Development Across the Life-Span: The Case of Intersensory Perception

Robert Lickliter and Lorraine Bahrick
Infant Development Research Center
Department of Psychology
Florida International University

“I will grant that someone might be able to generate an original thought concerning homology, but I doubt it”.

(David Wake, 1999)

“Everything that needs to be said has been said, but nobody was listening, so it needs to be said again”.

(Ron Oppenheim, 2005)

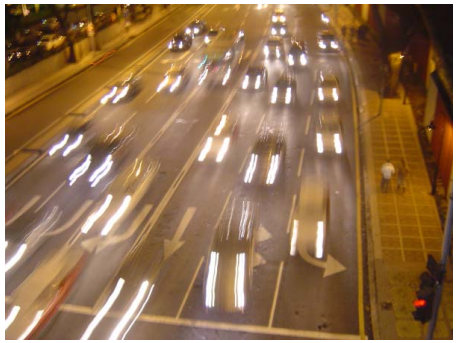
Perceptual Development

- As experienced adult perceivers, we take for granted our remarkable attentional and processing skills that allow us to quickly pick out information that is relevant to our needs, goals, and concerns, while ignoring irrelevant stimulation to our sensory systems.

- However, this was not always the case – as infants we all faced significant challenges in terms of attentional allocation to variations in incoming stimulation.

The World is Multimodal and Dynamic

- Objects and events can be concurrently seen, heard, and felt
- Visual information typically occurs at the locus of a sound
- Objects and events move and perceivers move in relation to them

The Challenge of Infancy

- How, with no prior knowledge of the world, do infants parse this flow of stimulation to all the senses?
- How do they perceive coherent, unitary, multimodal events?
- How do they attend to information that is relevant to their needs and ignore that vast amount of stimulation that is irrelevant?

One Solution: The Salience of Intersensory Redundancy

- Young organisms are highly sensitive to the redundancy or overlap provided by our senses across coordinated visual, auditory, tactile, and proprioceptive stimulation

- Virtually all multimodal stimulation provides redundancy for temporal, spatial, and intensity changes (*amodal* properties of stimulation)

- This overlap, which we have termed *intersensory redundancy*, has been shown to be highly salient and captures selective attention for both humans and animals

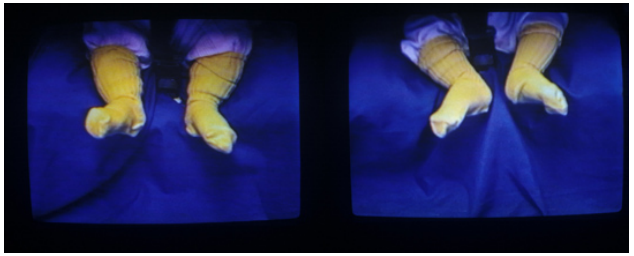
Intersensory Redundancy

- *Definition*: The simultaneous and synchronous presentation of the same information in two or more sense modalities (Bahrick & Lickliter, 2000, 2002)

- Only amodal properties (e.g., synchrony, rhythm, tempo, intensity) can be redundant because by definition, amodal information is information that can be conveyed by more than one sense modality

- How prevalent is intersensory redundancy during early development?

