The effect of attention on auditory streaming using a combined psychoacoustic and electrophysiological approach

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OUTLINE

• Background information / Aim
• Methodology
• Results
• Discussion
• Conclusions
• Ongoing Research
What is Auditory Streaming?
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The ability of the brain to distinguish sounds that are important to listen to, from the ones it should ignore is called auditory stream segregation.

A laboratory phenomenon of stream segregation is called auditory stream segregation.

In the laboratory it can be demonstrated in human listeners by the presentation of a repeating sequence of a triplet of tones ABA_ABA (Van Noorden, 1975).

A & B have different sound frequencies.
The perception of auditory streaming does not occur immediately but builds up over several seconds (Anstis & Saida, 1985; Bregman, 1978). Frequency difference between sound A and B can affect auditory streaming (Cusack et al., 2004; Carlyon et al., 2001) – though there is still some controversy.
Potential Real Life Applications

By investigating how auditory attention can affect auditory streaming we can develop an objective measure for use with people with:

- attentional problems
- Auditory Processing Disorder (APD)

‘APD is largely an attention problem, and clinical diagnosis and management should be based on this supposition’ (Moore et al, 2010)
Use of Electroencephalography (EEG) to study Auditory Streaming

EEG measures brain activity in response to sounds

When using an auditory stimulus for an EEG recording, an auditory event related potential (ERP) can be induced

N1 component could be indicative of attention to sound arrival (Naatanen, 1992)
Aim of the Study

Examine the effect of attention on auditory streaming in normal hearing individuals using psychoacoustic and EEG approaches by comparing the EEG peaks of first and last triplet of the ABA paradigm.

- Compare the EEG waveform generated at the beginning and the end of the sound sequences.
- Investigate how this is affected by shifting attention.
- Investigate the underlying neural activity related to streaming and attention.

Investigate the number of times participants responded as ‘2-streams’ as a function of each condition.
METHODOLOGY
Participants

Normal hearing participants - no known neurological problems
18-30 years (mean age 25.7)

Participants (14)

- Females
- Males

36 ring electrodes
Skin-electrode impedance < 5kΩ
Electrode digitisation used for more accuracy in source localisation
EEG was measured using NeuroScan®
Stimuli

Two sounds were used, A and B (4 semitones difference)
Presented in an A_B_A paradigm
Stimuli were presented sequentially in the ears i.e. one following the other
Presented at 75 dBSPL
Conditions

Four condition blocks ~ 10 minutes each
Conditions were randomly presented
Total testing time per participant ~ 90 minutes (including preparation time)

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Instructions to Participants</th>
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<tbody>
<tr>
<td><strong>Condition A:</strong></td>
<td>no frequency difference between the two sounds i.e. same sound presented in both ears. Sound A was presented to the right and left ear.</td>
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<td>Participants were instructed not to listen to any particular ear.</td>
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<td><strong>Condition B:</strong></td>
<td>sound A was presented to the left ear and sound B to the right.</td>
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<td></td>
<td>Participants were instructed not to listen to any particular ear.</td>
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<td><strong>Condition C:</strong></td>
<td>there was no sound presented to the left ear. Participants only heard sound B to the right ear.</td>
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<td>Participants were instructed to attend to the sounds occurring in the right ear only.</td>
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<tr>
<td><strong>Condition K:</strong></td>
<td>sound A was presented to the left ear and sound B to the right.</td>
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<tr>
<td></td>
<td>Participants were instructed to attend to the sounds occurring in the right ear only.</td>
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</table>
Experimental Set up
RESULTS
10 participants included

1. Auditory Streaming - Attention data
2. Dipole Strength Analysis - Dipole Maps
3. Psychophysical response
Auditory Streaming Data - N1 Component

Average of three electrodes (FCz, Cz & Fz) of all subjects and conditions for three seconds
There was a significant difference in the mean amplitude of the first and last triplet ($F(1,78)=53.550 \ p<0.05$)
There was no significant difference between the four conditions ($F(3,76)= 0.7335, 0.0854, 0.3482 \ p>0.05$)
Dipole Strength Analysis

There was a significant difference in the dipole strength between the first and last triplet (F(1,14)=11.914 p<0.05)
There was a significant difference in the dipole strength between the conditions (F(1,14)=8.571 p<0.05)

