The interdependence of visual salience and audiovisual synchrony on auditory contrast detection

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Background

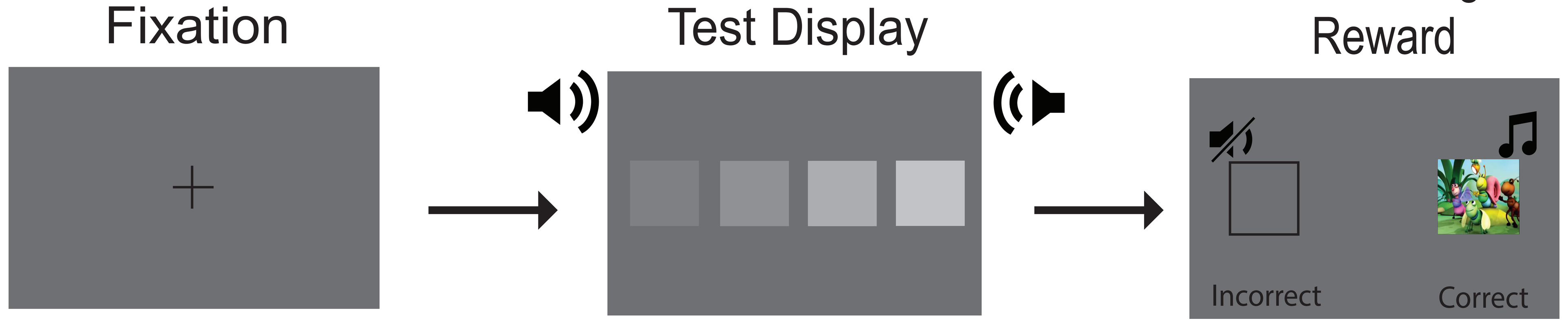
Our senses afford us unique and often complementary experiences of our environment, which can be integrated into a unified percept. The strength of multisensory integration has been shown to depend on spatial coincidence, temporal synchrony, and relative salience between sensory stimuli (principle of inverse effectiveness)[1].

Previous work suggests that a task-irrelevant light presented concurrently with a sound can enhance auditory detectability, enhancing percieved loudness of a sound[2,3]. Furthermore, more recent work suggests that stimulus intensity and the temporal relationship of audiovisual stimuli can interact, allowing a wider temporal binding window for synchronized stimuli which are less salient[4].

Here, we examined how salience and synchrony interact to alter auditory detectability by quantifying auditory detectability under varying conditions of visual intensity and audiovisual synchrony. We predicted:

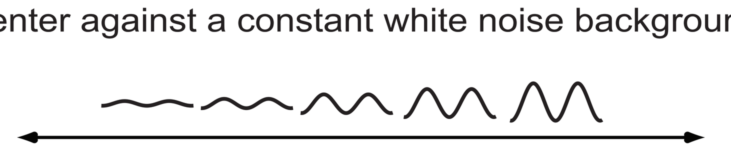
- performance gain would be greatest for in-phase (synchronous) compared to out-of-phase (asynchronous) visuo-auditory stimuli or unisensory stimuli (auditory only)
- performance gain would be greatest when visual salience was at an intermediate level.

Methods



Auditory Stimulus

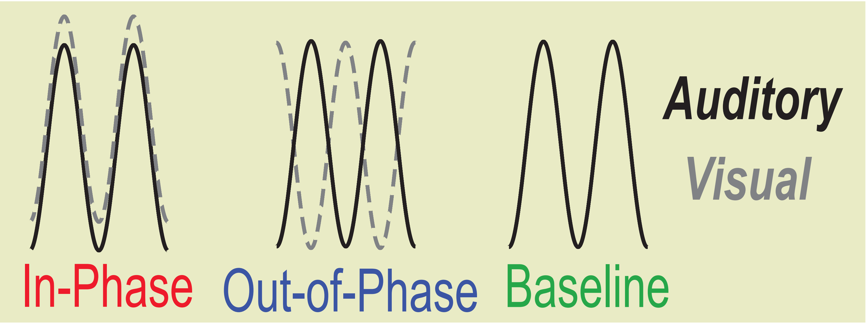
A white noise sound modulated (1 Hz) to one of five contrast levels and was presented left or right of center against a constant white noise background.



Visual Stimulus

Monitor brightness modulated (1 Hz) to one of four salience levels in-phase (IP), out-of-phase (OP), or no modulation in an auditory only baseline (BL) condition.