Self Exploration is Multimodal



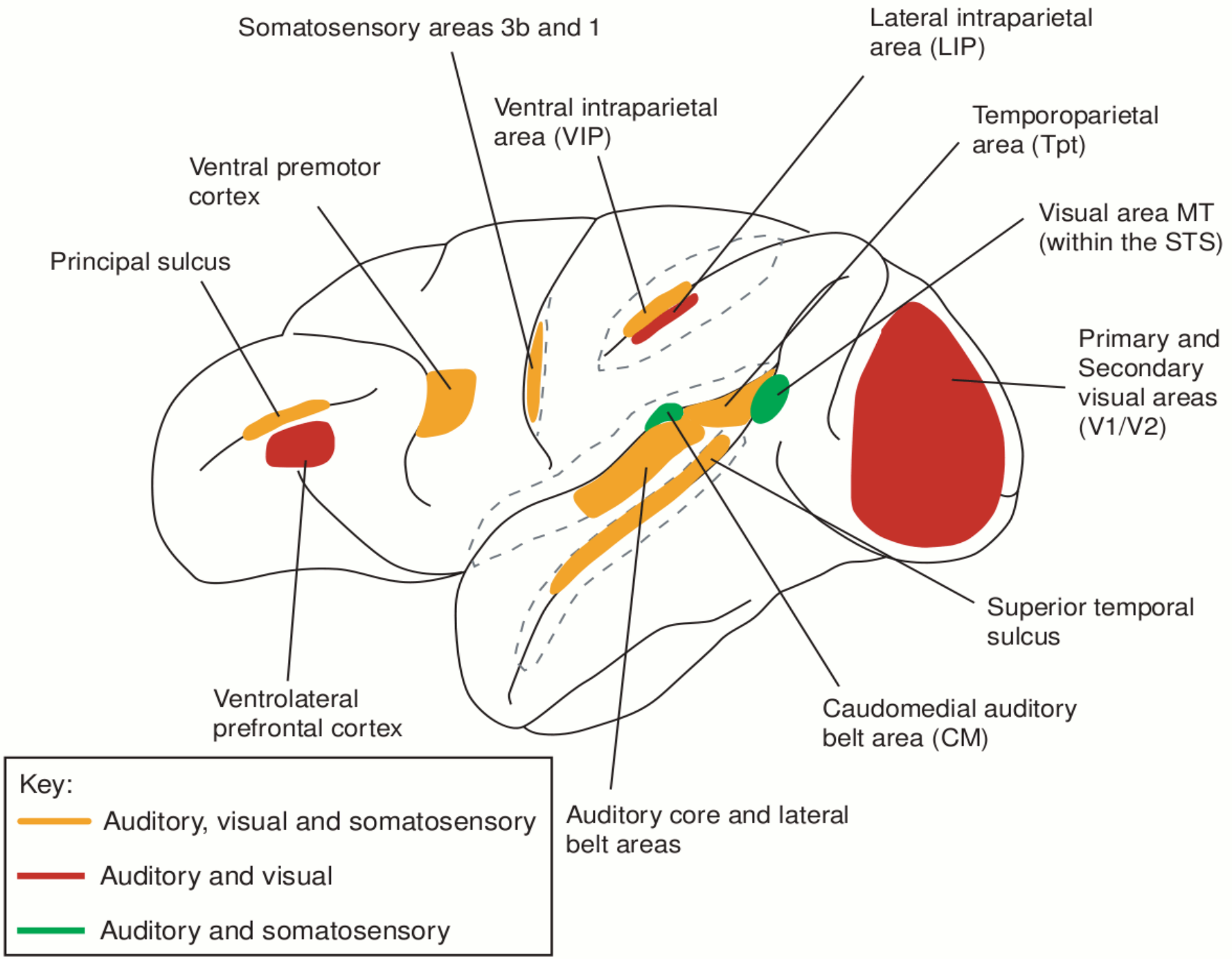
- Self exploration provides the first, most reliable and prevalent source of redundant multimodal stimulation
- Proprioceptive feedback always accompanies self generated movement, visual, vocal, and tactile stimulation (e.g. double touch; hand movement)
- We know infants are sensitive to this information: They detect visual-proprioceptive invariants uniting the movements of their bodies with visual feedback

  (e.g., Bahrick & Watson 1985; Rochat & Morgan, 1995)

People Provide A Rich Source of Intersensory Rendundancy in Early Infancy

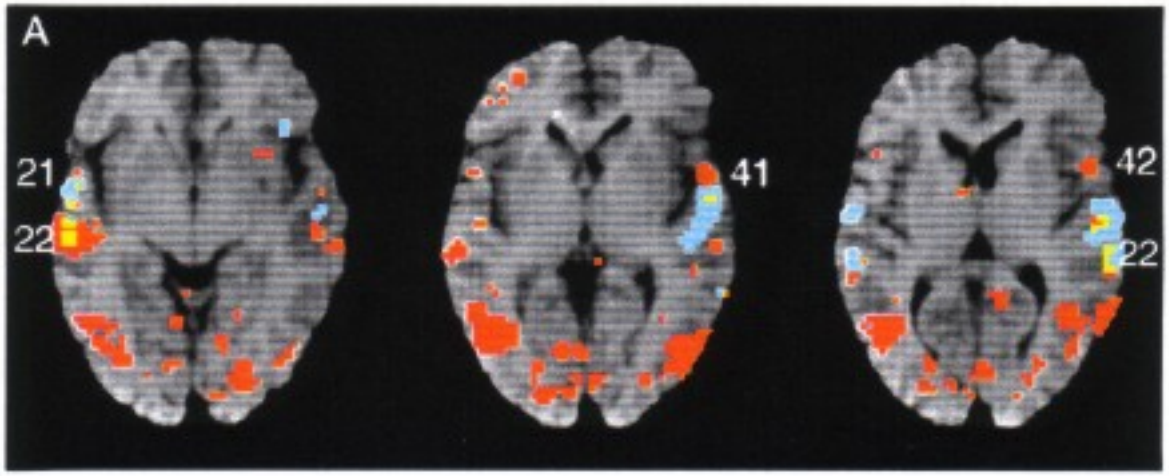
- Much of cognitive and perceptual development emerges in the context of close face to face interaction and involves coordinated sound, touch, and movement
- Infants detect face-voice synchrony and rhythm, and the spectral information uniting movements of the mouth with the sounds of speech
- They also detect affect common to faces and voices and audiovisual information conveying speaker gender and age

