Supporting Learning for Individuals with Visual Impairment

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Underlying Premise

- Humans live in a ‘cultural world’ designed for humans
- Humans are embodied beings (mind and body)
- Individuals with disability are ‘otherly enabled’ and have to overcome cultural designs grounded in expectations of embodiment
Embodiment and Language
Speech Example

S1  you know like those fireworks?
S2  well if we're trying to drive'em / out her<e #
    we need to put'em up her<e
S1  yeah well what I'm saying is we should*
S2  in front
S1  we should do it* we should make it a line<e
    through the room<ms / so that they explode
    like here then here then here then here
Multimodal Language Example
Co-Generation of Gesture and Speech

Embodiment: Thinking and Speaking

- Embodiment shapes Language
  - Laterality of human form
  - Symmetries and oscillatory processes of human structure & movement
  - Opportunities of spatial organization
- The mind appropriates embodied processes for language and thought
- Temporal cohesion between gesture and speech reveals the unfolding of thinking and speaking
Two-Projects

Will show impact of this thinking in 2 projects

- Supporting mathematics instruction discourse for Individuals with Blindness or Severe Visual Impairment (IBSVI)
- Developing of e-readers for IBSVI
Pointing is Gesture

- Pointing allows us to borrow space and imagery from the immediate surrounding for embodied language production.
- Temporal cohesion is maintained between pointing and speech for expression of thought.
- Pointing and pointing uptake must be part of expressive act, not an extraneous effortful action.
For mathematics discourse, 3 kinds of information are exchanged:

- Speech content in audible expressions
- Visual content in the form of graphical illustrations
- Situating information in the form of co-temporal deixes

Individuals with Blindness or Severe Visual Impairment (IBSVI) do not have access to this!
The Haptic Deictic System (HDS)

Embodied Behavior Tracking

Embodiment Awareness for the Instructor

Embodiment Awareness for the Student

Embodiment and Culture  Math Instruction  e-Reader for IBSVI
Developing the Technical System

- **Phase 1**: Haptic Glove Development
  - Iterative design and test to produce glove design

- **Phase 2**: Discourse Support
  - Phase 2a: Developed and tested discourse support system
  - Phase 2b: Game for Embodied Skill Training

- **Phase 3**: Mathematics Instruction
  - On to Inclusive Mathematics Instruction …
Phase 1: Haptic Glove Design

- Iterative Design-Prototyping-Testing
- Perception-action studies determined:
  - Glove supports navigation
  - Glove does not interfere with fingertip reading
  - User can navigate, listen to speech & read with fingertip simultaneously
Phase 2a: Developing Full Discourse Support System

- Full deployment of system with bi-directional awareness

Questions:
- Can device support fluid conversation while engaging in joint cognitive problem-solving?
- How do users adapt to the technology?
Testing Discourse: Phrase Charade Study

- The guide helps the follower to solve the charade.
- The puzzle consists of well known phrases, like: “Twinkle twinkle little star” that are encoded as clue phrases like “Blink blink small sun”. 
Early Charade Study

- Subjects could solve puzzle
- One third of the discourse time was about the interaction (device, navigation instruction etc.) and not on the problem

Figure based on Clark's Common Ground Theory
Phase 2b: Game Engagement as Training

Approach:
- Game to encourage skill acquisition
- Computer game & stationed it at the Office for Disabilities Services at Wright State University

Results:
- Improvements for all participants
  - 45% - 62% speed increase
  - Increase in accuracy as the game became more difficult
  - All 5 reached level 2, 3 got to level 3
- Long durations of use:
  - No desensitization detected
  - After game sessions of 30-60 mins, participants said they could play 45 mins or more longer

This is Agent Smith of the Agency of Impossible Missions (AIM). Your services are needed at this time. Dr. Evil has stolen all of the launch codes of our nuclear arsenal. With such codes he can destroy any city in the world. Your mission, if you decide to accept it, is to disarm the launch sequences as they are detected. The first launch sequence detected is for New York City. You have 2 minutes to find the codes and disarm them. Go!
Second Phrase Charade

- Participants solved charade 3x faster
- No discussion of technology
- No reference to pointing task itself
- All discourse was directed at problem and playful speech
On to Mathematics Instruction

