Crossmodal attention alters auditory contrast sensitivity for amplitude and frequency modulated auditory information via a mechanism of contrast gain

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BACKGROUND

Attending to a visual stimulus can increase perceived contrast and alter the visual contrast response function via a mechanism of increasing contrast gain, as found for sustained visual attention, or via a combination of response gain and contrast gain, as found for transient visual attention (see Carrasco 2006 for a review). It is unclear if sensitivity to auditory contrast can be altered via attentional mechanisms found to be important for visual processing.

Here we investigate covert, sustained, crossmodal attention and ask:
(1) How does crossmodal attention, varying task difficulty of a concurrent visual task, or visual attentional load, alter auditory performance?

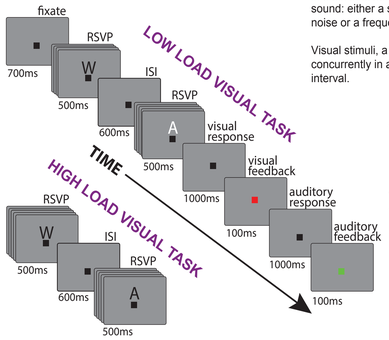
(2) Are changes in auditory contrast sensitivity seen with crossmodal attention similar to the effects of visual attention on visual contrast, namely, changes in response gain vs contrast gain?

METHODS

To determine if varying attentional load can influence the detectability of an auditory stimulus, we used a *two interval forced choice paradigm* (2IFC) to obtain auditory contrast detection thresholds for ampltiude as well as frequency modulated sounds under two attention conditions. We varied attentional load across blocks of trials by varying the difficulty of a simultaneous visual task. Either the visual task was less demanding or more demanding.

Subjects completed 10 blocks (1125 trials) of each of two attention conditions over several days, within a 2 week window. Each session lasting 1-2 hours.

Stimuli



Auditory stimuli were presented binaurally via headphones in each interval. Only one interval contained a modulated sound: either a sinusoidally amplitude modulated white noise or a frequency modulated 1000Hz tone at 5 or 10Hz.

Visual stimuli, a series of 5 letters, were presented concurrently in an RSVP stream at central fixation in each interval.

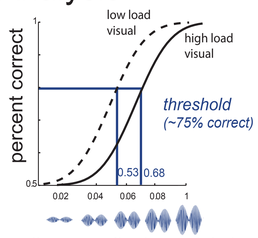
Low Load Visual Color Task:
judge which interval has white letters

High Load Visual Number Task:
judge which interval has more 'A's.

Auditory Task:
judge which interval has modulated sound.

Feedback: red (incorrect)
green (correct)
blue (too slow)

Analysis



Behavioral Measures:
Obtain auditory contrast thresholds for both visual attention conditions, the less demanding and more demanding.

Fit psychometric functions (Psignitfit 4 toolbox and Matalb) for each condition with a Weibull to determine ***threshold***: the stimulus supporting threshold performance (75% correct), ***slope:*** the rate of change to get to threshold, ***and asymptote***: the plateau in performance.

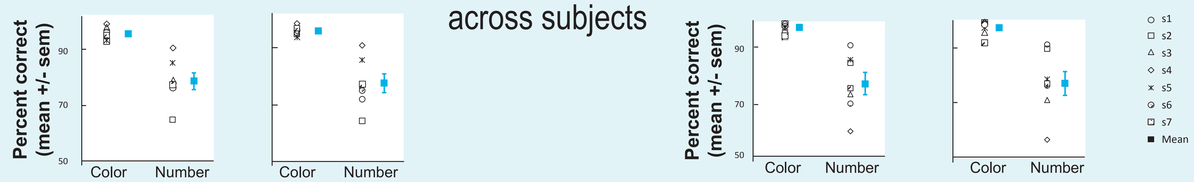
If varying attentional load of the concurrent visual task influences auditory detectability, auditory thresholds should differ between the low load (color) and high load (number) visual tasks.

RESULTS

Amplitude Modulation (AM) — Frequency Modulation (FM)

