COMPRESSION UPDATE: SELECTING THE RIGHT PARAMETER

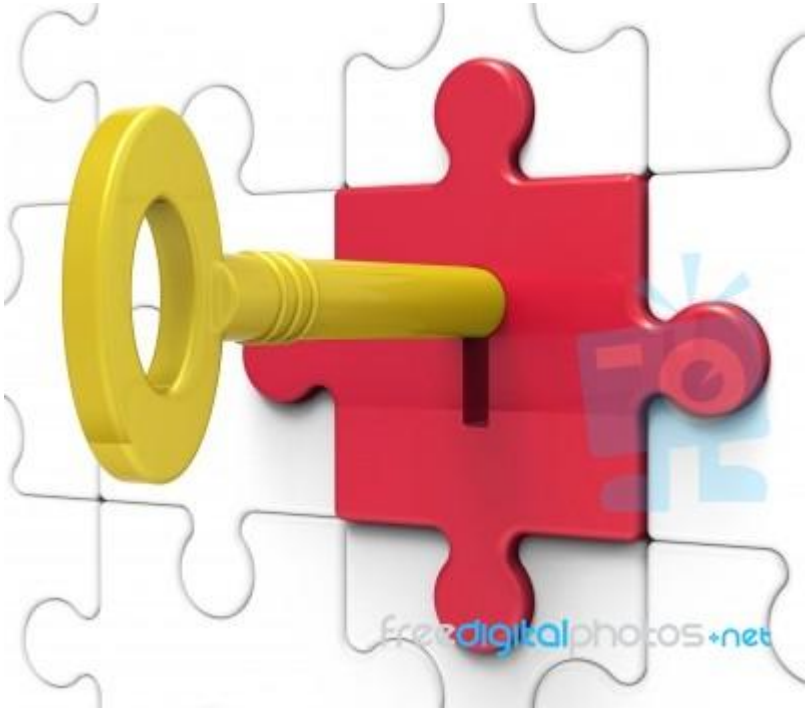
Learning Objectives

- After this course learners will be able to list the types of individuals who are particularly affected by temporal cues.

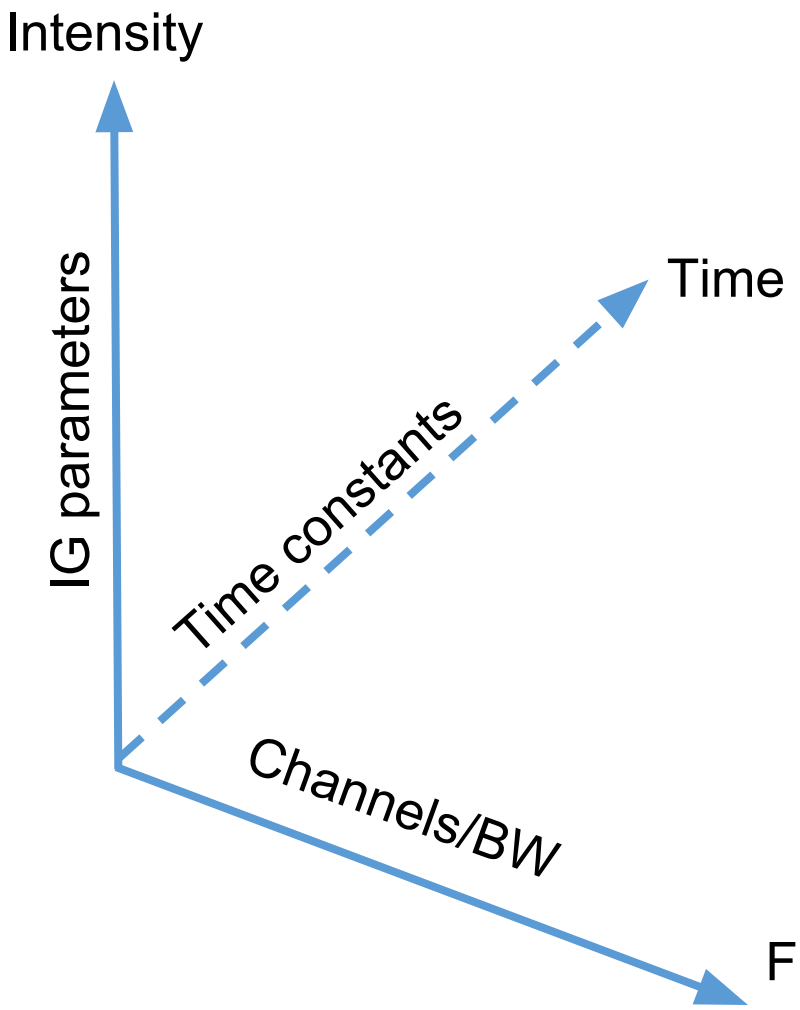
- After this course learners will be able to list the advantages of using fast-acting and slow acting compression.

- After this course learners will be able to list the considerations behind a variable speed compressor.

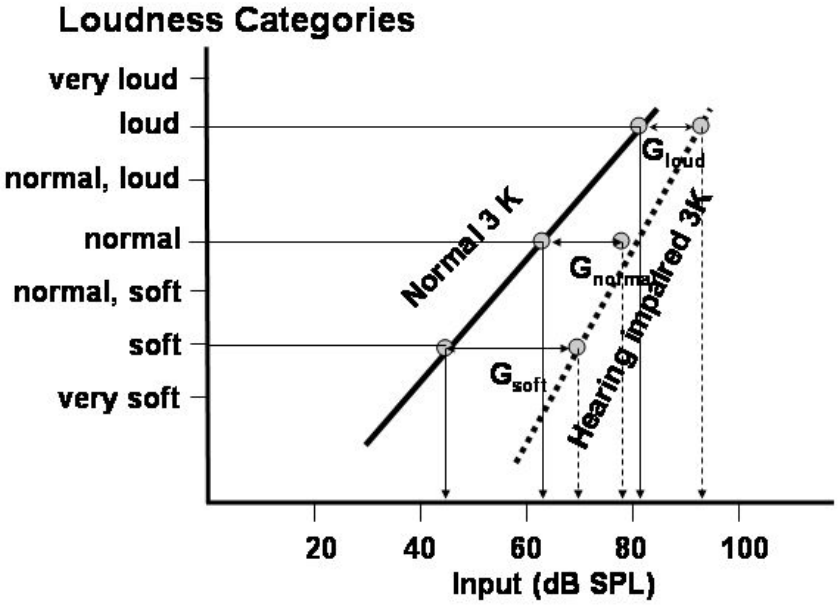
COMPRESSOR – KEY TO UNDERSTANDING HOW THE HEARING AID WORKS

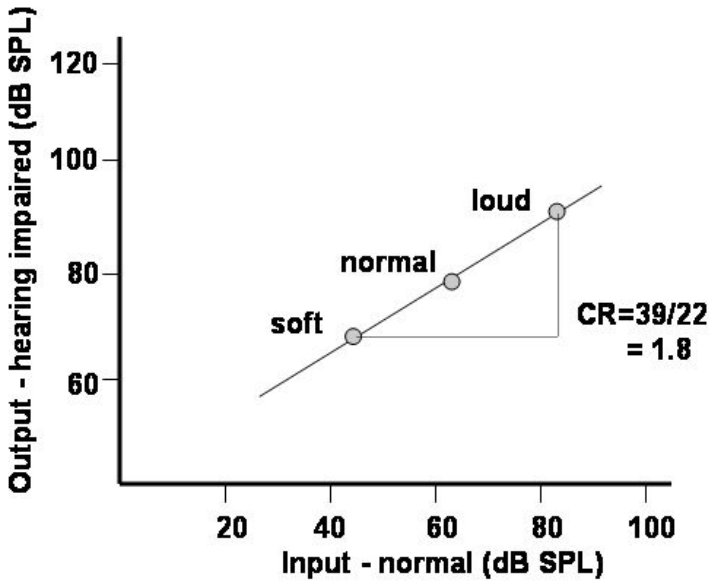


UNDERSTANDING COMPRESSION



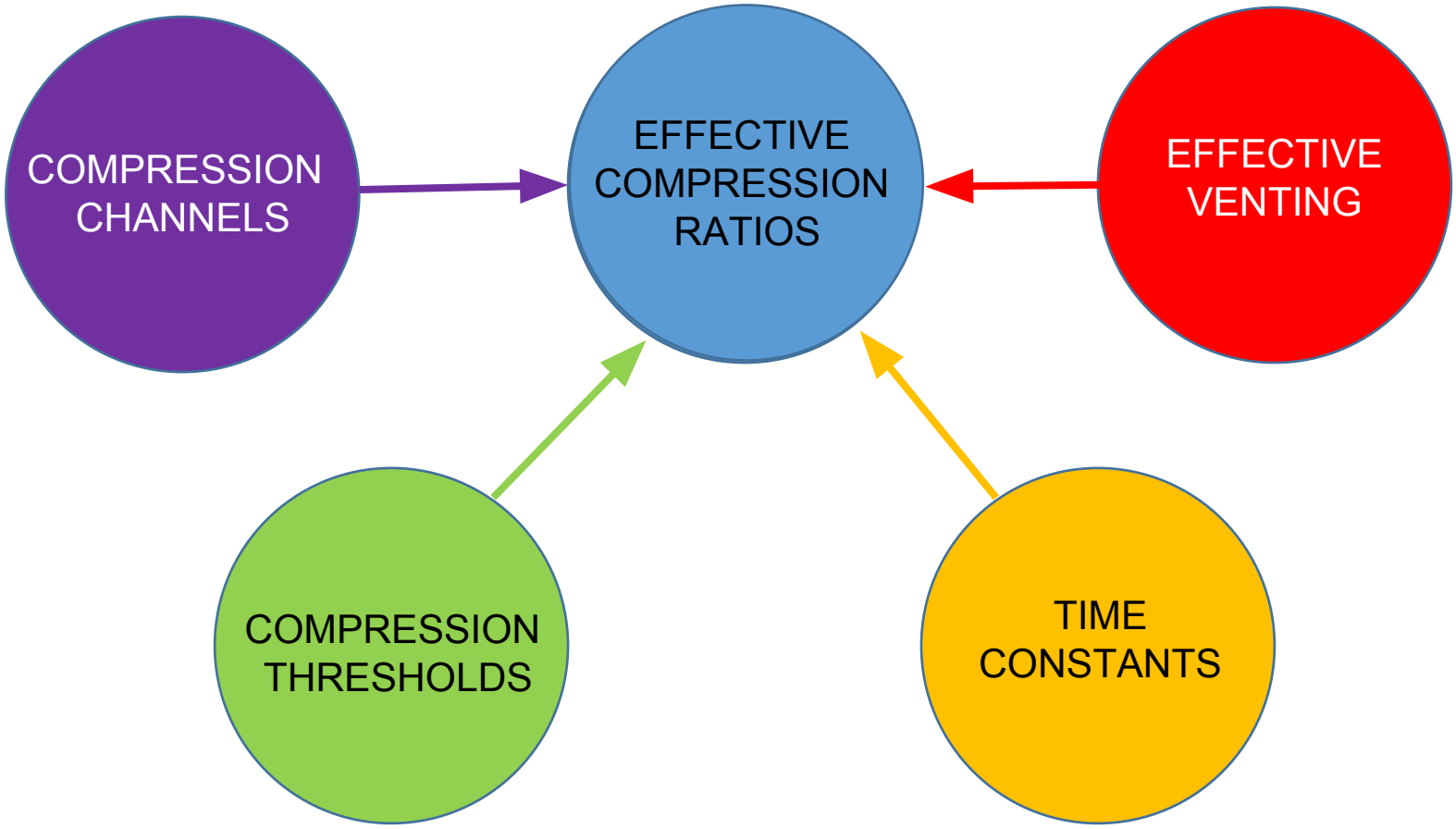
PREVIOUSLY COMPRESSION IS USED TO RESTORE **NORMAL LOUDNESS**





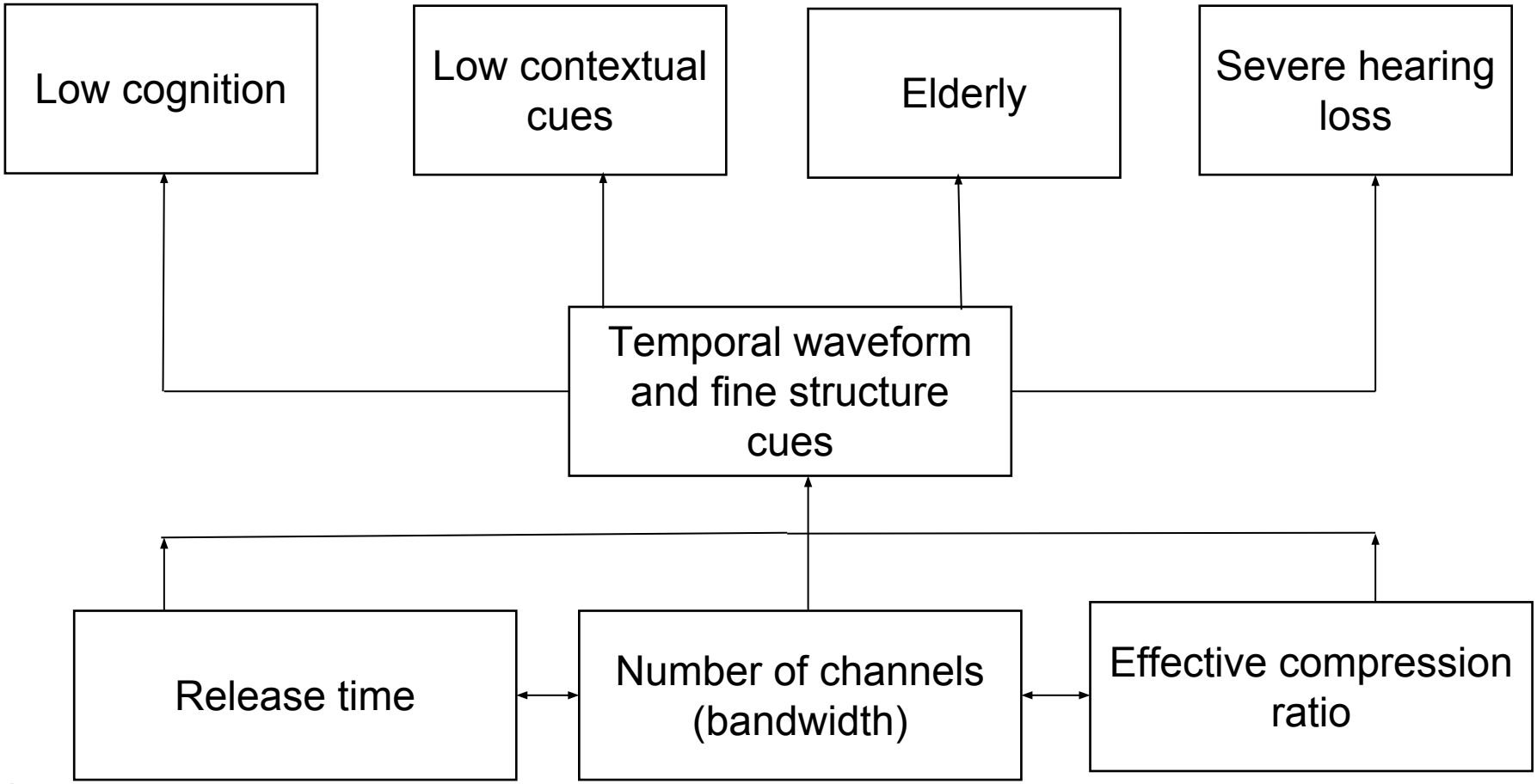
We talked about determining the compression ratio!

