1aSC12. Transmission and reception of visual speech signals produced by Cued Speech transliterators

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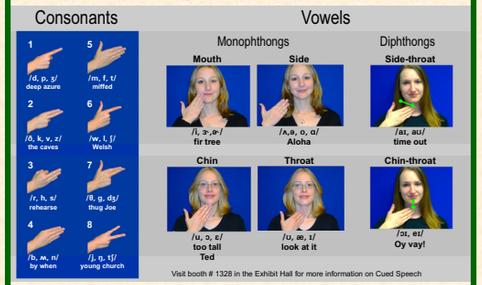
-Background-

Cued Speech (Cornett, 1967)

- Visual-only speech communication system used by some deaf individuals
- Hand "cues" are produced in synchrony with the mouth movements of speech
- Cues disambiguate visually confusable phonemes (i.e. visemes)
  - Eight handshapes represent groups of visually distinct consonants
  - Six placements represent groups of visually distinct vowels



- When used correctly, Cued Speech allow for near-perfect reception of everyday connected speech (Uchanski et al., 1994)

→ Some deaf people who use Cued Speech rely on **Cued Speech transliterators** as a means of accessing spoken information

-Accuracy vs. Intelligibility-

Cued Speech transliterator = an "interpreter" who uses Cued Speech

- Factors affecting interpreter intelligibility are unknown (Kluwin and Stewart, 2001)
- In investigating these factors, **two** aspects of the interpreted message must be considered:

- **Cued Speech** transliterators are attractive candidates for study
- One-to-one correspondence between spoken phonemes and cued phonemes means that both aspects can be easily quantified:
  - **Accuracy:** proportion of signal correctly ***transmitted*** by the transliterator
  - **Intelligibility:** proportion of signal correctly ***received*** by the deaf consumer

-Experiment 1: Accuracy-

Purpose

How does the accuracy of Cued Speech transliterators, measured by percent-correct cues produced, vary with:
- ***Speaking rate:*** slow, normal, fast
- ***Lag time:*** average delay between spoken and cued signals

Effect of experience was also examined

Participants

- Twelve (12) Cued Speech transliterators (CSTs), assigned to one of three categories based on level of experience
  - Two (2) **"novice"** CSTs - minimal or no certification and less than (the equivalent of) one year of experience
  - One (1) **"experienced"** CSTs - minimal certification with less than three years of work experience, or no certification with 3-5 years of experience
  - Nine (9) **"veteran"** CSTs - highest level of certification and/or more than five years of experience

Materials

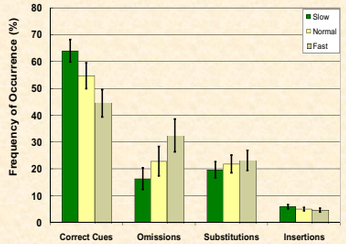
- Video recordings of the cued messages produced when each participant transliterated materials at three different speaking rates
  - Transliterators were presented with audio recordings of an 8th grade "lecture"
  - The lecture was presented in three segments, each at a different (conversational) speaking rate
    - **slow:** 88 wpm (speech expanded by a factor of 1.25)
    - **normal:** 109 wpm (original)
    - **fast:** 137 wpm (speech compressed by a factor of 0.8)
  - Speaking rate counterbalanced across segments

Procedures

- Transliterations were viewed in slow motion using Adobe Premiere Pro 1.5, and each cue produced was classified in one of four production categories:
  - **Correct cues**
  - **Omissions**
  - **Substitutions**
  - **Insertions**

Relationship to speaking rate

- On average, across all experience levels...
  - Correct cues: negative relationship with speaking rate
  - Omissions: positive relationship with speaking rate
  - Substitutions and insertions: no effect of speaking rate

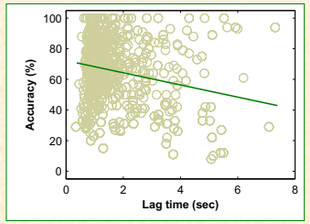


→ **Accuracy decline caused mostly by increased omissions**

- In addition, the negative relationship between accuracy and speaking rate was exhibited by all transliterators

Relationship to lag time

- **At the phrase level,** lag time is **inversely correlated** with accuracy (Spearman's rho = - .235, p<0.000)
  - However, it accounts for only 4% of the variance:



Overall Results

- **On average**, across all transliterators and speaking rates...
  - Correct cues occurred most frequently (54%)
  - Omissions were the most frequent type of error (24%)

Production category	Frequency of occurrence
Correct cues	54%
Omissions	24%
Substitutions	22%
Insertions	5%

- Accuracy of **individual CSTs** ranged from
  - 29% to 84% on average across rates
  - 40% to 89% at the slow-conversational rate

-Experiment 2: Intelligibility-

Purpose

How does the intelligibility of Cued Speech transliterators, measured by percent-correct words received, vary with:
- ***Accuracy:*** percent-correct cues transmitted
- ***Lag time:*** average delay between spoken and cued signals