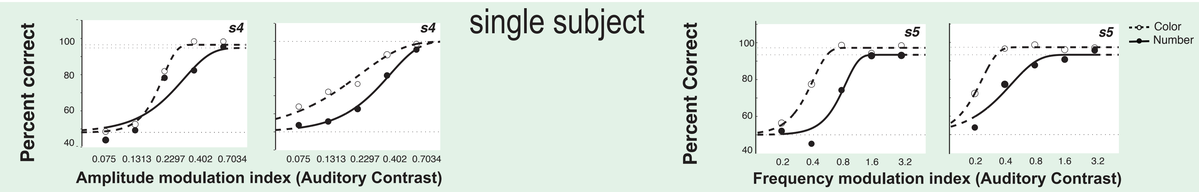
5Hz ***10Hz*** ***5Hz*** ***10Hz***

Visual — across subjects

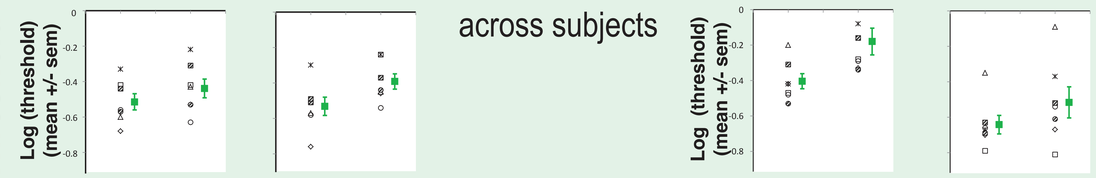


Visual percent correct performance was higher for the color task (low visual load) versus number task (high visual load) for both AM (p=.001) and FM (p=.002) sounds with no main effect of auditory modulation frequency or auditory contrast.

Auditory — single subject

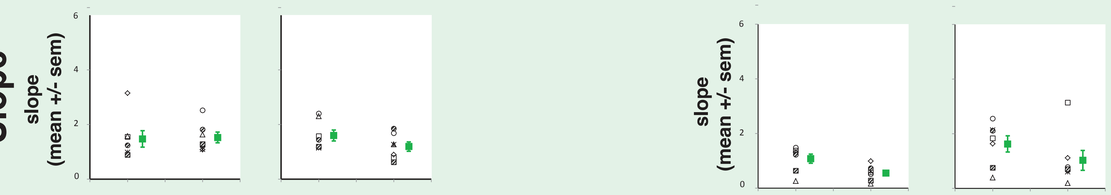


Threshold — across subjects



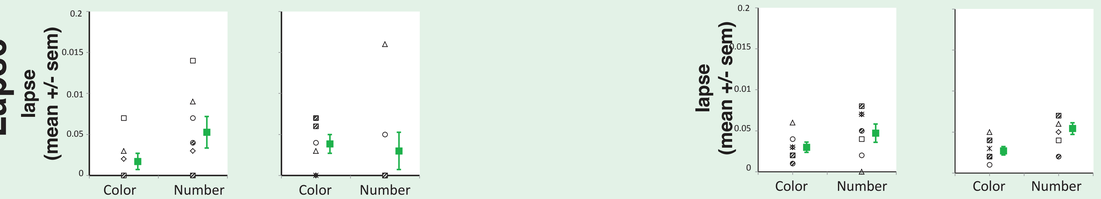
Auditory thresholds were lower for the color task (low visual load) versus number task (high visual load) for both AM and FM sounds (p=.006).

Slope



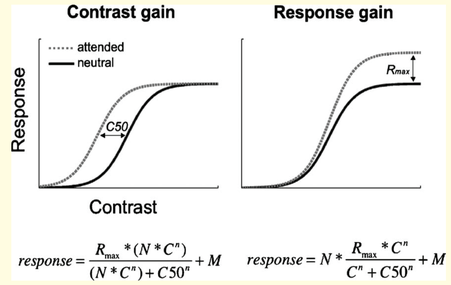
Auditory slopes (at threshold) were steeper for the color (low load) versus number (high load) task (p=.046) and steeper for the 10Hz vs 5Hz auditory modulation (p=.03) for FM sounds, with no significant effects for AM sounds.

Lapse



There was no main effect of visual load or auditory modulation frequency on estimates of lapse rate for either AM or FM sounds. For FM sounds lapse rate tended to be higher for the high vs low visual task (p=.05).

Contrast Gain vs Response Gain



from Carrasco, Progress in Brain Research (2006)

CONCLUSIONS

Subjects required a greater degree of modulation in the auditory stimulus, more auditory contrast, to achieve the same level of auditory performance when simultaneously performing the more demanding number task (high visual load) versus the less demanding color task (low visual load).

This attention effect was seen in both maniipulations of auditory contrast: amplitude (AM) and frequency (FM) modulated sounds.

Our results suggest that
(1) Attention can be a limited resource across modalities, such that devoting more attention to a concurrent visual task can result in a deterioration in auditory processing.

(2) Attention effects in the auditory domain can be similar to effects found in the visual domain. Our covert crossmodal sustained attention manipulation suggests that attention acts on auditory contrast via a mechanism of contrast gain, shifting the contrast response to the left when the visual task is more demanding, with no significant change in lapse rate.

The effects of visual task demand on FM contrast detection is driven by changes in auditory threshold and slope but not lapse rate.

The effects of visual task demand on AM contrast detection is driven by changes in auditory threshold but not slope nor lapse rate,

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