- What about the neural underpinnings?


Somatosensory areas 3b and 1
Lateral intraparietal area (LIP)
Ventral intraparietal area (VIP)
Temporoparietal area (Tpt)
Ventral premotor cortex
Visual area MT (within the STS)
Principal sulcus
Primary and Secondary visual areas (V1/V2)
Superior temporal sulcus
Ventrolateral prefrontal cortex
Caudomedial auditory belt area (CM)
Auditory core and lateral belt areas
Key:
Auditory, visual and somatosensory
Auditory and visual
Auditory and somatosensory

Multisensory integration has been found in neurons at many locations in the human brain, including sub-cortical areas like the superior colloculus, early cortical areas like the primary visual and auditory cortices, and higher cortical levels like the superior temporal sulcus and intraparietal areas

Superior temporal sulcus, particularly the posterior region, has been shown to be involved in the integration of audiovisual speech (Calvert et al, 2000)



red: viewing mouth movements without sound

blue: listening to speech

yellow: listening and viewing audiovisual speech

The Intersensory Redundancy Hypothesis (**IRH**)

- Is a framework that describes how selective attention is allocated to different properties of events (amodal vs modality specific) in multimodal and unimodal stimulation

- The IRH describes how detection of amodal and modality specific properties of events are intercoordinated.
  - when attending to a person talking, one could detect redundant amodal information (synchrony, rhythm, tempo of audiovisual speech), or modality specific information (appearance of the face, clothes or pitch/timbre of the voice)

- According to the IRH, redundant stimulation is highly salient; it recruits selective attention to redundantly specified properties and thereby organizes early perceptual processing.

Predictions of the Intersensory Redundancy Hypothesis

1. Amodal properties are most salient in multimodal, redundant stimulation (*intersensory facilitation*)

2. Modality specific properties are most salient in unimodal stimulation (*unimodal facilitation*)

3. Across development, infants' increasing efficiency of processing and flexibility of attention lead to detection of both redundantly and non-redundantly specified properties in unimodal and multimodal stimulation

4. Intersensory and unimodal facilitation are most pronounced for tasks of relatively high difficulty and thus should potentially be apparent across the life-span