Participants

- Eight (8) "expert" Cued Speech receivers
  - Profoundly deaf individuals with at least 10 years of experience using Cued Speech
  - Exposed to Cued Speech before age 10
  - Passed CS receptive screening (>90% reception of 5 sentences cued with 100% accuracy)

Materials

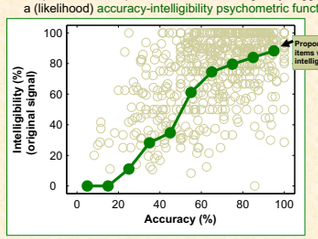
- Drawn from videos collected for Experiment 1
- ~2700 phrases excised from transliterator videos
- Only those elicited at the **slow-conversational rate** (~88 wpm) were considered (~900 possible stimuli, or ~75 clips per CST)
- Four stimulus blocks selected, such that
  1. The entire film narration (240 excised videos) could be presented phrase-by-phrase (in order) to each participant
  2. The range of accuracy scores was as well-distributed between 0% and 100% as possible

Presentation sessions

- Stimulus items presented **one phrase at a time**
- Stimuli periodically interspersed with excerpts from the original film, presented for context
- Each stimulus presented **once** on a computer monitor
  - Participant controlled pace via computer interface
  - Participant typed response **verbatim**

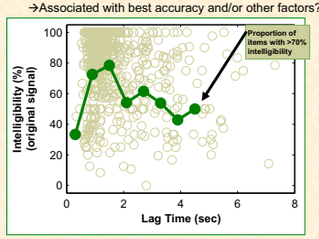
Relationship to accuracy

- **On average, intelligibility (72%) substantially higher than accuracy (54%)**
  - Also **higher for most (8) individual CSTs** (5 - 23 points)
  - Accuracy ~ equal to intelligibility for 4 CSTs:
    - Both novices (CST1, CST3)
    - Two veterans (CST7, CST12) – possible ceiling effect
- **For individual stimuli,** the relationship between accuracy and intelligibility is more variable. However, ...
  - Accuracy accounts for 26% of the variance in intelligibility and more when experience is controlled
    - Novices: 56% of intelligibility variance
    - Veterans: 28% of intelligibility variance
  - Proportion of data points with >70% intelligibility suggests a (likelihood) accuracy-intelligibility psychometric function:



Relationship to lag time

- **For individual stimuli,** the relationship between lag time and intelligibility is not linear. However, ...
  - The >70% intelligibility likelihood lag time - intelligibility psychometric function suggests an **optimal lag time**:
    - →**1-1.5 seconds**
    - →Associated with best accuracy and/or other factors?



Overall Results

- On average, across all receivers and transliterators...
  - 72% of all words in the original signal were received

Production category	Intelligibility
All words – original signal	72%
Key words – original signal	77%
Key words – transmitted signal	82%

- Intelligibility obtained by **individual receivers** varied up to 15 percentage points
  - 65% - 79% for original signal (all words)
  - 70% - 83% for transmitted signal key words
  - 74% - 89% for transmitted signal key words

-Conclusions-

- **Accuracy of "typical" CSTs is substantially lower than 100%**
  - Some highly experienced veteran CSTs are quite accurate
    - 2 veteran CSTs were above 85% at the slow-conversational rate
  - However, many "typical" (i.e. working, randomly selected) CSTs are not
    - 7 veteran CSTs: 40% to 73%, even at the slow-conversational rate
    - 3 less-experienced CSTs: 51% to 81%, with accuracy dropping markedly as speaking rate increased

  →Increased transliterator training and professional development opportunities should be created to address these issues in working transliterators
- **Accuracy plays a large role in intelligibility**
  - Accounts for 26% of the variance in this experiment
  - May account for more if accuracy measurements can be refined
    - Many substitutions are likely to be partially correct (e.g. right handshape, wrong placement)
    - No partial credit was awarded
- **Lag time also affects intelligibility** ("optimal" lag time is 1-1.5 seconds)
- **Other factors observed here that are likely to affect intelligibility:**

Transliterator factors
- Visual prosody
- Speechreadability
- Facial expressions and non-manual behaviors
- Cueing style: clear vs. conversational and highly co-articulated

Receiver factors
- Degree of reliance on speechreading vs. cuereading (making cueing errors easier or more difficult to tolerate)
- Current frequency of Cued Speech use

-Future Work-

- Refine accuracy analysis (e.g. partial credit for substitutions)
- Quantify effects of rate on intelligibility and accuracy x rate interactions
- Isolate and analyze other transliterator factors, such as speechreadability, that may also affect intelligibility
- Extend experiments to other visual communication options used by deaf individuals: Signing Exact English, American Sign Language, etc.
- Compare accuracy-intelligibility psychometric functions across communication options in order to
  - Increase understanding of intelligibility of visual signals
  - Gain insight into modality-independent aspects of perception

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