Compensating for Lack of Audio Input while Driving
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Abstract
Situational awareness in driving may sometimes rely on monitoring for important auditory signals (e.g., emergency sirens). When hearing is impaired (naturally or artificially), drivers may employ compensatory strategies to maintain safety. Given that hearing drivers can auditorily distract themselves (e.g., cell phones), and that deaf drivers are at no greater accident risk than hearing drivers, we tested how hearing deprivation affects normal-hearing drivers’ performance over time. We examined how hearing participants adapted to a continuous driving and emergency vehicle (EV) detection task for which the EV siren was either audible or silent. After two hours of practice, hearing-deprived drivers drove less accurately and responded more slowly to the EV. Critically, only hearing-deprived drivers improved significantly over time. A second experiment examined whether hearing-deprived driver improvements were strategic or perceptual. Results suggest that hearing-deprived drivers compensated with increased looking, but also improve in their ability to visually detect peripheral stimuli compared to hearing drivers.

Background
Vision appears to be the primary sense used while driving:
- Driver gaze determines steering direction.
- Vision impairments are negatively correlated with driving performance.

However, drivers are able to compensate for vision impairments:
- Some people can naturally compensate.
- Strategic Training in compensatory strategies mitigates performance decrements associated with mild vision impairment.

What about hearing impairments?
- There is some evidence that drivers can compensate for distracted hearing.
- However, there is little research on what those compensatory strategies are!

What could these compensatory strategies be?
- Hearing-impaired individuals pay more attention to the periphery.
- Attentional changes are not explained by sign language use or neuroplasticity.

Questions
Is hearing required in our driving task?
It is possible that drivers rely on the auditory nature of the emergency vehicle (EV) stimulus and thus will perform more poorly without sound. It is also possible that drivers use the siren to identify EV onset, but easily switch to peripheral visual detection when sound is removed.

Can participants compensate for hearing loss in our driving task?
If a performance decrement is observed in the hearing impaired condition, drivers may or may not be able to compensate. If drivers can adjust, hearing-impaired drivers should approach hearing-normal driving over the course of task practice.

If participants can compensate, is it perceptual or strategic?
If participants can compensate for the lack of hearing with practice, they may do so with a change in peripheral acuity.

Predictions: Experiment 1

Hearing
Artificially hearing-impaired drivers will perform worse at a driving task than drivers without the artificial hearing impairment.

Practice
Both conditions may improve with practice, but artificially hearing-impaired drivers’ will improve faster than drivers without the artificial hearing impairment.

Method: Experiment 1
Thirty-four participants (32% female) completed the emergency vehicle (EV) task and were paid based on their performance to motivate maximal effort.

Participants drove a low-fidelity driving simulator across two 1-hour sessions. Their task was to respond to an approaching red EV (in rear view mirror) by indicating which lane it was in (button press). Those in the Hearing condition were able to hear a loud EV siren, whereas those in the No Hearing condition could not.

EV onset detection performance was indexed using response time and accuracy (movement to the appropriate lane). Driving error was assessed by comparing the driver’s heading and the position of the visual target.

Results: Experiment 1

As predicted, the hearing manipulation had a significant effect on the performance of participants in the No Hearing condition compared to participants in the Hearing condition, F(1, 32) = 18.14, p < .001. Participants in the No Hearing condition were 190 ms slower than those in the Hearing condition at responding to the emergency vehicle (EV).

There was a significant interaction between time and hearing conditions, F(1, 174) = 5.90, p = .016. Participants in the Hearing condition improved at a rate of 3.40 ms per block, whereas participants in the No Hearing condition improved at a rate of 9.85 ms. Although both participant groups responded more quickly over time as a result of practice, the 90% increase rate observed in the No Hearing condition is most likely evidence that those drivers’ attempted to drive while monitoring EV onset visually rather than auditorily.

Method: Experiment 2

The artificially hearing-impaired drivers will exhibit a greater increase in peripheral acuity than drivers without the artificial hearing impairment.

Predictions: Experiment 2

Twenty-one unpaid participants (49% female) completed the task.

The method was identical to Experiment 1, except that a peripheral vision test was added before and after each session (four tests total). A fixation point appeared as either an L or an R at the center of the screen, directly in front of participant’s eyes. In approximately half of the trials, a red box (1° square) also appeared along the midline at one of many horizontal positions. If both the red box and an L appeared, participants used the left paddle on the steering wheel to indicate their response (likewise for both a red box and an R). If only an L or an R appeared, participants were to make no response. Peripheral vision performance was assessed by accuracy in response to each type of trial, as well as response time to the stimulus trials.

Results: Experiment 2

In the peripheral eye test, the difference in response time (RT) between the beginning of session two and the end of session two was significantly different depending on hearing condition, t(19) = 2.09, p < .05. Participants in the Hearing condition improved less than those in the No Hearing condition.

A linear multiple regression revealed that, for only participants in the No Hearing condition, change in peripheral eye test RT accounted for 61% of the variance in the change in RT to the emergency vehicle, F(1, 8) = 6.14, p = .024, r² = .79, R² = .62. Specifically, change in peripheral eye test RT across session one was the most impactful, b = -.79, 95% CI [−3.49, .p = .008]. There was no significant relationship between these variables for the participants in the Hearing condition.

Summary & Discussion
Summary:
- Drivers in the No Hearing condition exhibited 24% more driving error and responded 25% slower to the EV compared to those in the Hearing condition.
- After only two hours of practice, EV detection in the No Hearing condition improved at three times the rate of those in the Hearing condition.
- After practice, drivers in the No Hearing condition were four times faster at peripheral target detection than those in the Hearing condition.
- For participants in the No Hearing condition only, becoming faster at responding to peripheral stimuli was correlated with a greater improvement in RT to the EV.

Implications:
- The effect of in-car auditory distractions on hearing drivers’ ability to respond quickly may be temporary, and attenuate with practice.
- However, the effect on driving accuracy may persist over time.
- The apparent perceptual compensations typically observed in drivers with natural hearing impairments may not solely result from early neuroplasticity-based perceptual reorganization over long periods, given that adult participants in this study began to experience an increase in peripheral attention after only two hours of practice. Instead, it seems likely that perceptual learning resulting from practical strategic compensation may drive these results, possibly in conjunction with neuroplasticity effects.

Future Work:
- Establish how long this type of perceptual learning lasts.
- What happens with even more practice, as driving is often a daily activity.
- Use eye-tracking to determine the exact nature of changes in looking strategy.

References