- Two 3-session curricula
  - (A: Eratosthenes computation of Earth radius & B: Trigonometry)
- Participants grouped in all sighted and inclusive-instruction classes

<table>
<thead>
<tr>
<th></th>
<th>Curr. A (T1)</th>
<th>Curr. B (T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sighted</td>
<td>s16, s17, s18, s19</td>
<td>s20, s21, s22, s23</td>
</tr>
<tr>
<td>Blind w/ System</td>
<td>b1, s1, s2, s3, b2, s4, s5, s6</td>
<td>b3, s7, s8, s9, b4, s10, s11, s12, b5, s13, s14, s15</td>
</tr>
<tr>
<td>Blind w/o System</td>
<td>b3, s7, s8, s9, b4, s10, s11, s12, b5, s13, s14, s15</td>
<td>b1, s1, s2, s3, b2, s4, s5, s6</td>
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Situated Language Analysis

- To determine ‘opportunity to learn’

- David McNeill’s Growth Point Analysis:
  - Whether instructor & student are able to share the same ‘idea unit’
  - Student’s hand may arrive during idea unit, or at transition before next unit

- Herbert Clark’s Common Ground (Presentation-Acceptance Model)
  - CG based on Evidence (Immediate co-presence) or Assumption (Locatability assumption)
  - Three conditions: Resolved, Unresolved, Probably Resolved
## Summary of Lecture Fluency Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>A+B</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Words per Turn (WPT)</td>
<td>Fewer words per turn w/ HDS (Sig. Diff)</td>
<td>Fewer words per turn w/ HDS (Sig. Diff)</td>
<td>Fewer words per turn w/ HDS (Trend)</td>
</tr>
<tr>
<td>Duration of Instructor’s turn (DIT)</td>
<td>Inconclusive</td>
<td>Inconclusive</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Hand Positioning Events (HPE)</td>
<td>Fewer HPE w /HDS (Sig. Diff)</td>
<td>Fewer HPE w /HDS (Sig. Diff)</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Focus on lesson’s objectives (TLO)</td>
<td><strong>More</strong> focus w/ HDS (Trend)</td>
<td><strong>More</strong> focus w/ HDS (Sig. Diff)</td>
<td><strong>Less</strong> focus w/ HDS (Sig. Diff)</td>
</tr>
<tr>
<td>Deictic expressions (DE)</td>
<td><strong>More</strong> deictic expressions w/ HDS (Sig. Diff)</td>
<td><strong>More</strong> deictic expressions w/ HDS (Sig. Diff)</td>
<td><strong>More</strong> deictic expressions w/ HDS (Sig. Diff)</td>
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</tbody>
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Inclusive Learning Setting with HDS

Embodiment and Culture  
Math Instruction  
e-Reader for IBSVI
Inclusive Learning Setting without HDS
Results Summary

- Situated Analysis
  - Both Growth Point & Presentation-Acceptance analyses show IBSVI have opportunity to learn (access to relevant material)
  - Both show opportunity depends on communicative skill of instructor

- Fluency Analysis
  - Data shows fluency improvement
  - Fluency gains depends on instructor’s skill
Inclusive Mathematics Instruction for the Blind

- Collaborative across HCI, CS, psycholinguistics, special education
- Demonstrated importance of gesture uptake
- Developed analysis techniques to assess opportunity to learn
- All parties in inclusive classroom benefit:
  - Students with Blindness or Severe Visual Impairment: Access, decreased self-awareness
  - Sighted students: pace of class, overall instruction
  - Instructor: classroom awareness, feedback, pacing
Conclusion

- Humans appropriate embodied resources for language and thought
- Pointing (deixis) is an important species of gesture
  - Pointing allows us to borrow space and imagery from the immediate surrounding for embodied language production
  - Temporal cohesion must be maintained between pointing and speech
  - Pointing and pointing uptake must be part of expressive act, not an extraneous effortful action
- In IBSVI pointing uptake must be sufficiently automatic
- Demonstrated Haptic Deictic System that supports mathematics instructional discourse
- Presented analysis approaches to assess opportunity to learn
- All parties benefit
Embodiment and Culture

