**14. ABSTRACT**

Experiments with human subjects explored how auditory attention operates. Specifically, the experiments investigated 1) the hypothesis that room reverberation interferes with selective attention, 2) whether selective attention to an ongoing target improves with time when the target has a contiguous feature distinguishing it from competing sources, and 3) how visual cues help direct selective auditory attention through behavioral measures and computational modeling. Results demonstrate that 1) selective attention is adversely affected by room reverberation, 2) continuity of task-irrelevant sound features strongly enhances the ability to maintain attention on a stream based on some other, orthogonal feature, and 3) visual cues can be used to direct selective auditory attention.

**15. SUBJECT TERMS**

selective attention, streaming, grouping, sound segregation, auditory scene analysis

**16. SECURITY CLASSIFICATION OF:**

<table>
<thead>
<tr>
<th>a. REPORT</th>
<th>b. ABSTRACT</th>
<th>c. THIS PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>U</td>
<td>U</td>
</tr>
</tbody>
</table>

**17. LIMITATION OF ABSTRACT**

U

**18. NUMBER OF PAGES**

9

**19a. NAME OF RESPONSIBLE PERSON**

Barbara Shinn-Cunningham

**19b. TELEPHONE NUMBER (include area code)**

617-353-5764
Principal Investigator: SHINN-CUNNINGHAM, BARBARA
Organization: THE TRUSTEES OF BOSTON UNIVERSITY
Award Number: N000141010118
Award Title: Focusing, sustaining, and switching attention
Focusing, sustaining, and switching attention

A. Scientific and Technical Objectives

Acoustic information is conveyed by changes in sound over time, requiring listeners to sustain attention to understand acoustic signals. Moreover, sounds start and stop, requiring attention switching. To predict how well humans can communicate in complex acoustic scenes, we must understand the dynamics of focusing, sustaining, and switching selective auditory attention. However, most past work has ignored attentional dynamics. This project used perceptual and computational experiments to explore the dynamics of selective attention.

Aim 1. Influence of room acoustics. Using behavioral measures, we tested the hypothesis that room reverberation interferes with selective attention.

Aim 2. Effects on non-spatial features. We measured whether selective attention to an ongoing target improves with time when the target has a contiguous feature distinguishing it from competing sources.

Aim 3. Role of visual cues. We explored how visual cues help direct selective auditory attention through behavioral measures and computational modeling.

Our results may benefit sailors, commanders, and war veterans, many of whom deal with complex acoustic scenes full of competing sources (where selective auditory attention is challenging in the best of circumstances), and many of whom also suffer noise-induced hearing loss that disrupts selective auditory attention.

B. Comparison between actual accomplishments and goals

Work in the first reporting period explored Aim 1. Our work on Aim 2 was very productive, and was the main focus of our efforts in years 2-4. Given the advances made in Aim 2, we reduced efforts on Aim 3; however, we undertook one auditory-visual experiment to understand how grouping influences across-sensory integration.

C. Approach

Behavioral experiments were conducted to explore the ability of listeners to separate, understand, and identify messages from competing auditory streams. Spatial cues and other features in the acoustic signals were manipulated to explore how the continuity of the low-level acoustic information influences performance when listeners focus and maintain attention. In some experiments, multiple loudspeakers are used to present competing sounds from different locations. In other experiments, realistic spatial cues were simulated using virtual auditory space techniques. In selective attention tasks, listeners reported the identity or content of one source in the mixture. In segregation tasks, perceptual organization of the sound mixture was measured both directly and indirectly, by measuring the contributions of ambiguous sound elements to object identity and/or to object location. These methods do not deviate from those of the original proposal.

C. Accomplishments

We found that the ability to focus attention degrades as reverberant energy increases. Moreover, this degradation in selective attention is observed at levels of reverberation too low to interfere with speech intelligibility directly; the disruption is in the ability to
focus attention. This result highlights the need to minimize reflected sound energy if simultaneous sounds are likely (Aim 1)

We found that continuity of talker identity helps listeners extract information from an ongoing message. This result shows that the perceptual benefits of spatial continuity is one aspect of a more general result (Aim 2).

We found that the benefits of continuity of voice quality are not due to listeners volitionally focusing attention on the target, but are attributable to an automatic enhancement of whatever subsequent acoustic signal is similar to the acoustic signal currently in the attentional foreground. This result suggests that voice continuity effects are strongly obligatory and automatic (Aim 2).

Together, these results highlight the importance of conveying information in a single, continuous stream in order to maximize the rate of communication. For instance, when conveying information to a commander in a time of high communication volume, one should combine messages into a single continuous stream, rather than providing multiple, shorter messages (Aim 2).

We found that even when there are not competing sound streams, perceptual continuity has an influence on speech understanding. Specifically, when the talker in a sequence of digits changes from digit to digit, forcing listeners to switch attention over time from one source to another, intelligibility is degraded (Aim 2).

We found that temporal gaps in ongoing streams reduce the effects of feature continuity, but that gaps as long as 600 ms are insufficient to completely eliminate the effects (Aim 2).