Infants' Limited Attentional Resources Magnify the Effects of Redundancy

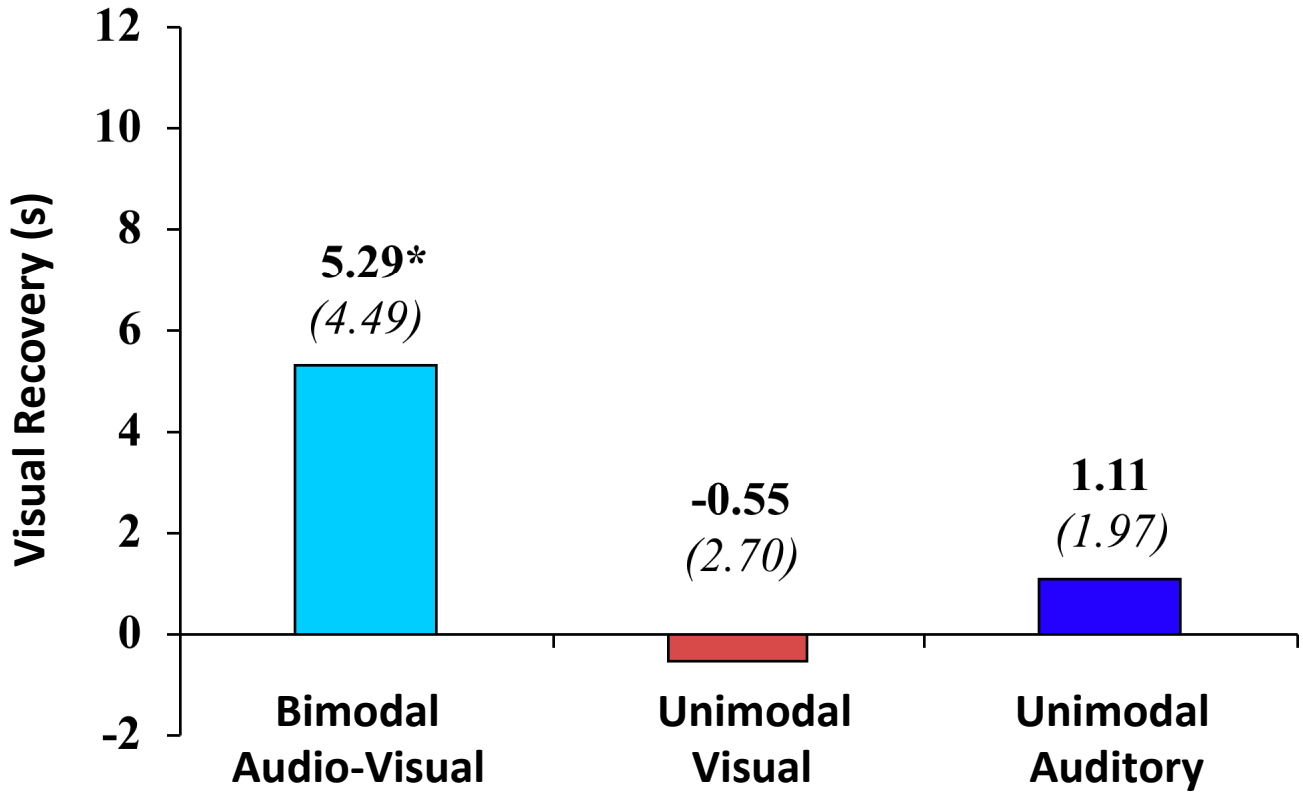
- In early development, attentional resources are most limited
  - younger infants likely attend and process only the most salient information in a given bout of exploration
- Later in development, attentional capacity, flexibility, and processing efficiency improve with experience
  - older infants attend and process more of the available stimulation; both the more salient and less salient.
- The most salient information will likely comprise a larger proportion of the younger infant's attentional focus and processing resources, resulting in salient information such as redundancy having a disproportionately large effect on early perceptual and cognitive development

Our Research Supports the Salience of Amodal Properties in Multimodal Stimulation

- discrimination of rhythm (Bahrick & Lickliter, 2000)
- **discrimination of tempo** (Bahrick, Flom, & Lickliter, 2002)
- discrimination of affect (Flom & Bahrick, 2007)
- discrimination of prosody in speech (Bahrick, Castellanos, & Shuman, in prep.)
- perceptual learning in bobwhite quail embryos and chicks (Lickliter, Bahrick, & Honeycutt, 2002, 2004)

5-month-old infants discriminate a change in rhythm following bimodal but not unimodal stimulation

(Bahrick & Lickliter, 2000*, Dev. Psychology*)

