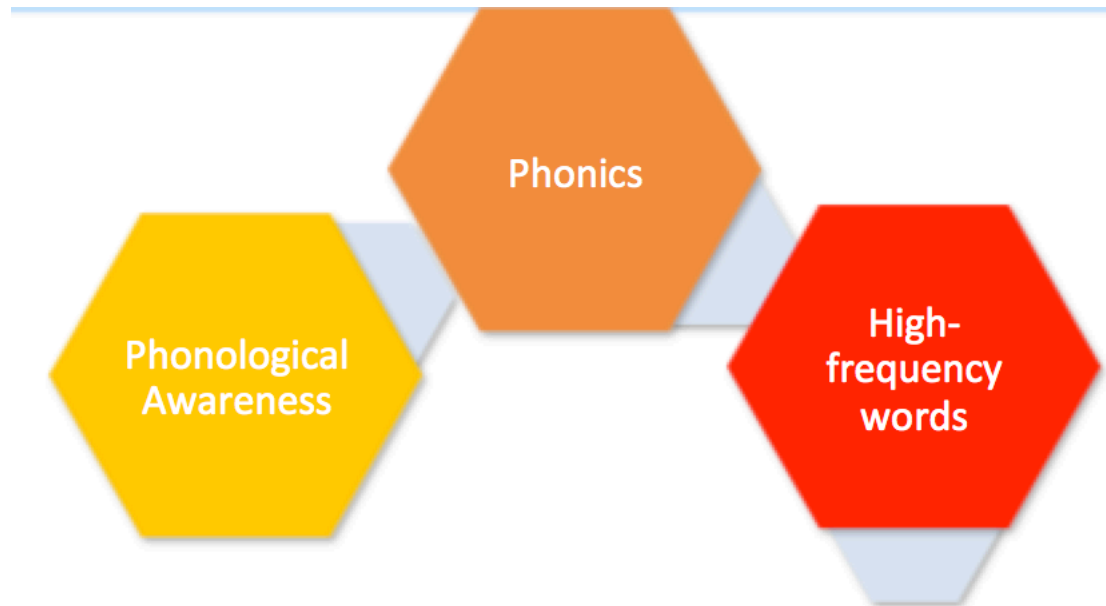


Spelling: the vowels denote the difference between consonants that are **slender** and consonants that are **broad**