Audito-Visual Temporal Synchrony

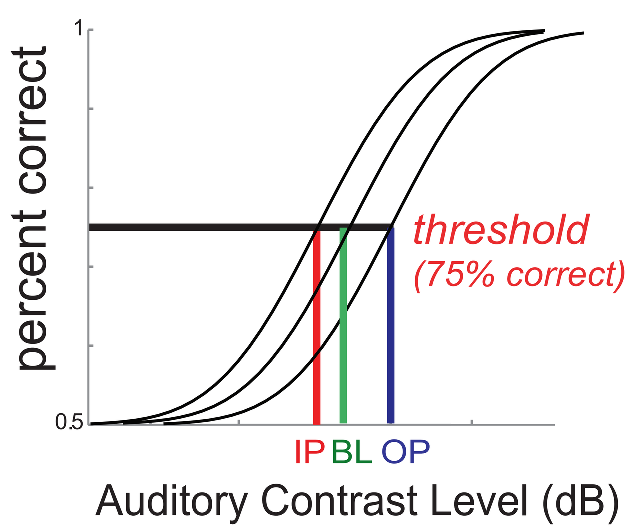


Analysis Methods

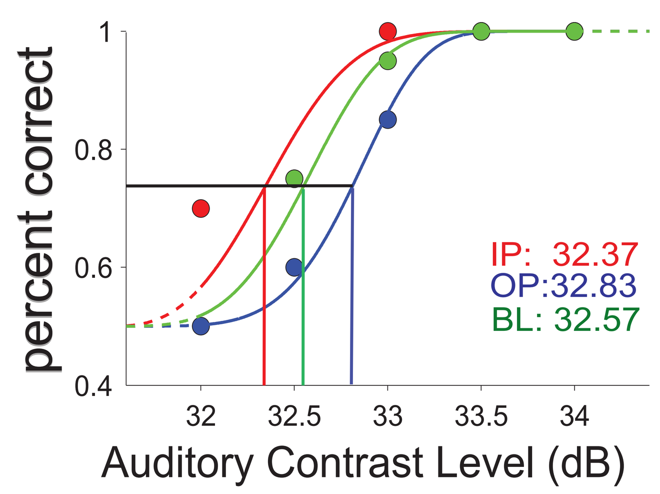
The task was a 2AFC. Participants judged if a sound was presented left or right of center. Percent correct performance was measured across auditory contrasts for diffferent audio-visual synchrony (OP, IP, or BL) and visual salience conditions. All 9 conditions were randomly interleaved. Percent correct data was fit with a Weibull function to determine threshold, the auditory stimulus supporting 75% correct performance.

Results

Expected Results



Visual Salience: 90 cd/m2



Sample data displays threshold estimates for IP, OP, and BL at visual salience 90 cd/m².

Trial Data

Average # trials per condition	Average # trials discarded per condition	Time of 1 cycle of paired stimuli
83.27	5	1.0 sec

Average RT of BL	Average RT 75 cd/m2	Average RT 90 cd/m2	Average RT 150 cd/m2	Average RT 180 cd/m2
0.911 sec	0.857 sec	0.864 sec	0.853 sec	0.906 sec