We found that a well-studied auditory-visual illusion, the “flash-beep” illusion, is influenced by spatial cues. In the standard illusion, the number of perceived visual flashes is strongly influenced by the number of auditory beeps presented at roughly the same time. Here, we showed that the influence of an auditory stream on visual perception depends on the difference in the locations of the visual and auditory streams, suggesting that the flash-beep illusion reflects integration of multisensory information that is perceived as coming from a single distal source (Aim 3).

D. Productivity

Refereed articles


Workshops and Conferences

Bharadwaj H, S Masud, and BG Shinn-Cunningham (2013). “Bottom-up and top-down contributions to individual differences in auditory spatial attention task performance,” Mid-Winter Meeting of the Association for Research in Otolaryngology, Baltimore, 16-20 February [invited talk].

Shinn-Cunningham BG (2013). “Choosing from the conversation smorgasbord of a cocktail party,” Mid-Winter Meeting of the Association for Research in Otolaryngology, Baltimore, 16-20 February [invited Presidential Symposium talk].

Shinn-Cunningham BG (2013). “Peripheral and central contributions to auditory attention,” Computational and Systems Neuroscience meeting, Salt Lake City, 28 February – 2 March [invited talk].
Focusing, sustaining, and switching attention


Shinn-Cunningham BG (2013). "Auditory attention (or how you hear a voice inside your head)," Eastern Auditory Retreat, University of Maryland, 15 June [invited talk].


Shinn-Cunningham BG (2012) "The importance of perceptual continuity in focusing auditory attention," MRC Cambridge, UK, 11 April


Shinn-Cunningham, BG (2011). "Designing to human perceptual constraints in command and control displays," NUWC, Newport, RI.


Shinn-Cunningham, BG (2010). "Segregating and selecting auditory objects," Mid-Winter Meeting of the Association for Research in Otolaryngology, Anaheim, CA, 6-10 February

Schwartz, A, J McDermott, and BG Shinn-Cunningham (2010). "Influences of interaural time differences in grouping of ambiguous Auditory scenes," Mid-Winter Meeting of the Association for Research in Otolaryngology, Anaheim, CA, 6-10 February

Bressler, S, S Masud, V Best, and BG Shinn-Cunningham (2010). "Influence of voice continuity on selective auditory attention," Mid-Winter Meeting of the Association for Research in Otolaryngology, Anaheim, CA, 6-10 February

Neilans, EG, TE Welch, R Maddox, BG Shinn-Cunningham, and M Dent (2010). "Are all syllables perceived equally? A comparative analysis of song syllable perception in zebra finches (Taeniopygia Guttata) and budgerigars (Melopsittacus Undulatus)," Mid-Winter Meeting of the Association for Research in Otolaryngology, Anaheim, CA, 6-10 February


Shinn-Cunningham, BG (2010). "Top-down influences on auditory perception," Eaton-Peabody Laboratory, Massachusetts Eye and Ear Infirmary, Boston, 26 February [invited]
Focusing, sustaining, and switching attention


Ruggles, D and BG Shinn-Cunningham (2010). “Reverberation disrupts spatial selective auditory attention,” Mid-Winter Meeting of the Association for Research in Otolaryngology, Anaheim, CA, 6-10 February

Awards and Honors

Founding Director, Center for Computational Neuroscience and Neural Technology, 2011-

PI and Director, CELEST NSF Science of Learning Center, 2012-

Vice President Elect / Vice President / Immediate Past Vice President, Acoustical Society of America, 2013-2016

Executive Council, Acoustical Society of America, 2010-2013

Executive Steering Committee, Hariri Institute for Computational Science and Engineering, 2011-

Mentorship Award, awarded by the Student Council of the Acoustical Society of America, 2013

Provost’s Senior Hiring Initiative Committee, 2012-

Associate Provost’s Administrative Strategy Group, 2012-2013

College of Fellows Steering Committee, Acoustical Society of America, 2010-2012

Chair, Internal Affairs Council, Acoustical Society of America, 2013

Audit Committee, Acoustical Society of America, 2010-2013

Student Council Advisor, Acoustical Society of America, 2011-2013

External Advisory Committee, MGH/Harvard/MIT Advanced Multimodal Neuroimaging Training Program, 2012-2013

Director Search Committee, Medical Research Council Institute of Hearing Research, Nottingham, UK, 2013

National Academies Panel on Human Factors Science at the Army Research Laboratory, 2013-2014

Presidential Symposium Speaker, Mid-Winter Meeting of the Association for Research in Otolaryngology, February 2013

Keynote Speaker, Binaural Active Audition Symposium, Kyoto Japan, March 2013

Keynote Speaker, Annual Meeting of the Academy of Audiology, Anaheim, CA, April 2013

National Academies of Science Soldier Systems Panel, 2011-2012

Appointed Member, Advisory Panel, Hearing Fitness for Duty initiative (DoD), 2011-2-12

MRC Institute of Hearing Research Review Subcommittee, 2011-2012
Focusing, sustaining, and switching attention


Chair of the AUD study section for the National Institutes of Health.

J. Award Participants

PI: Barbara Shinn-Cunningham

Research Staff: Scott Bressler, Salwa Masud, Nathaniel Durlach