E-Reader for the Blind (STAAR: Situated Tactile Audio Annotator and Reader)

- Books and pages are information design for embodied humans with visual spatial ability
- Walter Ong (1982) literature designed for aural consumption is fundamentally different from current literature
- Since Guttenberg, visual layout has become the dominant organizational structure
Reading for IBSVI

- State-of-art
  - Braille – literacy and portability problems
  - Audio Readers – obliterate space
- Visually-dominant technology threatens to widen the gap
STAAR Reader

- STAAR augments iPad with tactile overlay for landmarking
- Text is read as it is touched
- User fuses spatial (touch) and aural (words sounded) information
- STAAR supports self-paced active reading and re-reading
- The devil’s in the design details
Models and Systems

Embodiment and Culture

Math Instruction

e-Reader for IBSVI

The discovery was made by volunteers using the website Planethunters.org along with a team from UK and US institutes; follow-up observations were made with the Keck Observatory.

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The discovery was made by volunteers using the website Planethunters.org along with a team from UK and US institutes; follow-up observations were made with the Keck Observatory. Mary Leakey

Mary Leakey 100th birthday: Her son, Philip Leakey, who learned to walk at a dig site, discusses the scientist’s adventurous parenting style. A bio about Mary Leakey might tell modern moms as much as any parenting advice book.

Today’s helicopter parents might want to explore the parenting techniques of famed paleoanthropologist Mary Leakey, whose birth 100 years ago is celebrated today. Instead of hovering over or reigniting her three sons, Mrs. Leakey handed them responsibilities early in life and brought them out on dig sites from infancy.
STAAR with Overlay
Supporting Reading for the Blind

- Theory
- Initial Design
  - System Architecture
  - Page model
  - Basic touch reading
- Testing with IBSVI Consultants
  - Initial overlay structure
  - Page structure
  - Initial reading requirements
- User study with IBSVI Pool
  - Final overlay & page structure
  - Critical incident failures
- 2-week ESM Study
  - Demonstrate effectiveness of basic system
  - Highlight need for intelligent reading support
- Intelligent Reading Support Study
  - Demonstrate minimal reading system

Embodiment and Culture  Math Instruction  e-Reader for IBSVI
Line Straying Problem

The discovery was made by volunteers using the website Planethunters.org along with a team from UK and US institutes; follow-up observations were made with the Keck Observatory.
Reading Support

Sonic Gutter

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Effect:
Dynamically fatten the line being read
Intelligent Reading Support Study

- Goals are to evaluate:
  - Effectiveness: Ability to answer questions
  - Efficiency: Reading & Re-finding time
  - Spatial perception: Page structure understanding

- Within subjects 2x2 study design:
  - Overlay (with or without)
  - Active Reading Support (Simple or Intelligent)

- Participants:
  - 10 IBSVI: ages 18 to 77, $\mu = 50.8$ (SD=15.75) 5 F, 5 M
  - Total Blind: 6; Born visually impaired: 7; Legally blind: 4
  - 8 participants read Braille, 2 have touch devices

- Data was collected via:
  - Experiment video
  - Post-experiment questionnaire
Intelligent Reading Support Study: Results

- In all three:
  - Efficiency (reading speed, re-find time)
  - Effectiveness (question answering)
  - Preference (confidence in reading, ease of use)

- Overlay + Intelligent ARS:
  - Minimal effective design configuration
  - Outperforms Sonic Gutter and Basic STAAR system (p < .05)

- Page Structure:
  - STAAR supported effective strategies for page structure understanding (e.g. semantic idea identification, short lines, spatial exploration)
Summary: E-Reader for the Blind

- Reading is not the same as interaction
- Stepwise incremental approach allowed us to determine the minimal effective design
- Details of design choices and implementation are critical to the success of the system
- Spatial access to the page enables self-paced reading: comprehension, refinding, page-structure
Conclusion

- Recognition of challenges faced by IBSVI owing to cultural design and expectations uncovers rich research opportunities
- Research begins with understanding these challenges with the help of members of the target population
- HCI, disabilities and technology research must be tightly linked
- Research needs to go the extra step of careful validation with IBSVI population
Thanks!

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More Information at:
http://vislab.cs.vt.edu/~quek