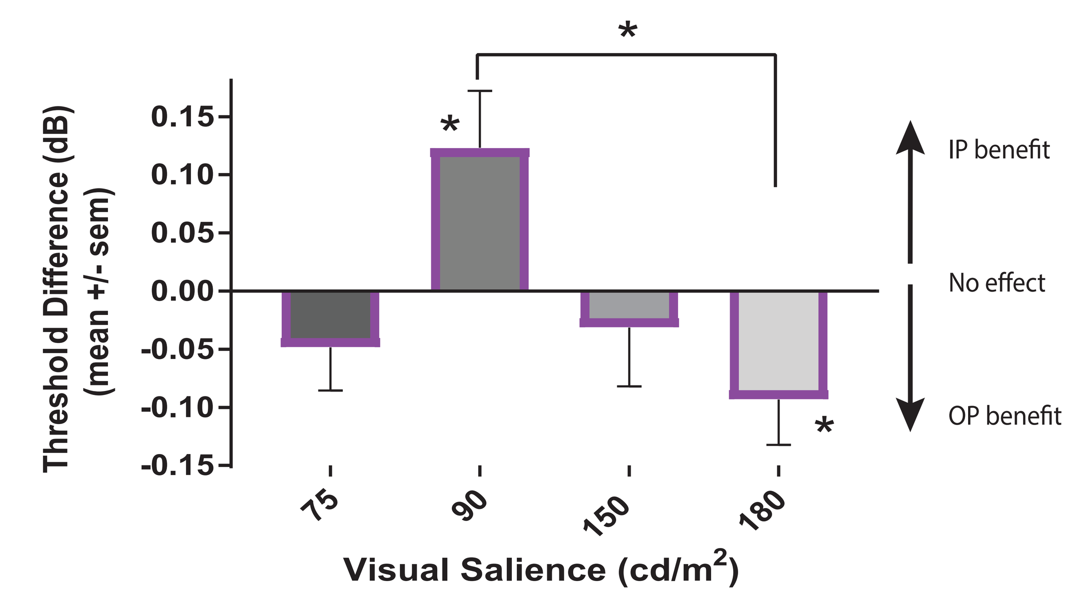
Participant Data

N	Male (%)	Age Range	M	SD
16	2 %	19 – 31	23	3.18

Which conditions show the largest gain in performance?

Threshold (OP-IP)

* = Statistically significant (p<0.05)

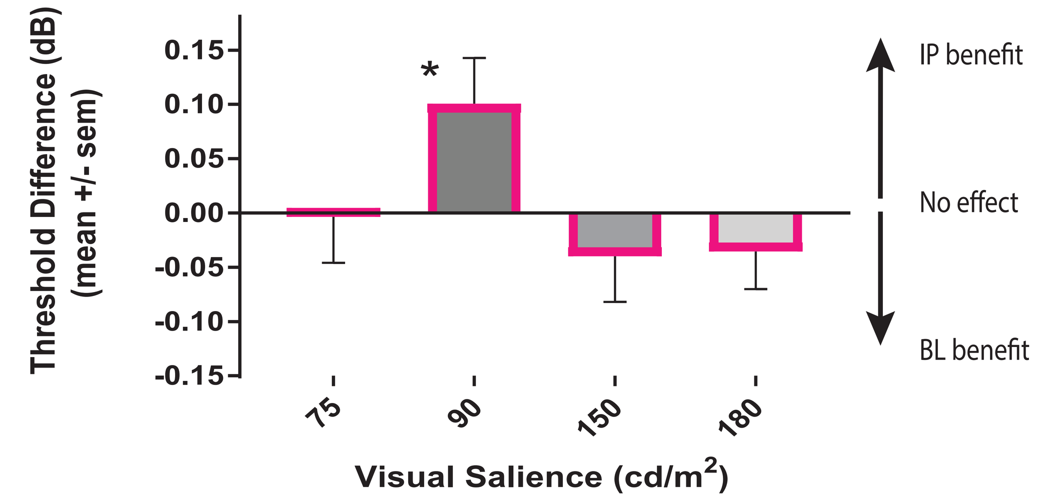


We found an expected IP compared to OP benefit when visual salience was low (90 cd/m²). Auditory thresholds were lower, participants were more sensitive, in the IP condition.

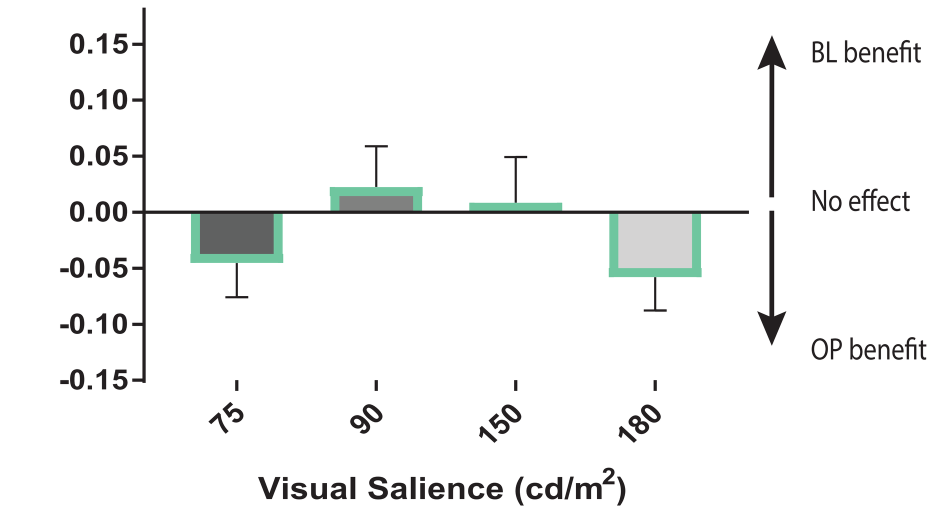
We found an unexpected OP compared to IP benefit when visual salience was higher (180 cd/m²). Auditory thresholds were lower, participants were more sensitive, in the OP condition.