A: tone A in both ears
B: tone A (left) and B (right)
C: tone B (right) - listen to the right
K: tone A (left) and B (right) - listen to the right

There was a significant difference in the dipole strength between the first and last triplet (F(1,14)=11.914 p<0.05)
There was a significant difference in the dipole strength between the conditions (F(1,14)=8.571 p<0.05)
Psychophysical Response

Conditions C & K (attention was required) - greatest ‘2-stream’ response

![Graph showing percentage of 2-stream response for conditions A, B, C, and K. The bars for C and K are significantly higher than for A and B, indicating a greater response under conditions requiring attention.]
DISCUSSION
Auditory Streaming

✓ Findings support the literature that the percept of one stream to two streams can change after several seconds (Carlyon et al, 2001; Snyder et al, 2006)

✓ Evidence of differences in dipole strength and location between the four conditions
Objective measure for attention?

Was the process of auditory stream segregation reset?

**Dipole Strength** – neural activity strength suggests that attention does affect the way the brain perceives one or two streams

**Dipole Maps** – dipole sources occupy more parietal/frontal regions (especially parietal in conditions C & K)
‘An increased activity in the parietal regions of the auditory cortex, may indicate increased involvement of the attentional and memory circuits’ (Verhey et al, 2012)

**Psychophysical response** – all participants perceived a ‘2-stream’ response for all conditions but more in attention conditions
CONCLUSION
Conclusions

Auditory Streaming takes time to build-up and is highly dependent on attention.

Over several seconds the percept of a single stream can turn into ‘2-stream’ percept.

Electrode digitisation facilitates accurate source localisation.

Results could be used as a preliminary study for future research.

Good evidence that indeed attention plays an important role in the formation of auditory streams.
Ongoing Research

• Great Ormond Street Hospital for Children

• 60 candidates

• 8-11 year old children with and without APD

• EEG and psychoacoustics

• 18 month study
Acknowledgements

• Supervisors
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• Participants
  Adult Diagnostics
  Zena Butt, Paul James

• Action Medical Research
Thank you for listening
References


Thank you for listening
• Repetition rate
• Now, when the repetition rate of the ABA sequence is slow (long inter-stimulus interval - ISI), or when the frequencies of tones A and B are close, listeners can hear a galloping rhythm corresponding to the repeating triplets. In this case, the sequence is heard as a single stream (Gutschalk et al, 2005; Carlyon 2004; Carlyon et al, 2001). However, at faster rates (brief ISI) and wider frequency separations, the A and B tones split into two separate streams and the galloping rhythm is lost (Van Noorden, 1975). Hence, the sequence is heard as two regular isochronous streams (Gutschalk et al, 2005; Carlyon 2004; Carlyon et al, 2001).

• H0) is that there will be no significant difference in the mean amplitudes between the first and last triplet
• H2: The null hypothesis (H0) is that there will be no significant difference in the mean amplitudes between the conditions
• H3: The null hypothesis (H0) is that there will be no significance difference in the dipole strength between each group (right and left, triplets or condition)
• Participants were gathered by personal communication and sending out emails to the student body

• This was done to reduce order effects and the possibility of fatigue that may occur due to the length of the test battery

• The stimulus was presented by NeuroScan Labs STIM system to the NeuroScan STIM Audio system. The response signals were then amplified by a 40 channel digital NuAmps model. The NeuroScan 4.3 software acquire option (Compumedics NeuroScan, El Paso, TX, USA) was used to record EEG activity

• The electrode box was connected to the EEG amplifier for safety reasons.
• Four electrodes were used to record eye movements (electro-oculograms/EOG), for subsequent eye-movement (i.e. blinking) artefact rejection.
Auditory Processing Disorder and Auditory Streaming

‘APD is a collection of symptoms that can co-occur with a range of neurodevelopmental symptoms such as poor reading, language difficulties and inattention’ (Dawes and Bishop, 2009; Sharma et al, 2009; Ferguson et al, 2010)

‘APD is largely an attention problem, and clinical diagnosis and management should be based on this supposition’ (Moore et al, 2010)

Auditory streaming can be examined in this population through EEG testing and the effect of attention on auditory streaming can be examined