COMPRESSION IS **DYNAMIC** BECAUSE SOUNDS ARE DYNAMIC …



ESPECIALLY IN THE LAST 10 YEARS WE RECOGNIZED THE IMORTANCE OF **TEMPORAL NUANCES** ON COGNITION

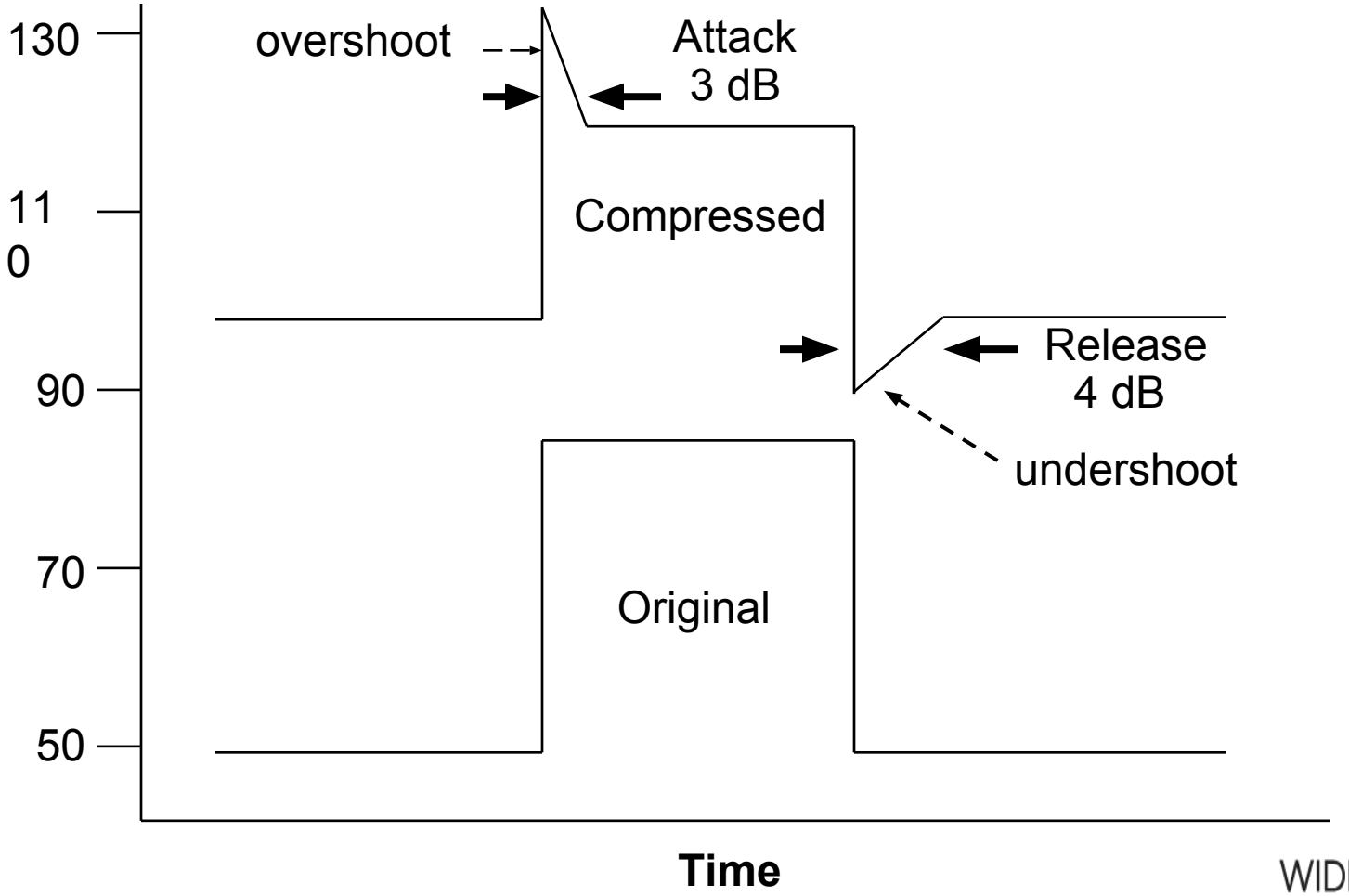
THOSE WHO ARE **SENSITIVE** TO TEMPORAL WAVEFORM … AND FACTORS AFFECTING



EFFECT OF **RELEASE TIME** ON TEMPORAL CUES

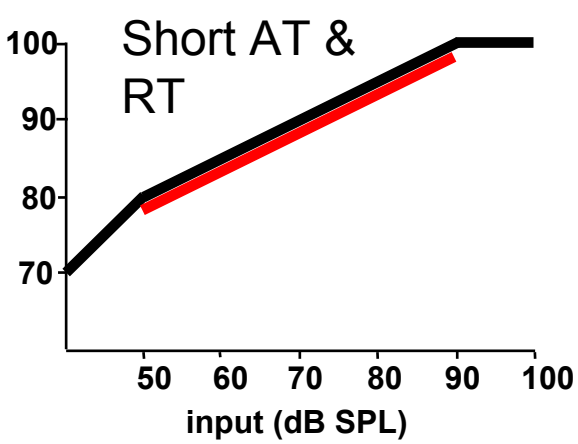
- Neuman et al (1995, 1998) – HI people preferred longer release time
- Hansen (2002) people preferred long release time for sound quality
- Davies-Venn et al (2009) – fast acting compression benefits audibility for soft sounds but degrades conversational and loud speech for people with severe loss
- Cox and Xu (2014) – 2/3 elderly preferred long release time, especially in people with low cognition and for low context speech materials
- Souza and Sirow (2014) – fast acting compression good for people with good cognition, slow acting good for older people and those with more severe loss

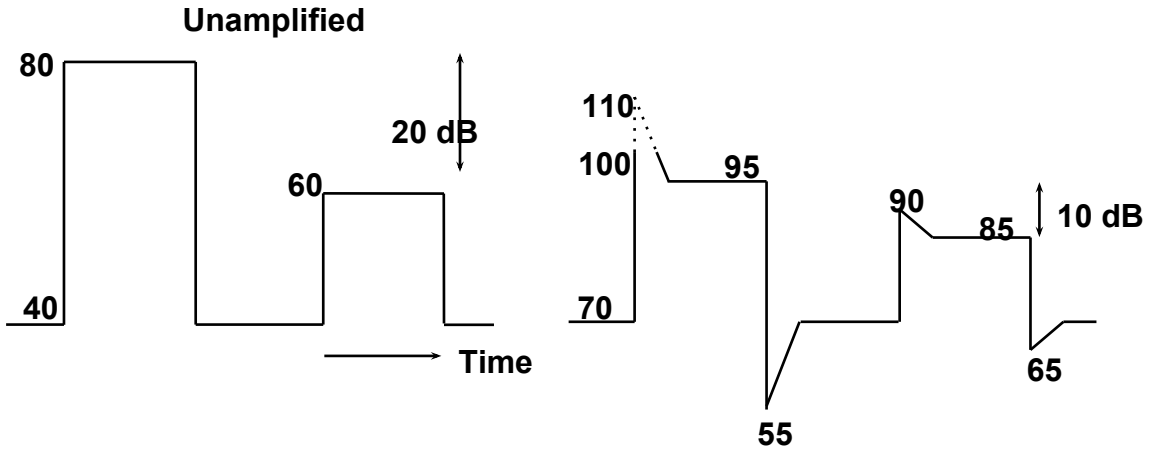
HOW IS TIME CONSTANT MEASURED?



ADVANTAGES OF USING **FAST ACTING** COMPRESSION

- Hearing impaired people have reduced dynamic range
- Speech sounds vary in intensity
  - Ensuring audibility of soft sounds
  - Follows syllabic variation
- Loudness “normalization”





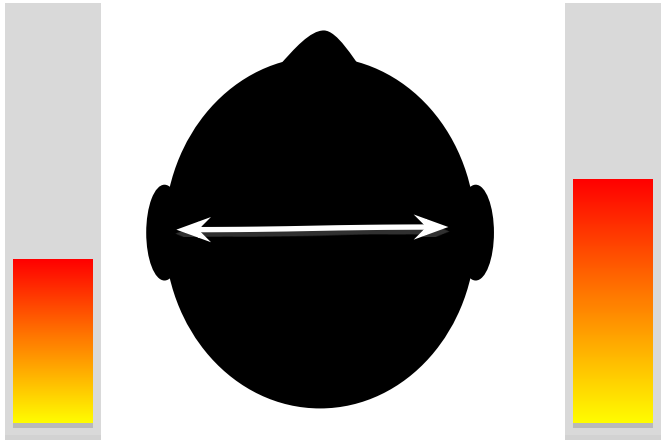
DISADVANTAGES OF USING FAST ACTING COMPRESSION ONLY

- Reduces temporal cues – affecting those with cognitive issues
- Lower speech intelligibility when used with a high CR (> 3) (Plomp, 1988).
- Spectral smearing in a multichannel compression hearing aid, resulting in poorer speech intelligibility despite enhanced audibility (Bor et al, 2008; Souza et al, 2005)
- Ambient noise becomes more perceptible during pauses between speech
- Reduces signal-to-noise ratio in moderate levels of background noise
- Reduces inter-aural level difference between two hearing aids of a bilateral pair. This could make spatial awareness and localization more difficult
- More prevalent in compressors with more channels and a higher CR