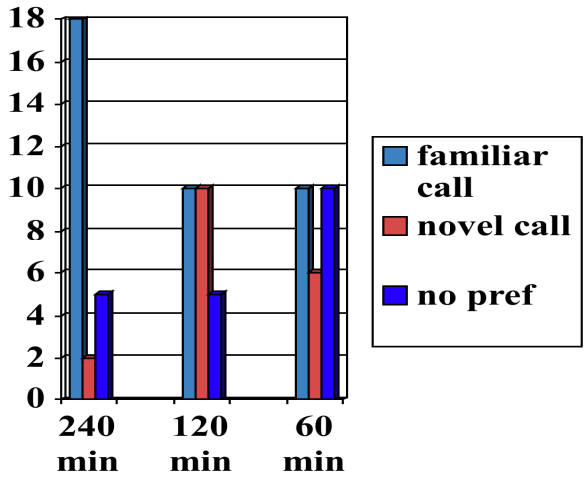


*p < .05

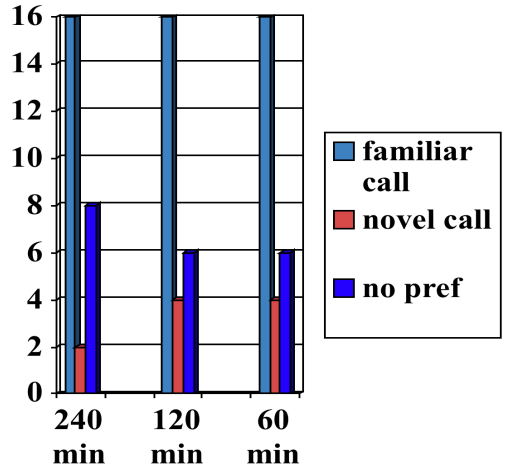
Results of Animal Research

- Quail embryos receiving redundant audio-visual stimulation prenatally learned an individual maternal call four times faster than those who received unimodal stimulation, and those who received nonredundant stimulation did not learn the call (Lickliter, Bahrick, & Honeycutt, 2002).
- A further study demonstrated that redundant stimulation also extended memory for thefamiliarized call
  - memory lasted four times longer following redundant bimodal than unimodal stimulation (Lickliter, Bahrick, & Honeycutt, 2004, *Infancy*)

Quail embryos receiving redundant audio-visual exposure to an individual maternal call learned the call with one fourth the exposure time of embryos receiving unimodal exposure to the same maternal call prior to hatching (Lickliter, Bahrick, & Honeycutt, 2002 *Developmental Psychology*)



unimodal exposure



bimodal exposure

- Results of our animal research converge with those of human research:

  - intersensory facilitation
  - unimodal facilitation
  - education of attention
  - enhanced memory

We have used this convergence to argue that we have discovered general principles of perceptual development

Homologous?

Developmental Change

- With increasing experience, perceptual differentiation progresses and early attentional biases should become less apparent as attention becomes more flexible and efficient

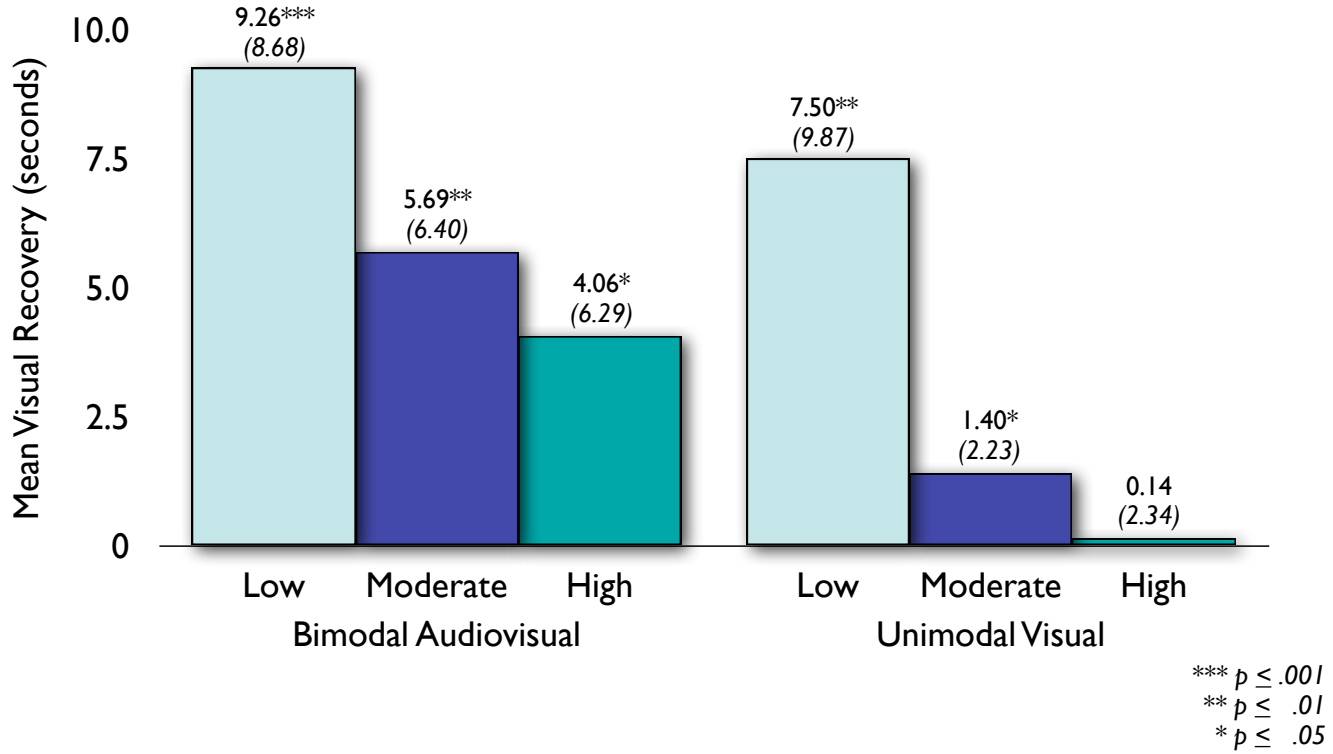
- Once infants successfully differentiate properties of events, they can more easily switch attention among those properties (from amodal to modality specific)