Which conditions show gains in performance relative to baseline?

Threshold (BL-IP)

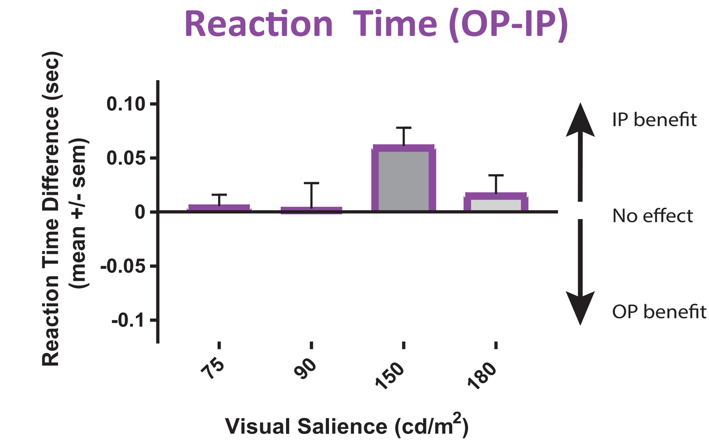


Threshold (OP-BL)

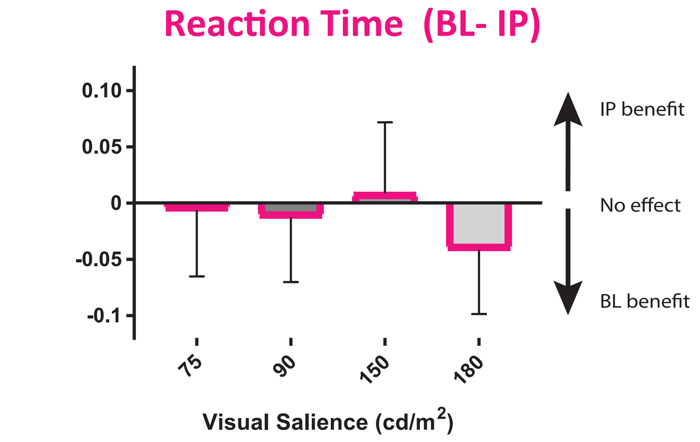


Does reaction time contribute to these findings? NO

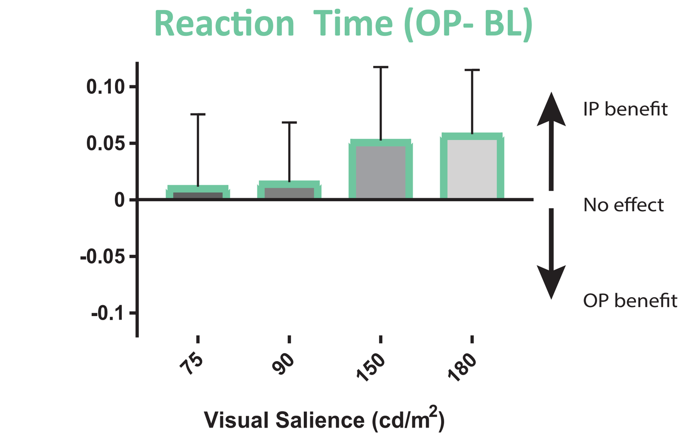
Reaction Time (OP-IP)



Reaction Time (BL- IP)



Reaction Time (OP- BL)



Conclusion

We found a significant benefit, lower auditory thresholds, for the in-phase relative to out-of-phase condition when visual salience was low (90cd/m2) but found a significant benefit for the out-of-phase relative to in-phase condition when visual salience was high (180 cd/m2). These results suggest that the salience of visual information can not only alter the magnitude of integration but may switch an in-phase to an out-of-phase benefit.

References:

[1] Meredith, M.A. & Stein, B.E. (1986) Visual, auditory, and somatosensory convergence on cells in superior colliculus results in multisensory integration. Journal of Neurophysiology, 56(3): 640-662.

[2] Lovelace, C.T., Stein, B.E., & Wallace, M.T. (2003) An irrelevant light enahnces auditory detection in humans: a psychohysical analysis of multisensory integration in stimulus detection. Cognitive Brain Research,17: 447-453.

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[4] Fister, J.K., Stevenson, R.A., Nidiffer, A.R., Barnett, Z.P., & Wallace, M.T. (2016) Stimulus intensity modulates multisensory temporal processing. Neuropsychologia, 88:92-100.

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