HYPOTHETICAL **INTER-AURAL LEVEL DIFFERENCES** BETWEEN FAST AND SLOW ACTING COMPRESSION

55 dB + 15 dB = 70 dB
55 dB + 5 dB = 60 dB

70 dB + 10 dB = 80 dB
70 dB + 5 dB = 75 dB



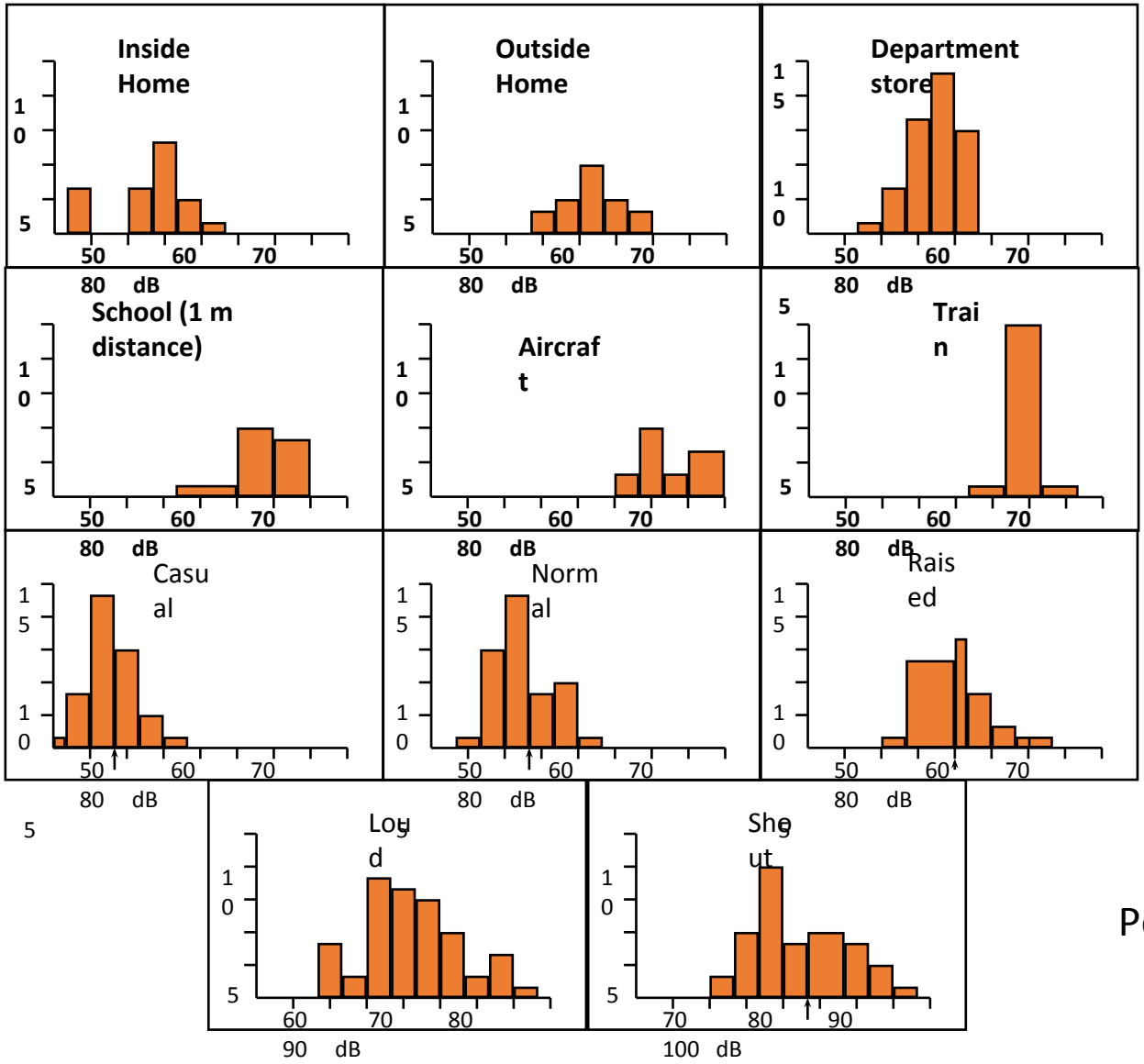
Left Right

Natural ILD = 70 dB – 55 dB = 15 dB

Fast acting ILD = 80 dB – 70 dB = 10 dB

Slow acting ILD = 75 dB – 60 dB = 15 dB

WHY SLOW ACTING? **SOUND DISTRIBUTION**



Pearson et al

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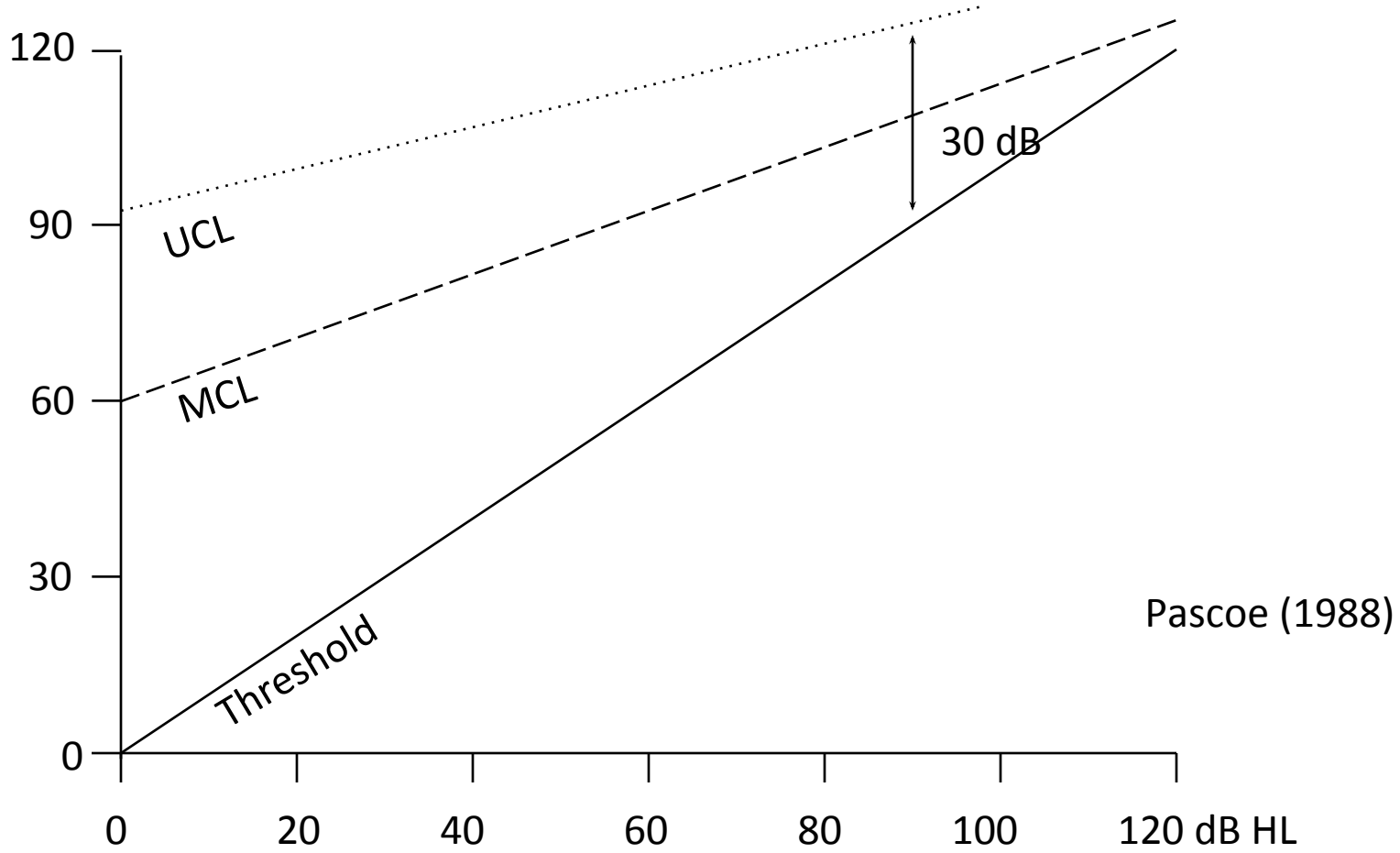
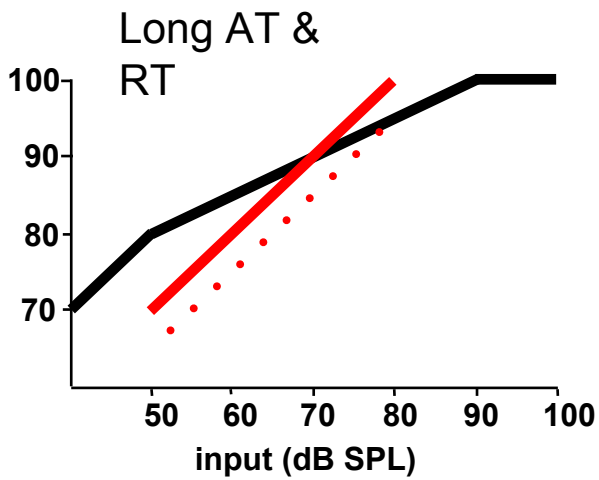
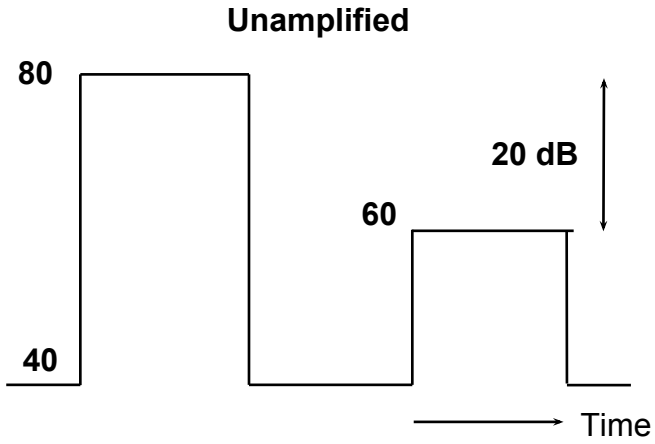
WHY SLOW ACTING? **DYNAMIC RANGE**

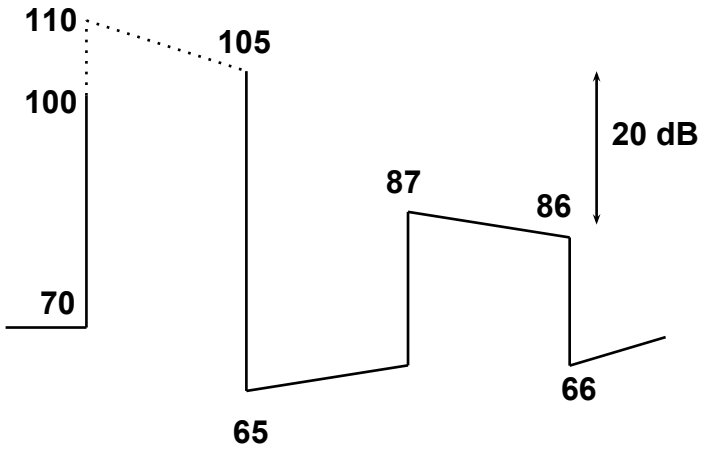


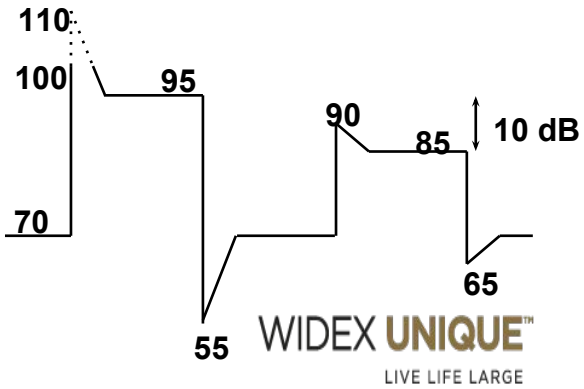
Pascoe (1988)

CONSEQUENCE OF A **LONG RELEASE TIME**









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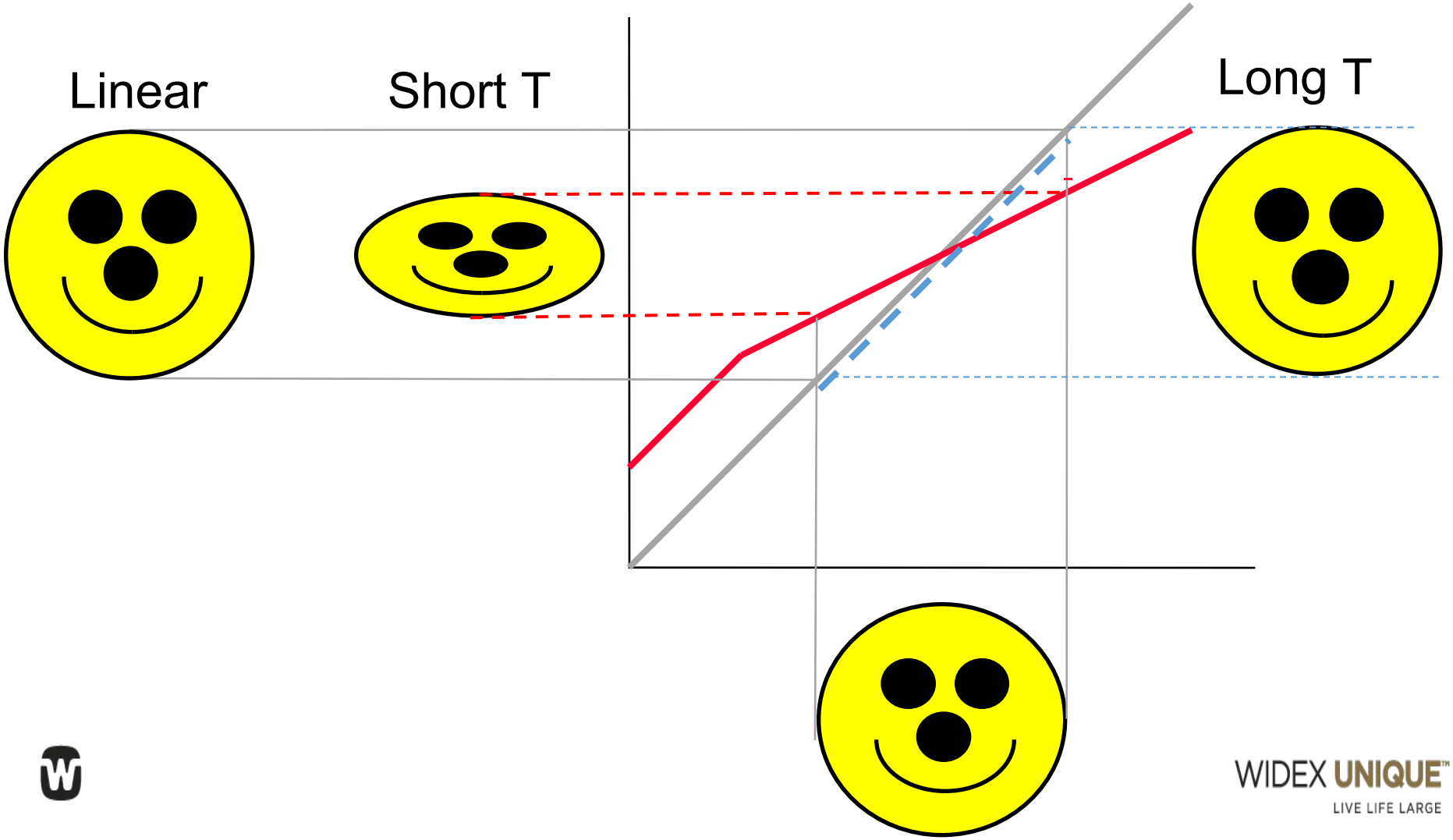
LONG TIME CONSTANTS **LINEARIZE** A NONLINEAR HEARING AID