- In this framework, we predict that the attentional biases of infancy will once again become apparent in older infants, children, and even adults if the task is made difficult in relation to the perceiver's ability or expertise

Manipulating Task Difficulty

- We predicted that by increasing task difficulty, older infants would revert to patterns of intersensory facilitation shown by younger infants.
- Results confirmed our prediction and demonstrated that in difficult discrimination tasks 5-month-olds performed like 3-month-olds, showing intersensory facilitation for tempo discrimination. In contrast, in tasks of low and moderate difficulty older infants discriminated tempo changes in both redundant audiovisual and non-redundant unimodal visual stimulation.

Mean visual recovery (and *SDs*) to a change in tempo as a function of condition (bimodal audiovisual vs. unimodal visual) and difficulty level (low vs. moderate vs. high)



Bahrick et al., 2010 *Dev. Science*

Implications for Later Development

- Early attention biases may set up a processing sequence that persists across the life span (e.g., in bimodal stimulation, amodal → modality specific).
- We are currently investigating how these biases influence perception, learning, and memory into adulthood
- We predict that adults would show these attention biases when stimulation is difficult to discriminate

  (for example, the use of audiovisual speech in a noisy environment)

- A very preliminary study

Adult Discrimination of Tempo

- How does selective attention in adults compare to infant attention?
  - adults have more flexible attention
  - adults are more experienced and efficient processors of information

- Will adults show *intersensory facilitation* in difficult discrimination tasks?

Adult Tempo Experiment

- N=32

- Condition = Bimodal AV, Unimodal V (between subjects)
- Short familiarization = 1 repetition of 4-beat rhythm

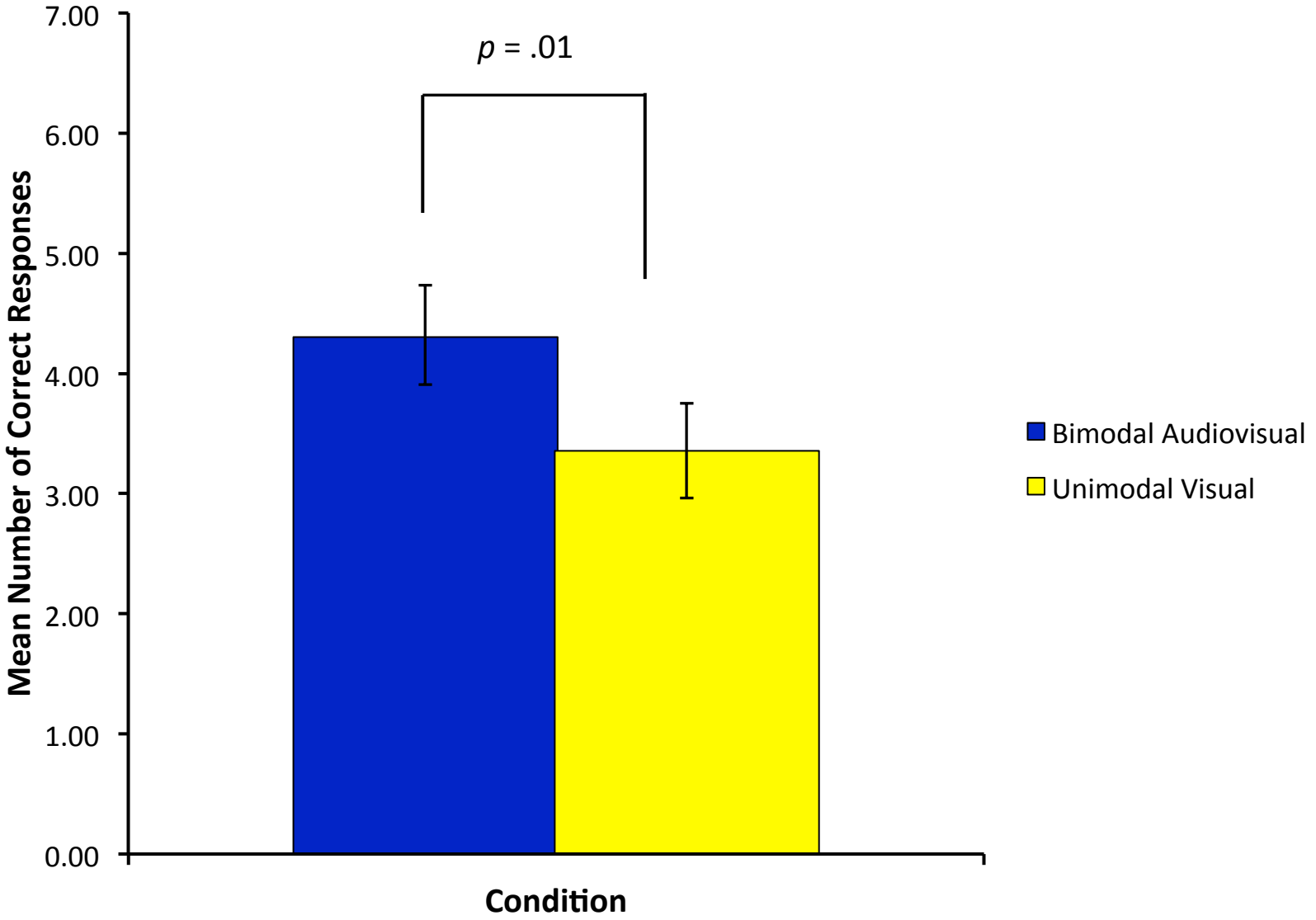
- 2 blocks, comprised of a tempo standard (159 or 192 bpm) followed by 16 test trials