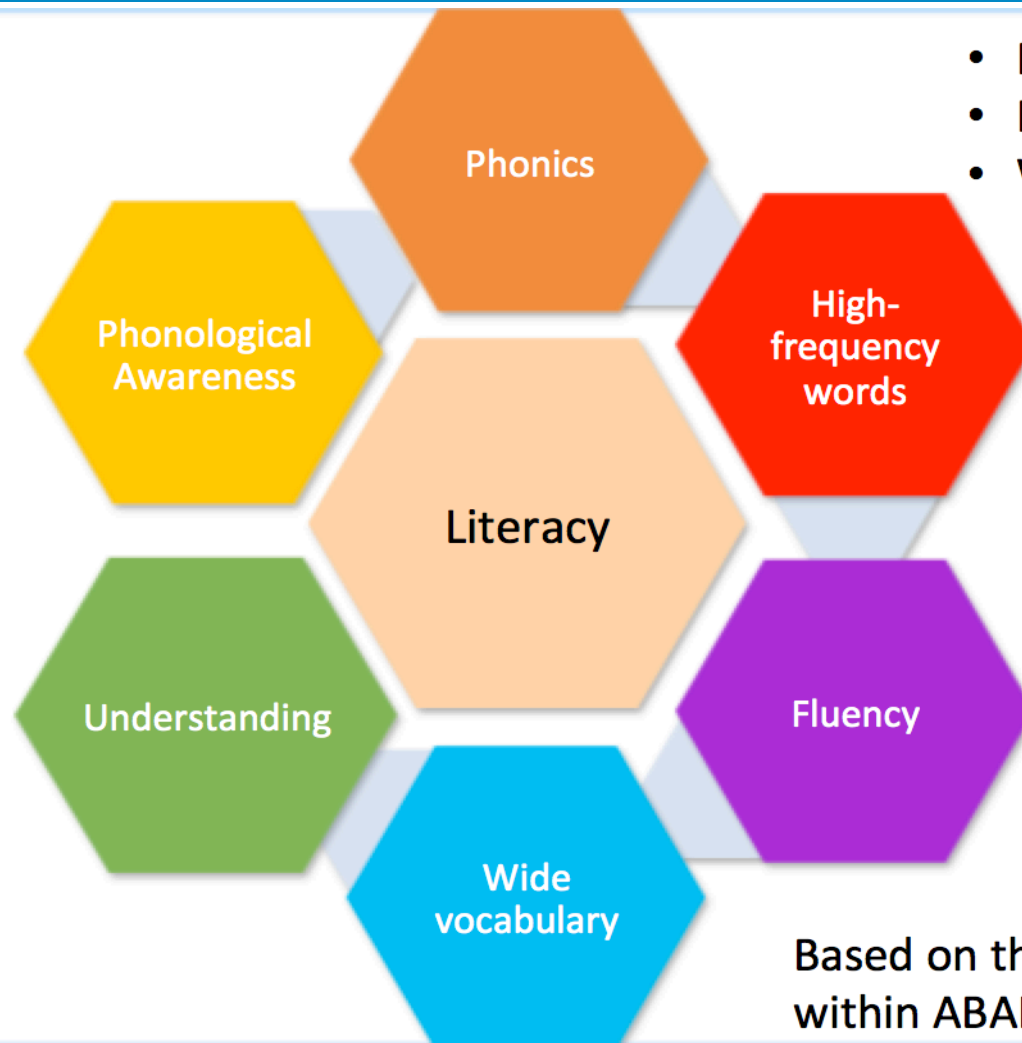
# High-frequency words→

from the spoken corpora



High-frequency words→  
from the spoken corpora

# The Future...



# Educational Games

## Virtual Reality *Fáilte go TCD*

### real-time crowd in a virtual model of Dublin



Front Square, TCD animation:  
user is eavesdropping on  
conversations of characters



Animations: Metropolis Project, Graphics, Vision & Visualisation Group, TCD



# Educational Games

Video: *Fáilte go TCD*





# Educational Games

Prototype dialogue partner

*Taidhgín*



INPUT FORM:

Neasa is ainm dom.

☒ Synthesise input

☐ Conamara (male voice)

☒ Gaoth Dobhair (female voice)

INPUT: Go maith, go raibh maith agat



RESPONSE: Tá sé sin go maith! Cén t-ainm atá ort?



Have a conversation in Irish with the talking monkey! Type into the system and listen to the monkey replying in your choice of dialect!

## Video: *Taidhgín*





INPUT FORM:

☐ Synthesise input

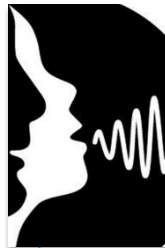
# Future directions

## Documentation



(1) Building the phonetic-linguistic components

## Preservation



(2) Recognition →  
dialogue systems  
(children's voices)

## Revitalisation



(3) Education - CALL

# Technology for Endangered Languages → ideally entails:

---

Collaboration of phonetician/linguist/technologist

Understanding minority language, challenges & priorities

Vision - impact: end users should drive priorities for development



Coláiste na Tríonóide, Baile Átha Cliath  
Ollscoil Átha Cliath

abair.ie

# Buíochas le...



*An Roinn  
Ealaíon, Oidhreacht agus Gaeltachta*  
*Department of  
Arts, Heritage and the Gaeltacht*

An Chomhairle um Oideachas  
Gaeltachta & Gaelscolaíochta



**NCBI**  
Working for People  
with Sight Loss

*Urraithe ag*



Foras na Gaeilge



Project part financed  
by the European Union





Trinity  
College  
Dublin

The University of Dublin

**Sin agaibh mo scéal...**

**...agus má tá bréag ann, bíodh,**

**...mar ní mise a chum ná a cheap!**



Trinity  
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Dublin

The University of Dublin

**Go raibh maith agaibh**