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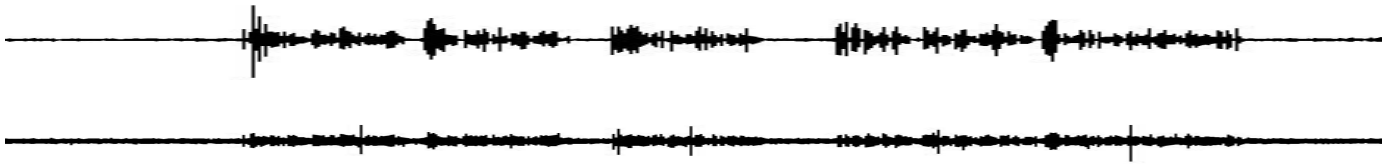
ADVANTAGES OF USING SLOW ACTING COMPRESSION

- Longer release time, less effective compression ratio, more linear – preserve temporal structure
- Preserves short term changes within the envelope (and temporal fine structures)
- Preservation of signal-to-noise ratio in moderately noisy places (Neuman et al, 1998)
- Preservation of natural interaural level difference cue for spatial hearing
- Higher naturalness and better sound quality (e.g., Neuman et al, 1995, 1998; Hansen 2002).
- Better speech intelligibility for people with more than a moderate loss (Souza et al, 2005; Davies-Venn et al, 2009)



COGNITION AND RELEASE TIME

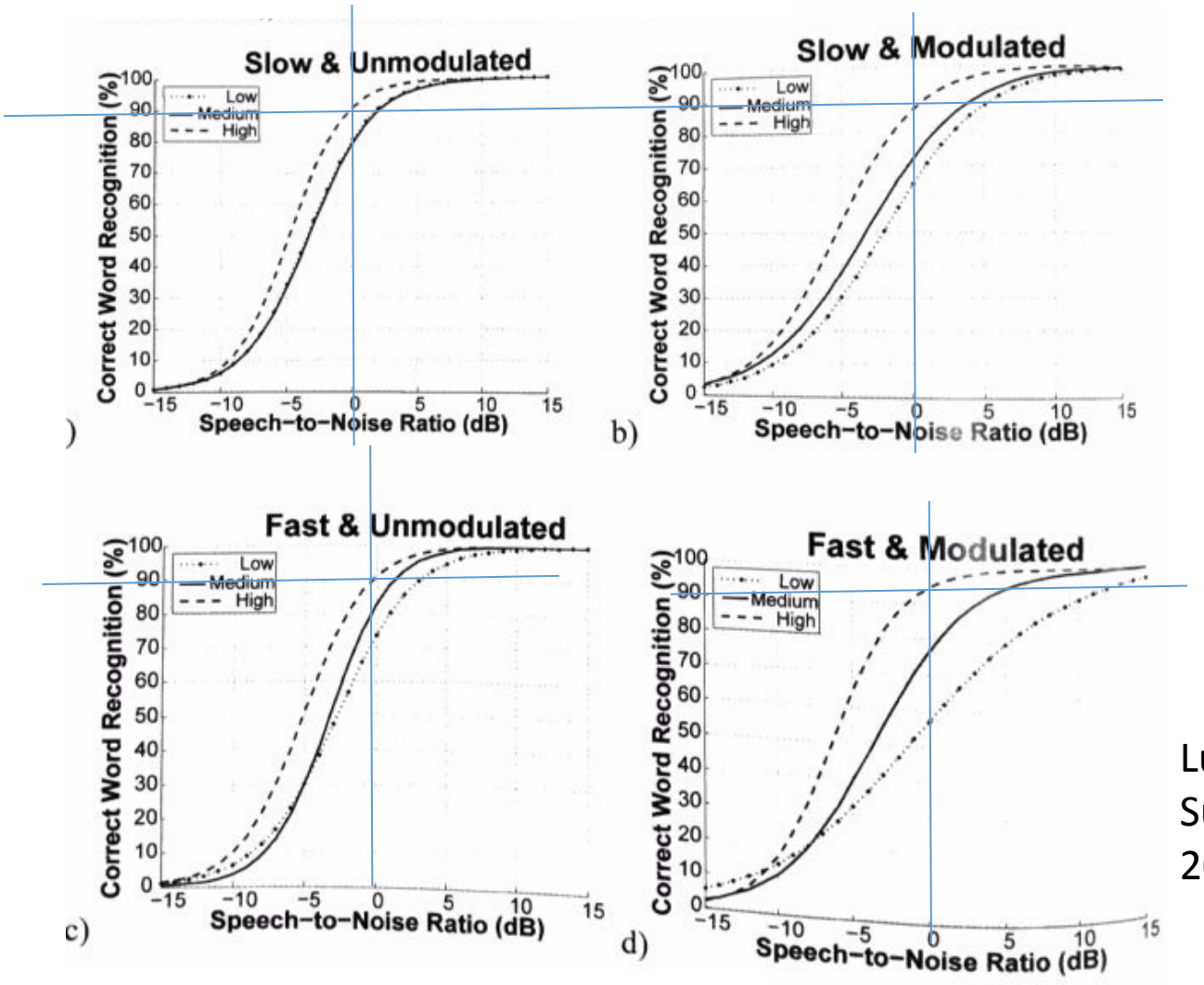
- Gatehouse (2003, 2006) - subjects with lower WM performed better on speech recognition tests with long time constants than with short time constants, while subjects with high WM showed the opposite pattern
- Pichora-Fuller (2003) suggested that age-related differences in cognitive performance during spoken language comprehension may be secondary to auditory temporal processing differences
- Lunner et al (2007) – repeated Gatehouse findings
- Foo et al (2007), Rudner et al (2009) – cognitive capacity (reading span score) predicted speech performance with mismatched phonological information/representation
    - Subjects wore fast/slow acting compression for 9 weeks. Tested with same/different types of compression settings. When test setting matched experienced setting, WM did not predict performance. Prediction when mismatch occurs.
- Name and Vanaja (2009) - Envelope enhancement of speech signal improves speech identification scores in quiet and in background noise for individuals with AN
- Spirakis (2011) - Slower release times provided 32 percent greater WRSs than fast release times in children with auditory neuropathy
- Rudner et al (2012) – compression setting affected listener effort
- Cox and Xu (2014); Souza and Sirow (2014) - Better speech intelligibility for people with limited cognitive resources with longer release time

SUMMARY BETWEEN COMPRESSION SPEED AND COGNITIVE ABILITY

	Fast acting	Slow acting
Good WM	Distortion – present, not bothered Audible cues - useful	Distortion – absent Audible cues - loss
Poor WM	Distortion – present, bothered Audible cues - useful	Distortion – absent Audible cues – loss

All people (good and poor WM) can use audibility cues; but only good WM can tolerate a loss of temporal cues (or poor WM rely more on temporal cues)

DO PEOPLE WITH GOOD WM PERFORM **POORER** WITH SLOW TIME CONSTANTS?

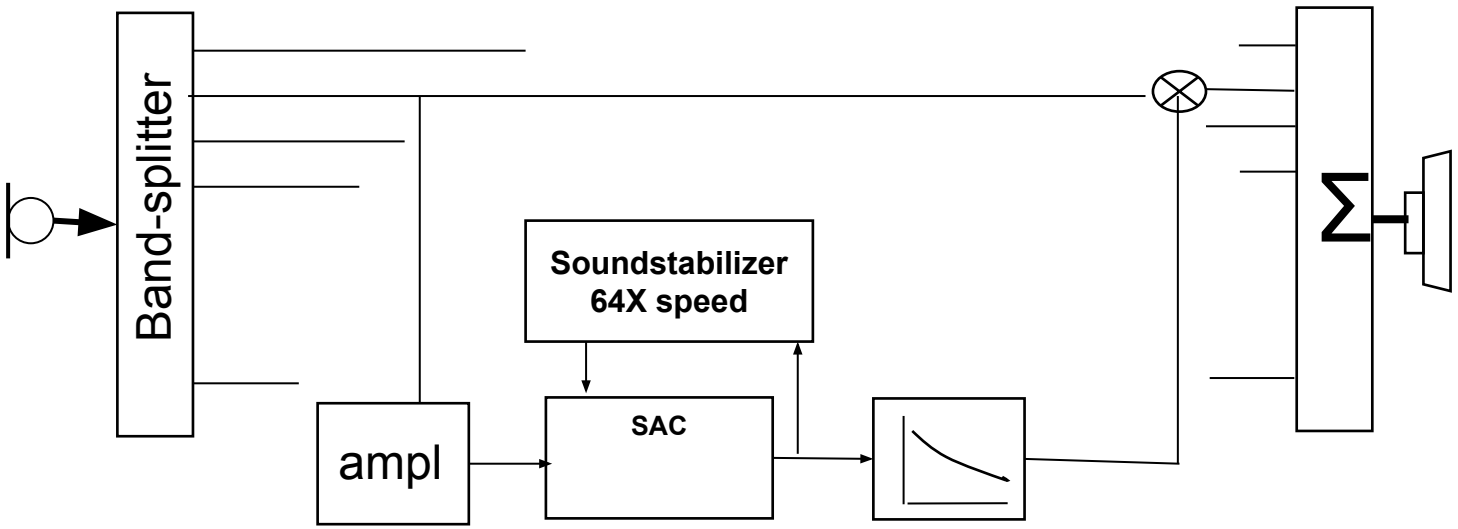


Lunner and Sundewall-Thoren, 2007

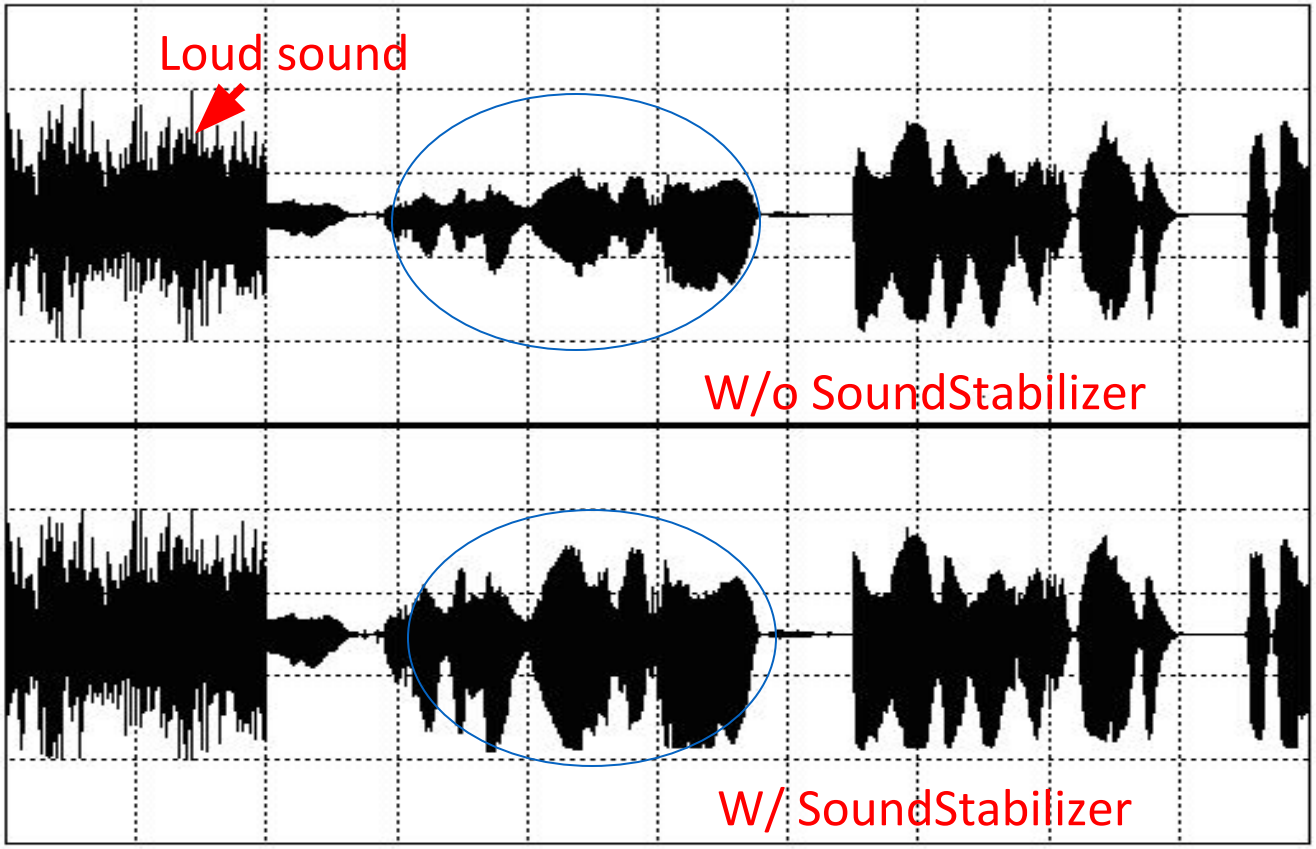
IMPLICATIONS FOR HEARING AID DESIGN AND AUDIOLOGY

- Immediate reaction
  - Fast acting compression for people with good WM
  - Slow acting compression for people with poor WM
- Considerations
  - Research done with only one form of compression
    - Combination of compression speeds?
  - Sacrifices
    - Good WM with poorer sound quality from FAC
    - Poor WM with compromised audible cues from SAC
  - Difficulty classifying people into good and poor WM
    - Sensitivity of test measure? Scope of practice? Time?
- Need a compressor that can preserve the temporal cues AND audibility cues to benefit people with good and poor working memory