- DV: Same/different responses

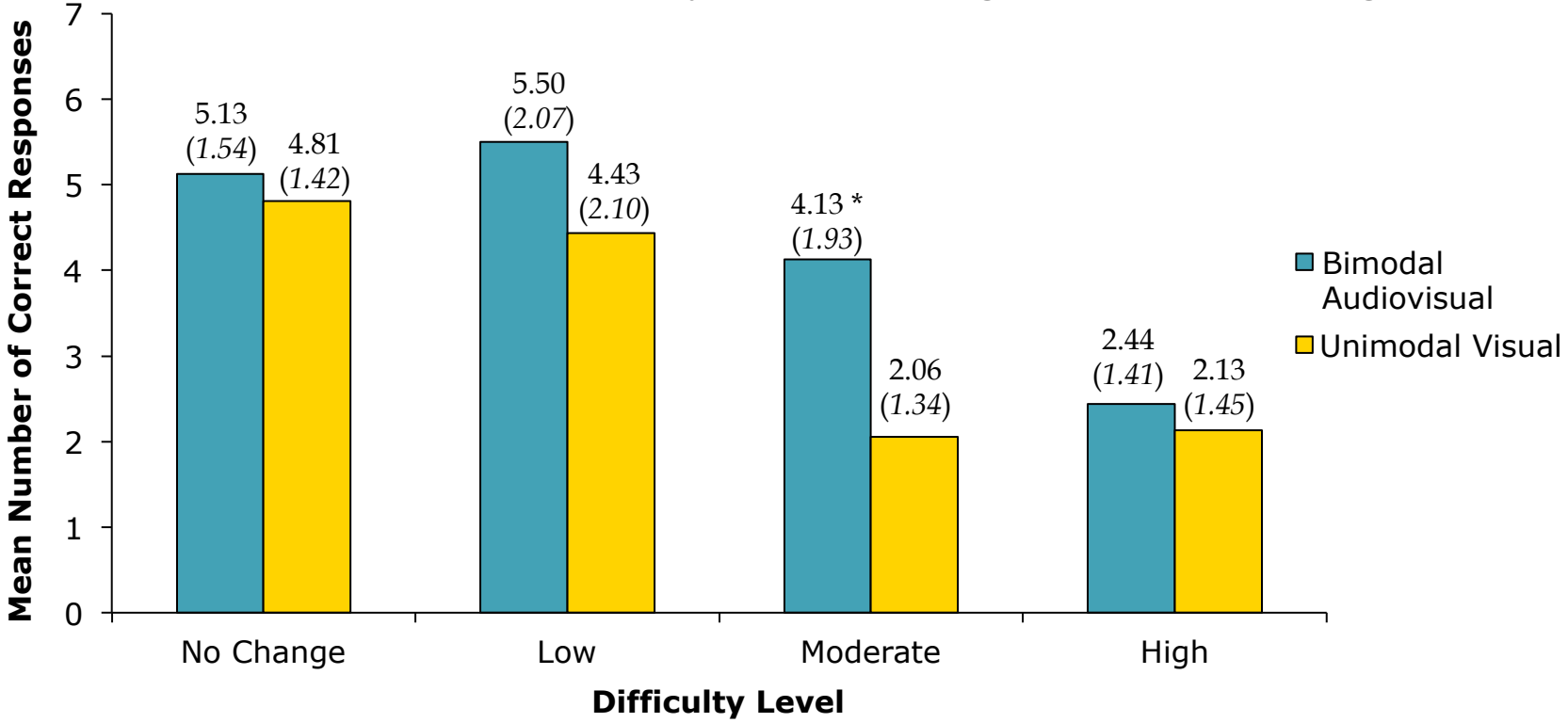
- Difficulty levels of tempo contrasts (4 trials each):
  - No change
  - Low difficulty = 25% (40 bpm) difference
  - Moderate difficulty = 17% (27 bpm) difference
  - High difficulty = 9% (15 bpm) difference

Number of Correct Responses

- Main effect of condition, $F(1, 30) = 8.47$, $p = .007$
  - More correct responses for bimodal than unimodal
- Main effect of difficulty, $F(3, 90) = 22.05$, $p < .001$
  - More correct responses for no change & low than moderate & high
- Difficulty x condition interaction, *n.s.*


7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Mean Number of Correct Responses
p = .01
Condition
Bimodal Audiovisual
Unimodal Visual

Mean number of correct responses as a function of condition (bimodal audiovisual, unimodal visual) and difficulty level (no change, low, moderate, high)



Potential problems with our current design

- Possibly too difficult for adults to remember the standard tempo across 16 test trials
  - mean number of correct responses was low (48%; 3.8 of 8), suggesting our task was very difficult
  - provide more repetitions of standard tempo prior to testing?

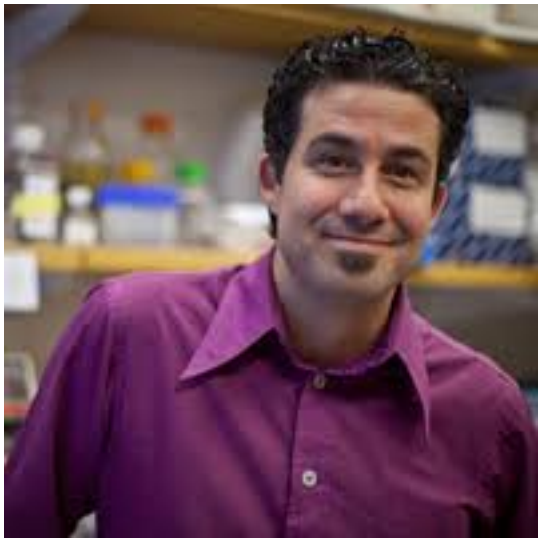
- Lack of interaction between difficulty and condition?
  - likely more evident in a within subjects design (to increase power)

Developmental Homology?

- Does our preliminary demonstration that adults show enhanced processing and discrimination of amodal properties in the context of redundant audiovisual stimulation represent an example of a behavioral homology?

- In other words, in novel tasks or in tasks requiring discrimination of fine detail or speeded responses, do adults revert to the processing patterns seen in earlier development?

To begin to answer this question, it seems important to identify how intersensory facilitation comes about initially from the coordination of existing skills and processes and ***how things change and how they stay the same*** in terms perceptual processing over the course of development.



- Pressing questions

How to think about continuity vs. variability in the deployment of selective attention? What persists, what is conserved in the adult repertoire?

What constitutes “sameness” across development?

What is the role of context in assessments of homology vs. novelty?

Thanks to:

Chris and David (the Moores) for organizing our workshop

National Institute of Health (NICHD) and the National Science Foundation for funding our research

and the dedicated undergraduate and graduate students and post-docs (past and present) of the Infant Development Research Center at Florida International University