SINGLE SPEED COMPRESSOR (SLOW) WITH **ADAPTIVE** COMPRESSION



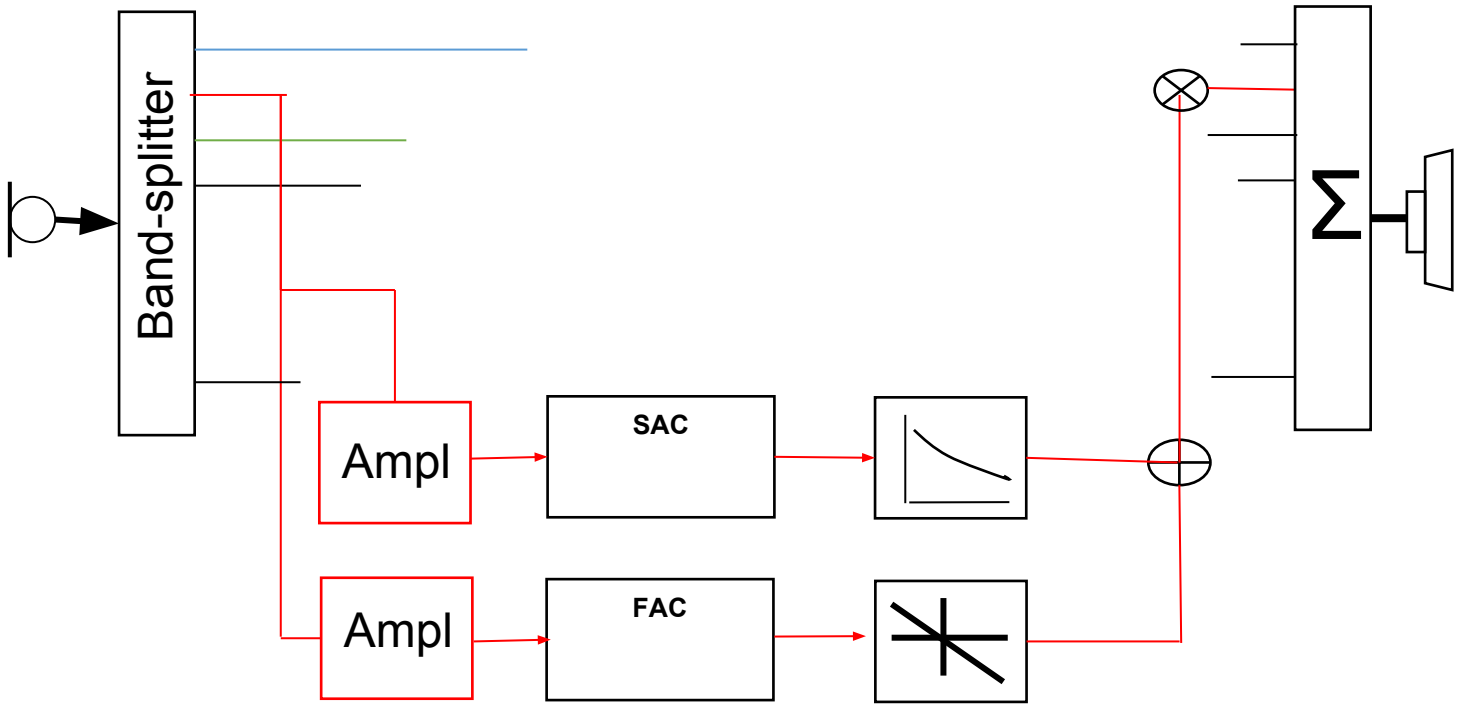
ADAPTIVE COMPRESSION VIA **SOUND STABILIZER**



DESIRABLE ENHANCEMENTS IN SINGLE SPEED COMPRESSORS

- Fast acting compression
  - Need to preserve waveforms at all levels, and especially loud inputs (because of potential saturation)
- Slow acting compression
  - Need to achieve audibility for soft sounds (especially after loud sounds)
  - Transition from low gain to high gain (and vice versa) must be rapid enough but seamless
- Ideal solution is a slow acting compressor (primary) working in parallel with a fast acting compressor (secondary) – preserves temporal structures and audibility cues

VARIABLE SPEED COMPRESSOR



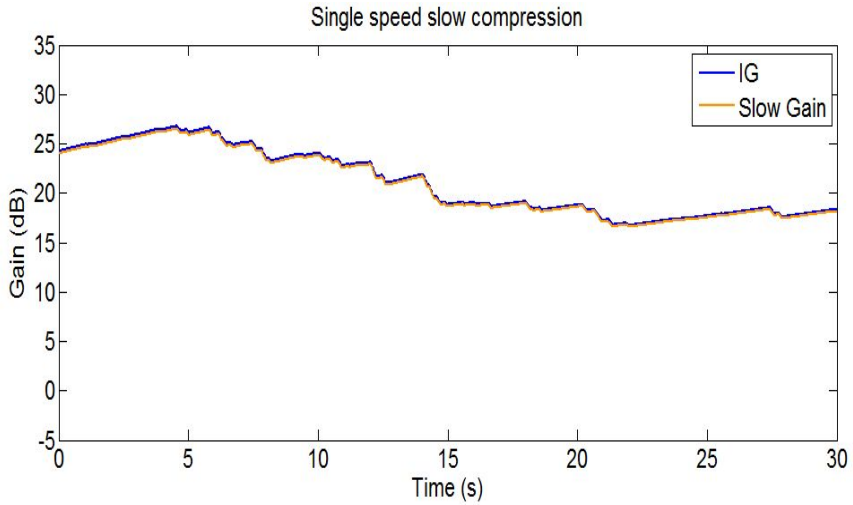
Overall IG = SAC gain + FAC gain

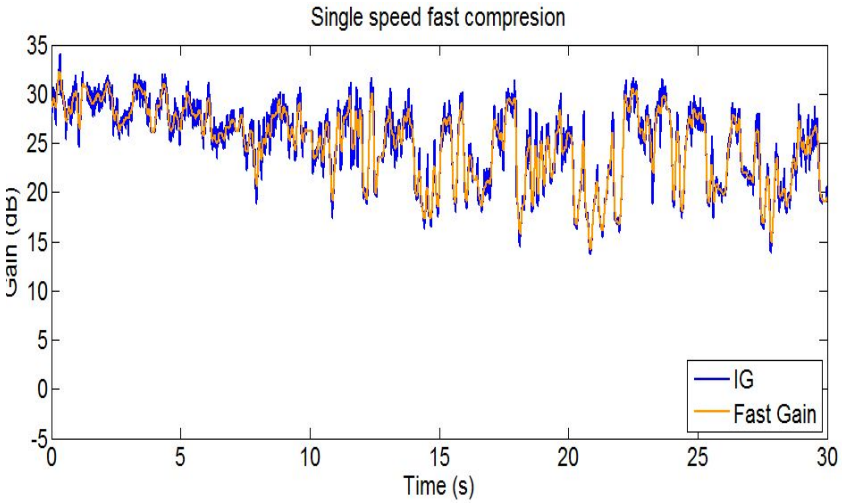
VARIABLE SPEED COMPRESSOR – DESIGNED FOR **EFFORTLESS HEARING**

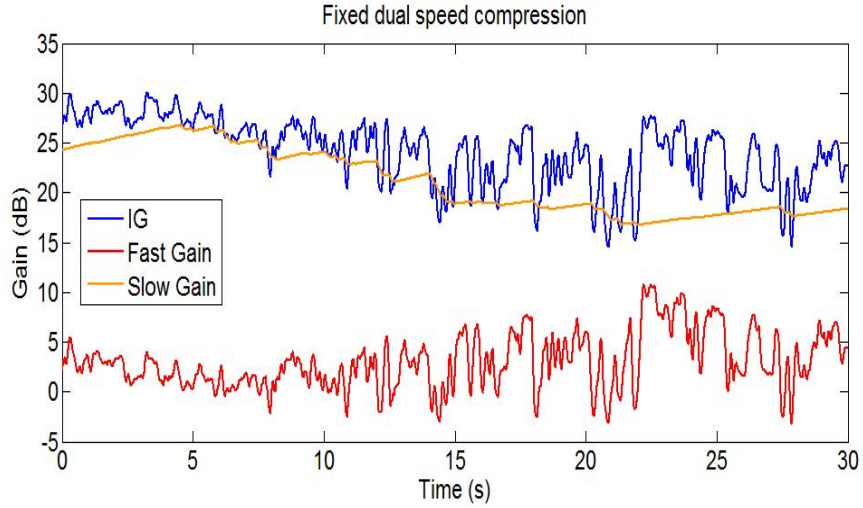
- *Effortless Hearing* design – people with good and poor working memory can all realize their potentials
- The variable speed compressor has a slow-acting and a fast acting component
- Slow acting component preserves temporal characteristics of input (needed by people with poorer WM) and fast acting component picks up the audibility cues from sudden changes in input levels (benefits both good and poor WM)

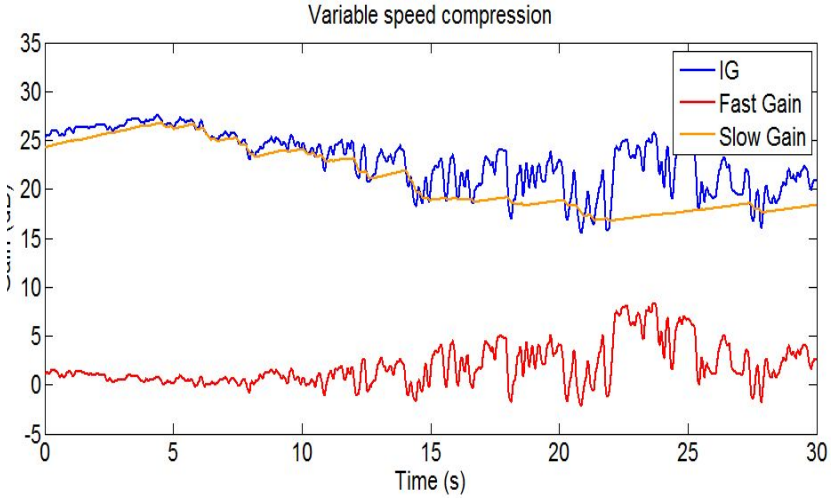
HOW THE COMPRESSORS CHANGE THEIR GAIN WILL BE UNIQUELY DIFFERENT AMONG MANUFACTURERS

EXAMPLE OF GAIN AT EACH COMPRESSOR









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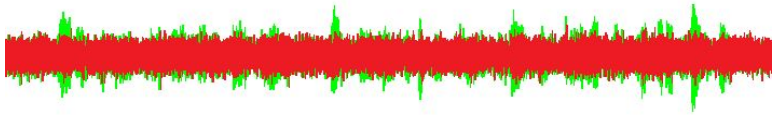
ADDITIONAL MEASURES TO **MINIMIZE TEMPORAL SMEARING**

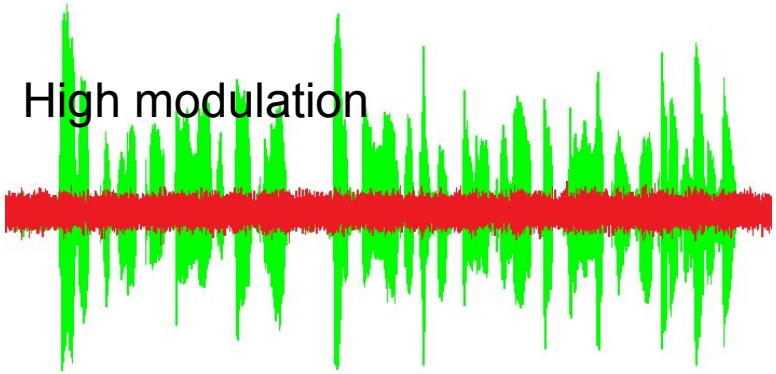
- Slow acting compression as primary compressor
- Use fast-acting only when it is needed:
  - Use of modulation control – only use FAC on highly modulated signals, i.e., not in noise
  - Linking nearby channels in release time – reduces effective channel numbers and reduces smearing
  - Limit FAC only to those < 75 dB HL

MODULATION CONTROL

Low modulation

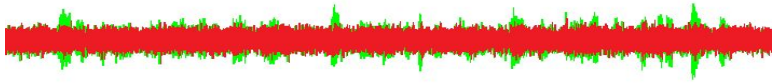


High modulation

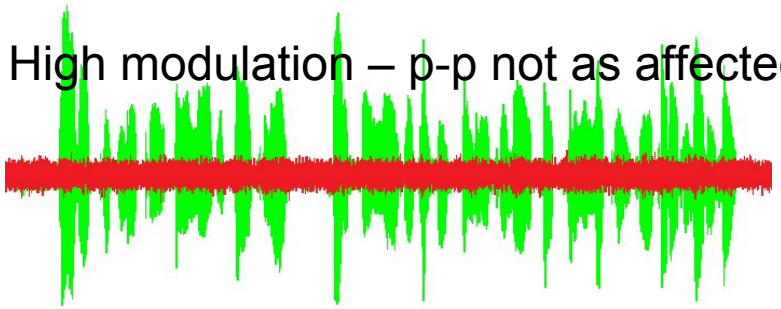


After FAC action:

Low modulation – reduced peak-to-peak



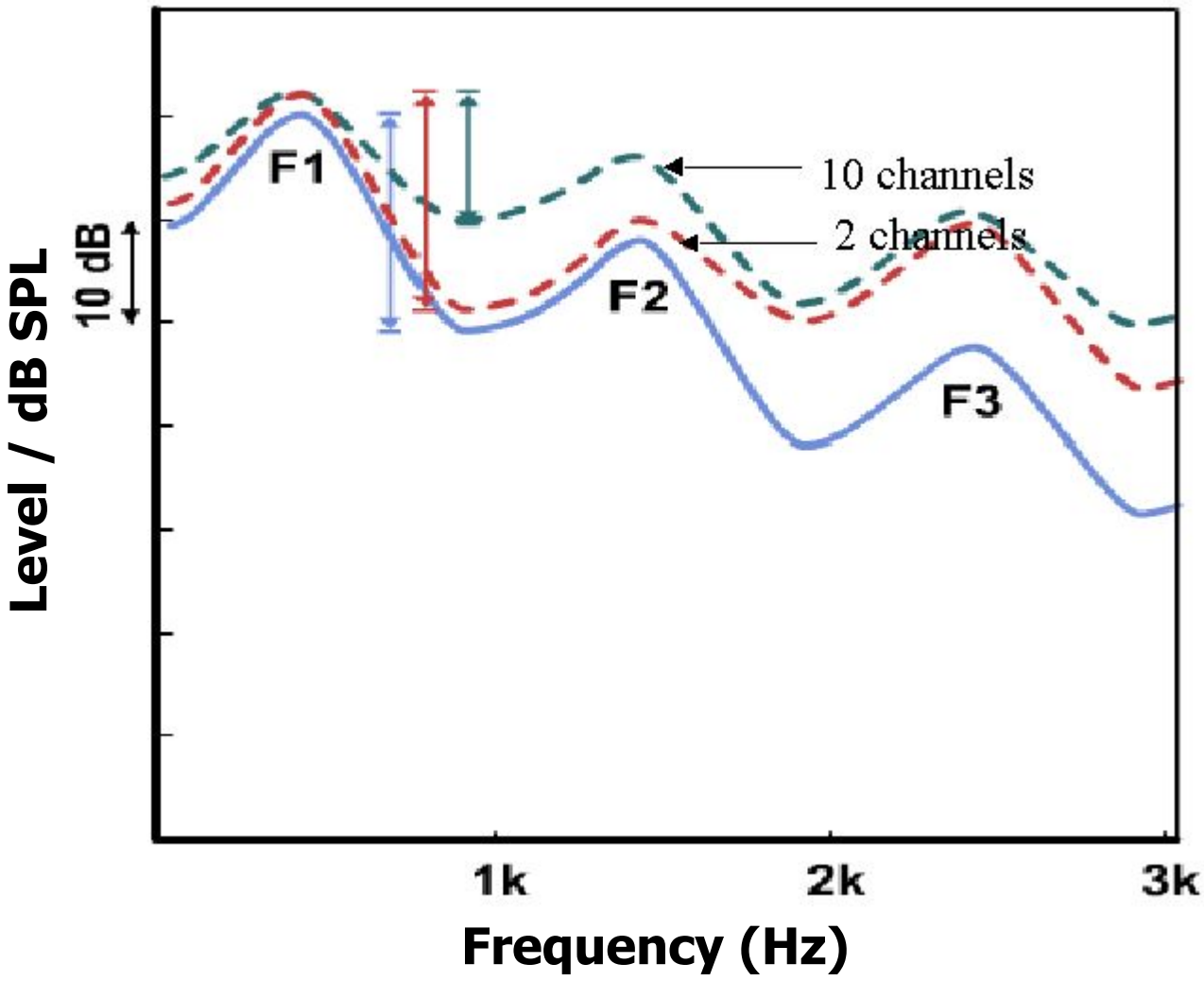
High modulation – p-p not as affected



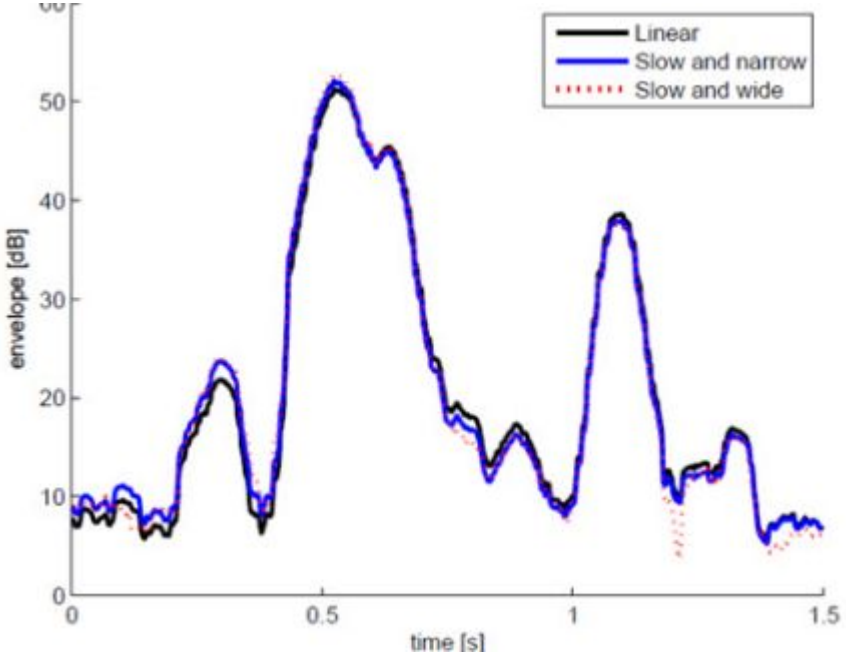
EFFECT OF **CHANNEL BANDWIDTH** ON TEMPORAL CUES

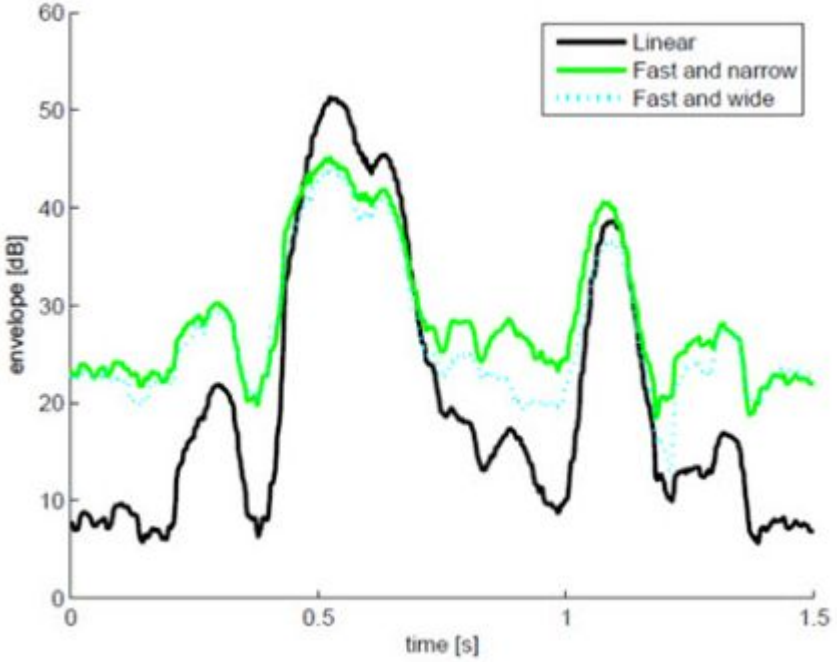
- More channels, less intensity difference among frequencies, more smearing
- Souza and Turner (1996) – single channel compressor does not affect temporal structure
- Souza (2005) – even a 3 channel system degrades speech identification
- Bor et al (2008) – as # channel increases, spectral flattening occurs with vowel formants
- Alexander and Masterson (2015) - short RT was slightly better when only 4 channels were used and that long RT was better when 16 channels were used

SPECTRAL SMEARING



EFFECT OF CHANNEL BW AND RELEASE TIME ON **TEMPORAL ENVELOPE**





wide (3-channel) and narrow (15-channel) frequency bandwidths

Fast AT/RT = 10/105 ms, CR=2: Slow AT/RT = 700/7000 ms, CR=2)

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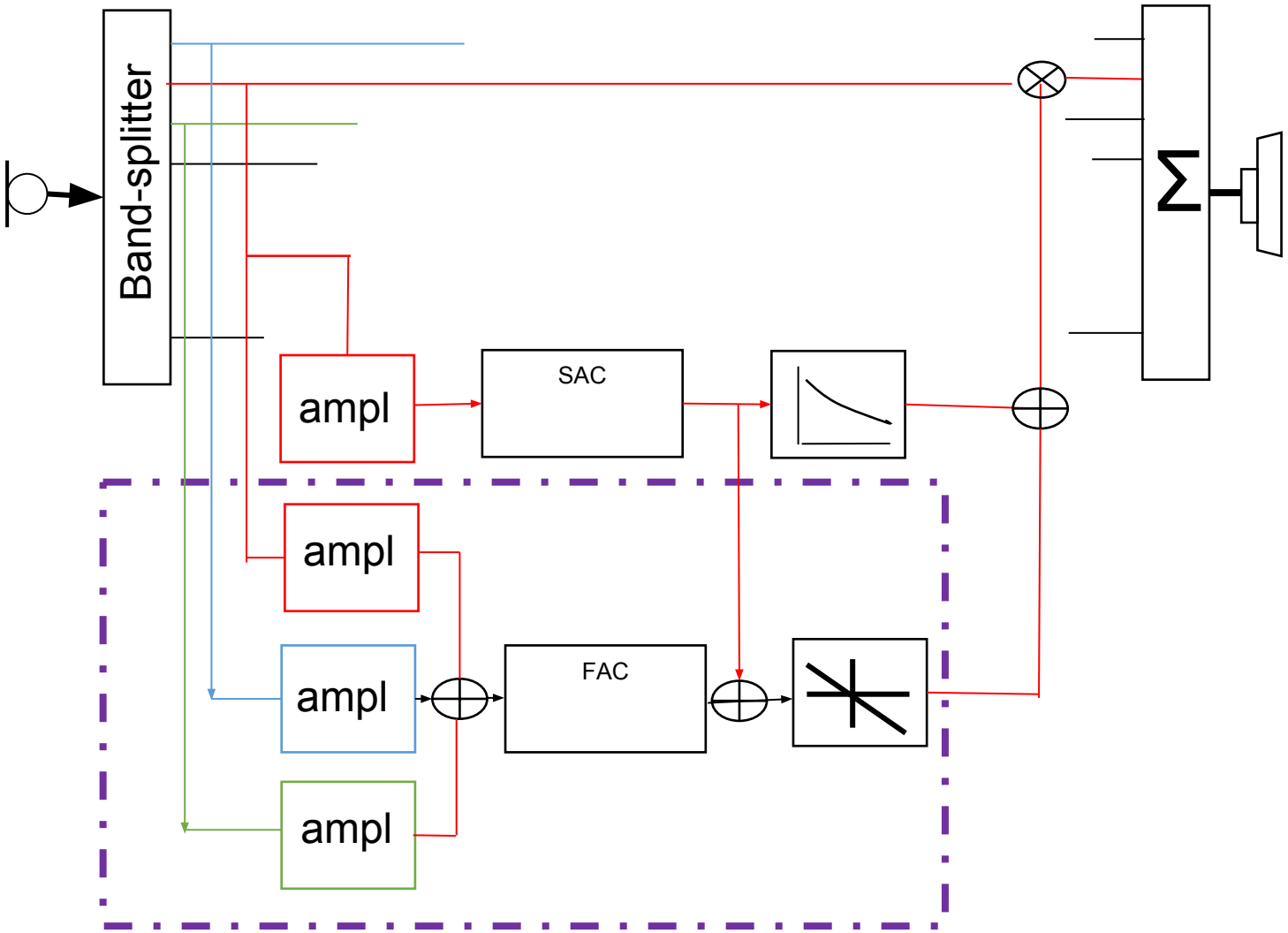
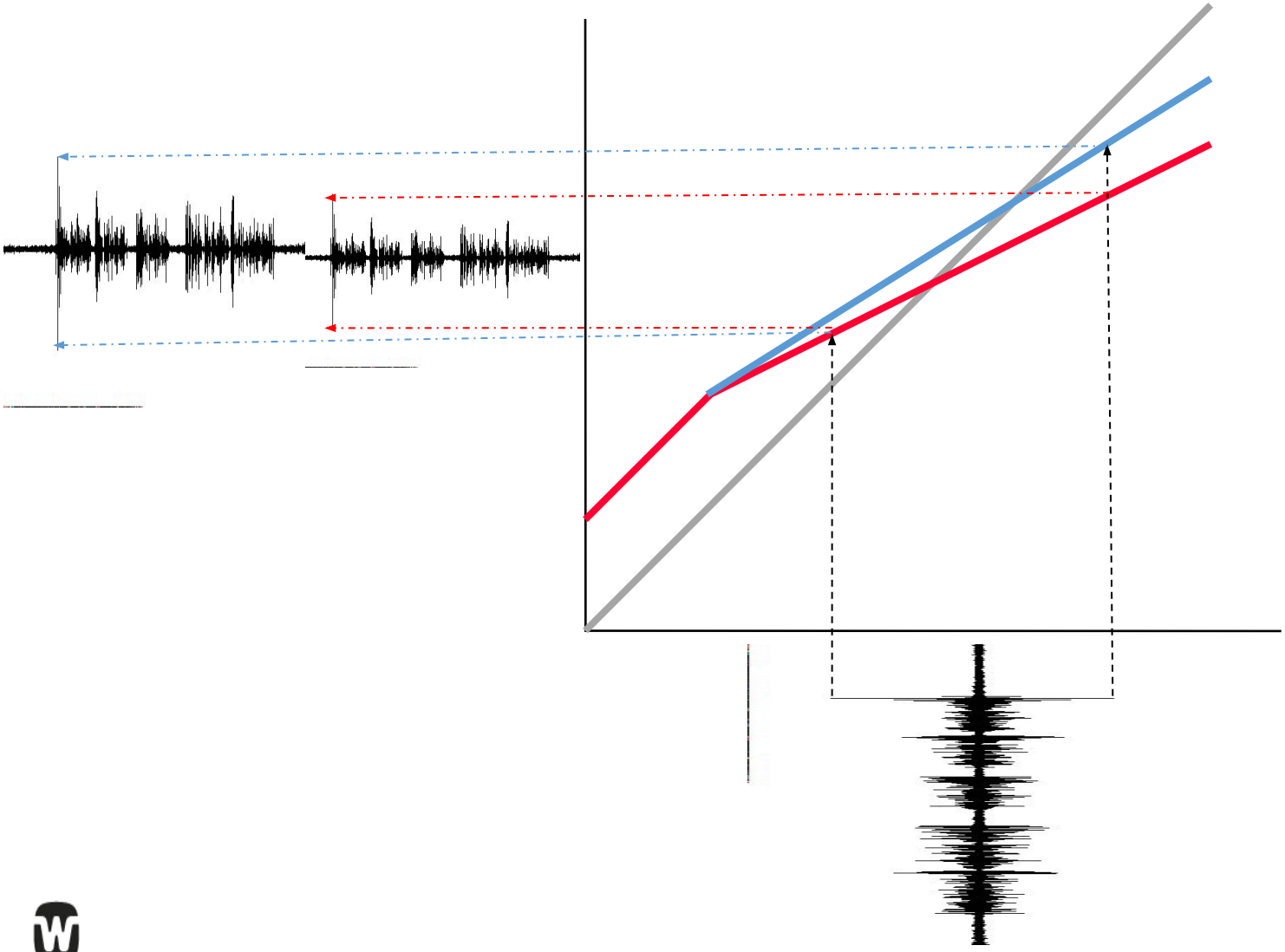
LINKING NEARBY CHANNELS



EFFECT OF **COMPRESSION RATIO** ON TEMPORAL CUES

- Higher CR, less intensity difference, more temporal smearing
- Effective compression ratio affected by release time and also venting (for CR > 2:1; and > 2 mm vent)
- Boike and Souza (2000) showed increasing CR, poorer speech performance
- Neuman et al (1994, 1998) – stronger preference for lower CR than higher CR in different noises

ILLUSTRATION OF **COMPRESSION RATIO** ON TEMPORAL ENVELOPE



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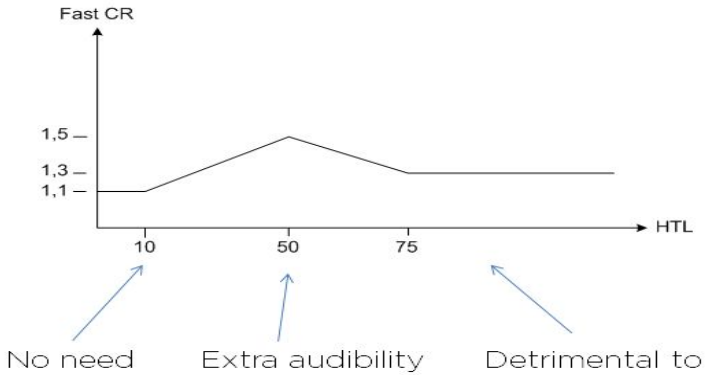
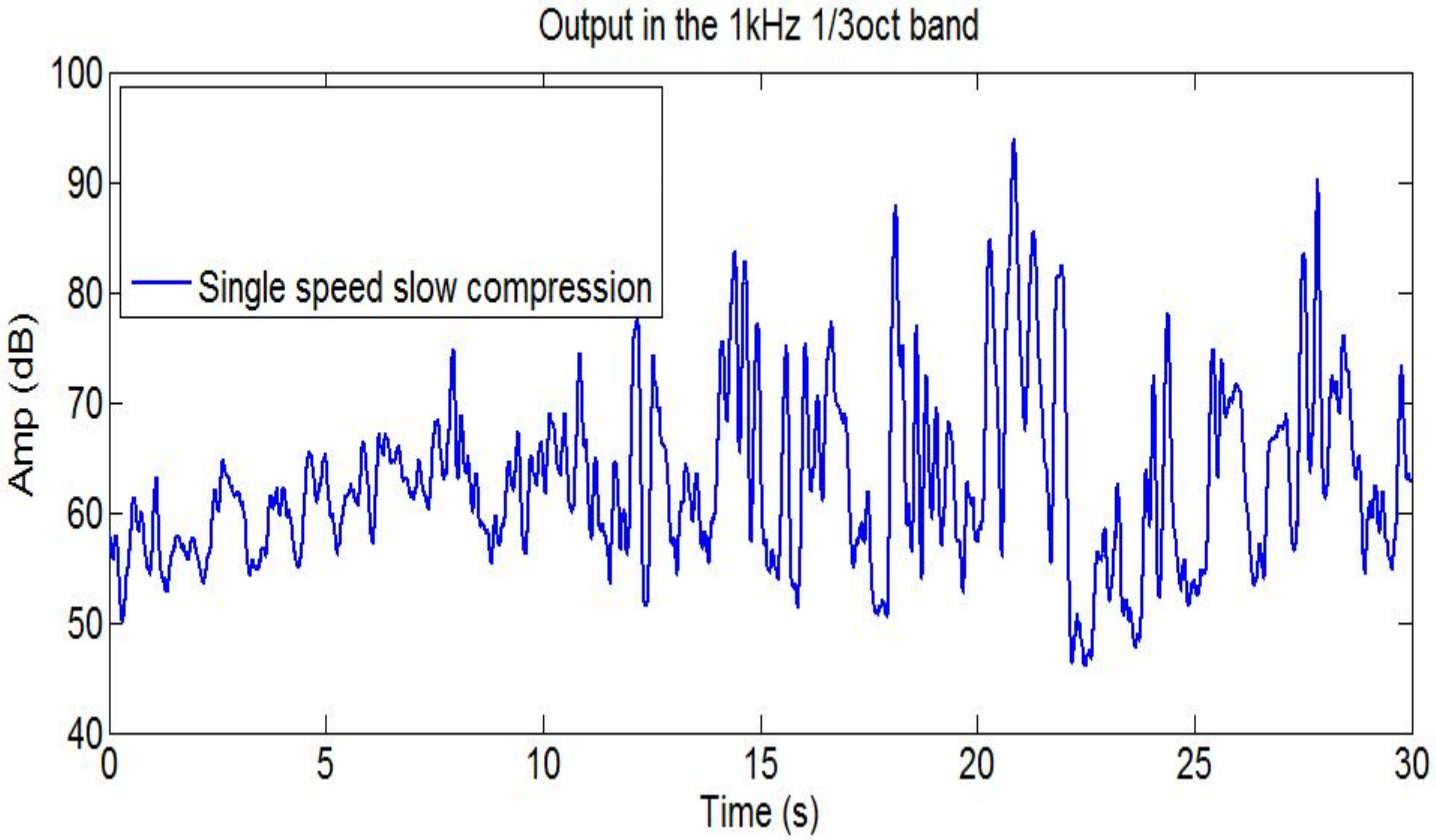
ACCEPTABLE CR RE: HEARING LOSS

- People with a severe hearing loss would require a higher compression ratio (CR) because of the reduced dynamic range
- But a higher CR also means more smearing, leading to poorer performance
- People with a more severe loss prefers less compression

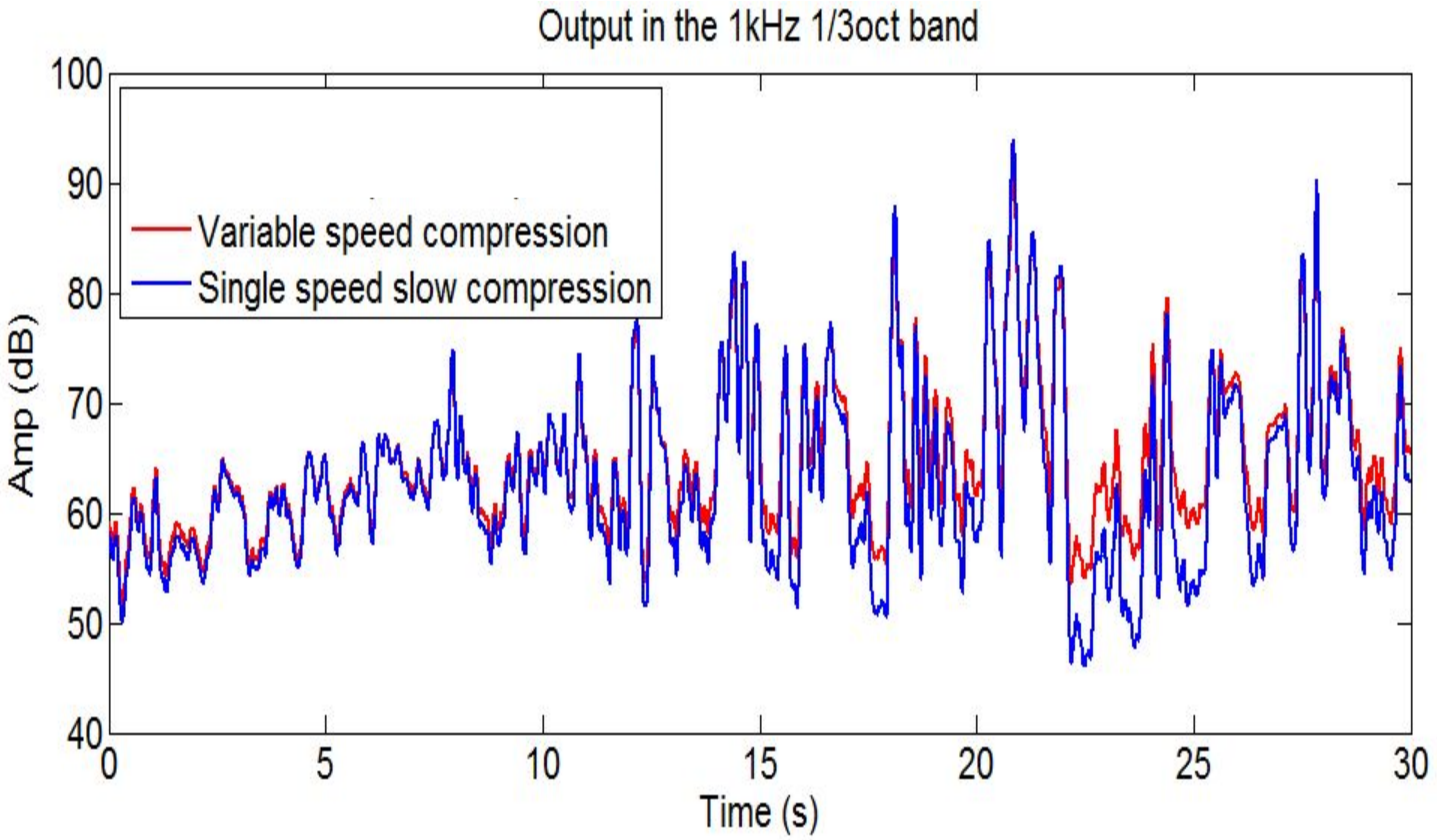
User specific



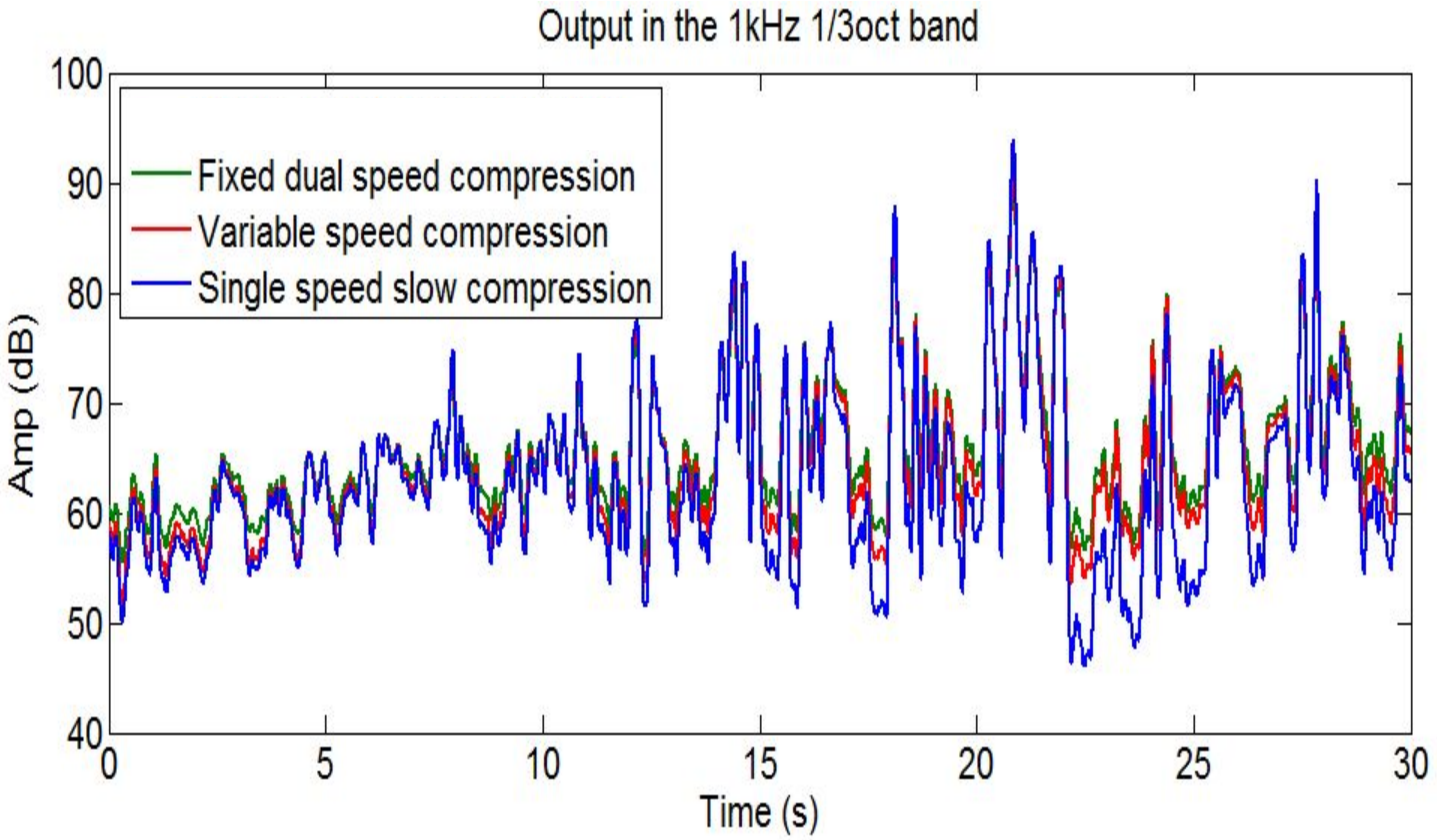
FINAL WAVEFORM – SINGLE, SLOW



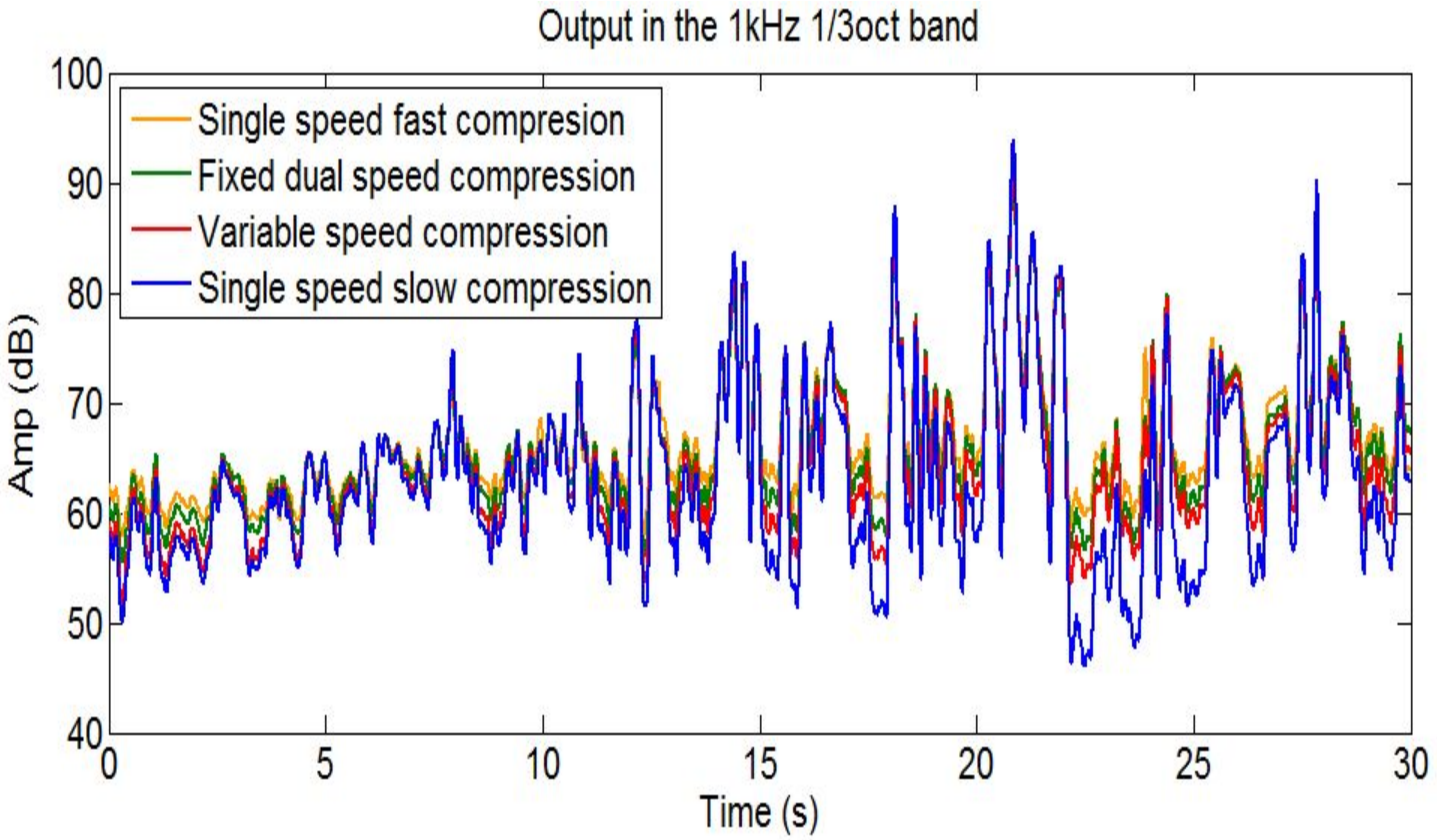
FINAL WAVEFORM – **DUAL, VARIABLE**



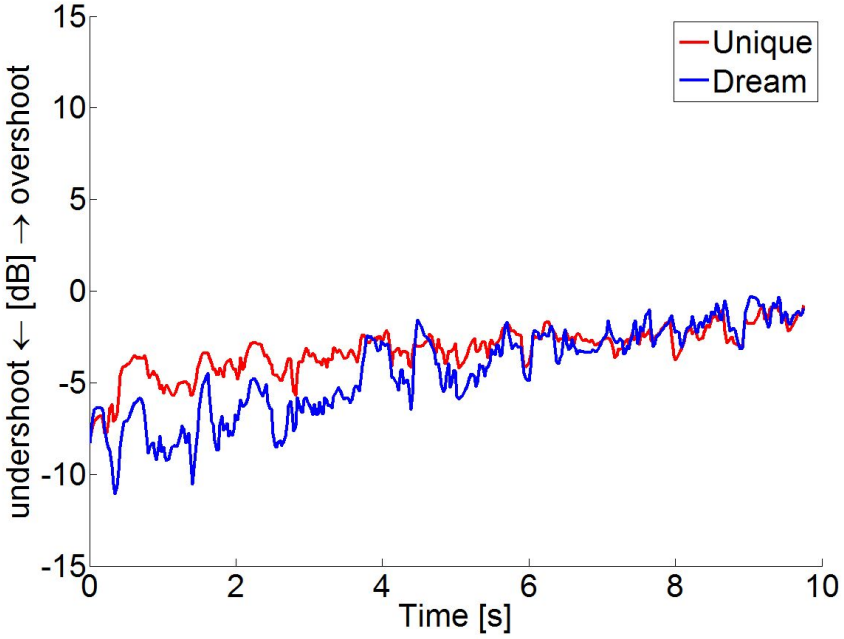
FINAL WAVEFORM – **DUAL, FIXED**



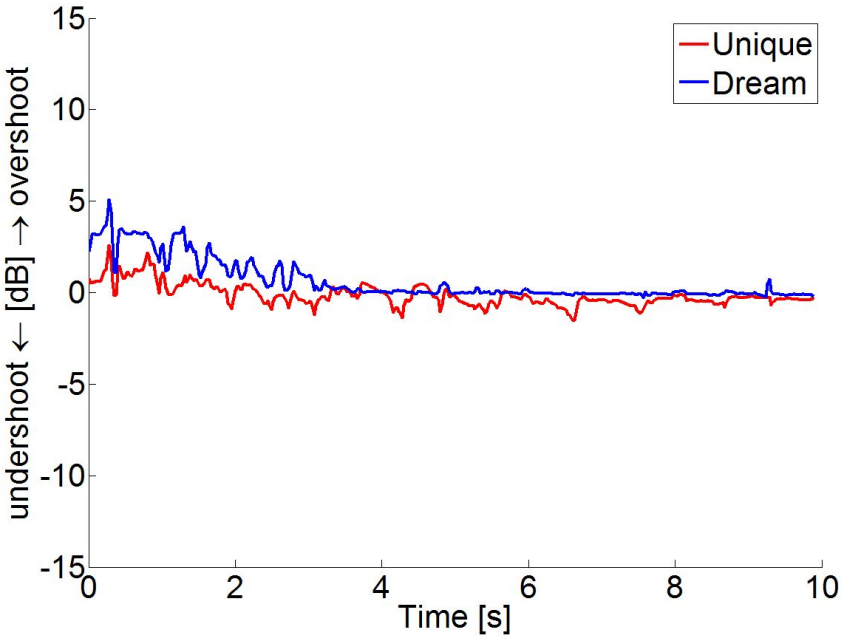
FINAL WAVEFORM – **SINGLE, FAST**



RESPONSIVENESS OF THE VARIABLE SPEED COMPRESSOR



From 80 dB to 50 dB
Quicker restoration of gain



From 50 dB to 80 dB
Quicker settling of gain

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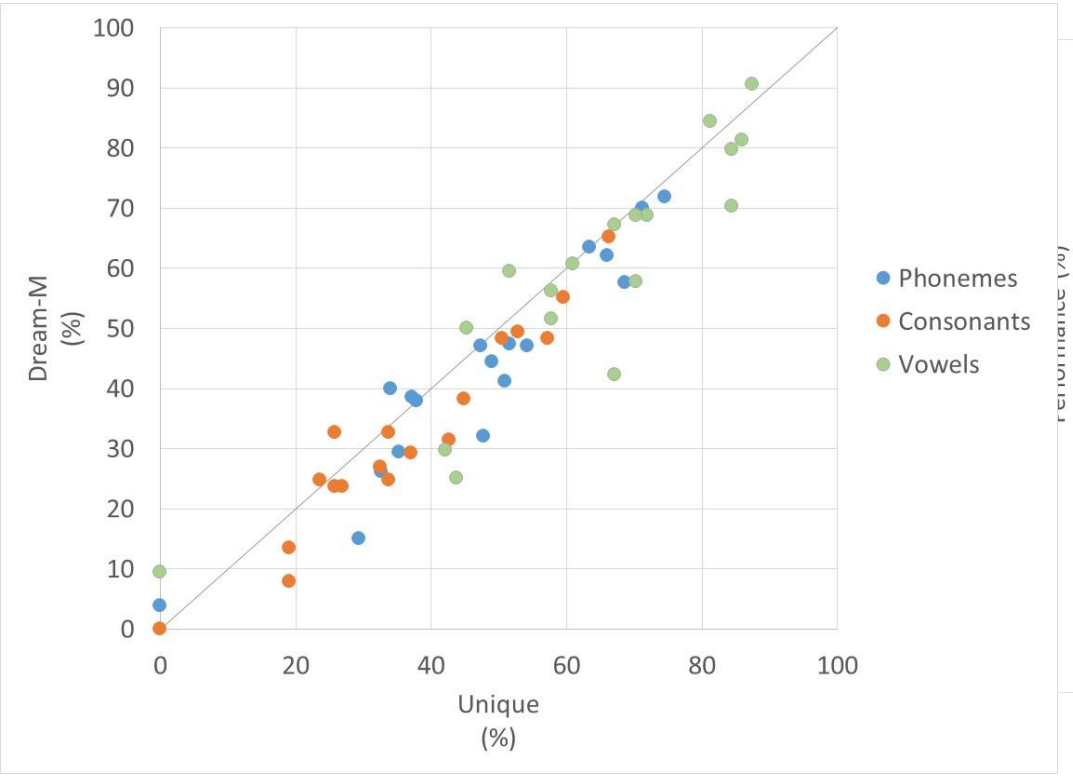
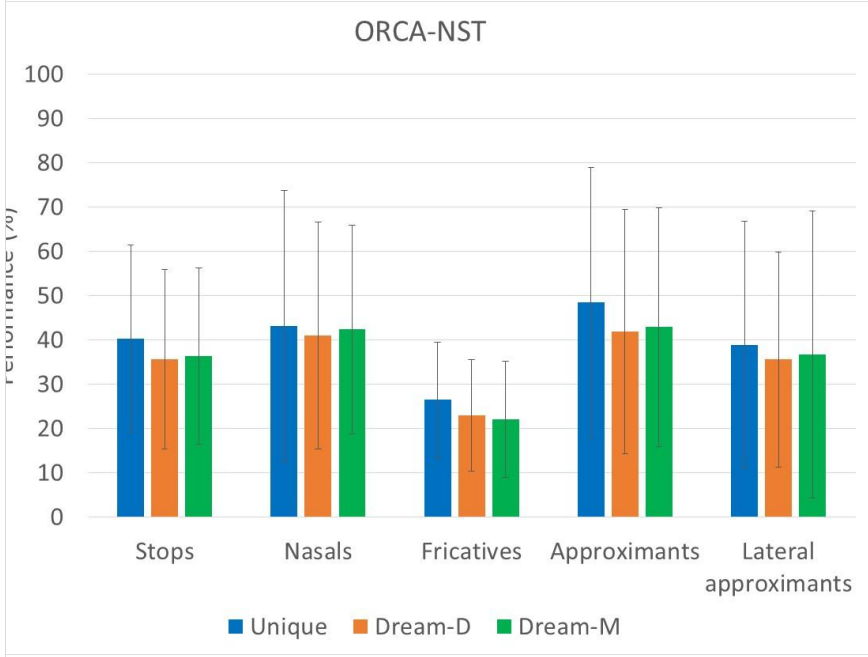
BENEFITS FROM VARIABLE SPEED COMPRESSION – **CONSISTENT AUDIBILITY**





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ADVANTAGES OF A VARIABLE SPEED OVER A SINGLE SPEED COMPRESSOR

- More consistent audibility for soft sounds, especially after a loud sound
- More comfort for transient sounds, and when transitioning from soft to loud sounds
- Better SNR at high input level, preserving the temporal structures (and better speech understanding in noise)
- Better preservation of temporal waveform at ALL input levels
- Optimal for people with good and not-so-good working memory and those with a severe hearing loss

CONCLUSIONS

- The speed of compression has important consequences on wearer success
- Fast acting only compression gives extra audibility at the expense of temporal distortion
- Slow acting only compression preserves temporal nuances at the expense of potential audibility loss
- Research on compression speed and cognition is based on single speed compression
- If implemented properly, variable speed compression preserves temporal structures and audibility cues, and may be desirable for ALL people - good and poor working memory