Headphone and Loudspeaker Screening for Web-Based Auditory Experiments: Suggestions for a Reliable Estimation of Data Quality and Sample Size

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1 Background

- Suggestions for screening methods already exist (Woods et al., 2017) ➔ Test C in Methods.
- Their practical application does not consider the prevalence of playback devices.
- The proportion of headphones to loudspeakers in web-based experiments seems to be unknown.
- In the current state of research, the assessment of correctly identified playback devices (data quality) based on screening methods is unclear.

2 Aims

- To develop a reliable screening method for detecting headphones and loudspeakers as playback devices.
- To determine the screening method's metrics sensitivity (ability to correctly identify headphone users) and specificity (ability to correctly identify loudspeaker users) analogous to epidemiology.
- To provide an online tool which calculates application-oriented data quality and the required sample size for web-based surveys, that also considers both the prevalence of playback devices and the test procedure metrics.

3 Method

Pre-Study

Acquisition
- mailing lists, Facebook, Posters

Participants
N = 40, female: 25, male: 15
Age: *M* = 31.83, *SD* = 13.48

pre-study - laboratory - 4 items per screening test:
General viability of Test A and B was examined

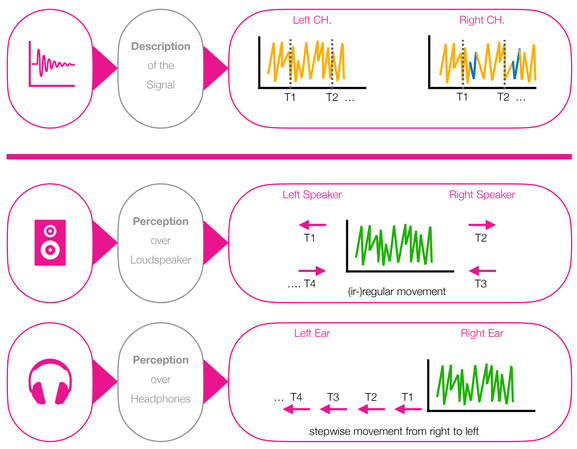
main study - online - 6 items per test:
Three of the stimuli used for Test A and B are exactly as described in the respective figures below whereas the channels are reversed for the remaining three. 0-6 correct answers for each screening test (A, B, and C).

Main Study

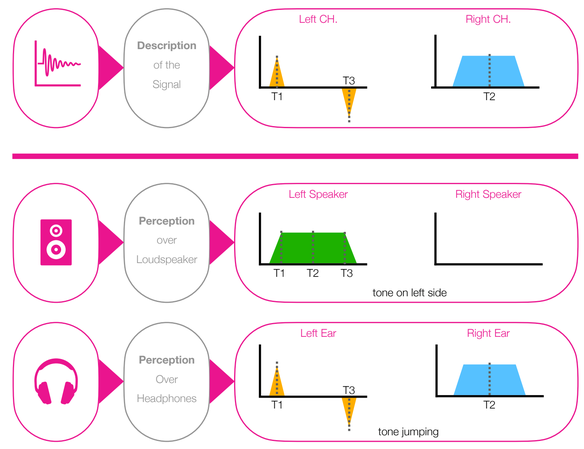
Acquisition
- panel by *mo'web GmbH*

Participants
N = 211, female: 117, male: 94
Age: *M* = 42.4, *SD* = 11.35

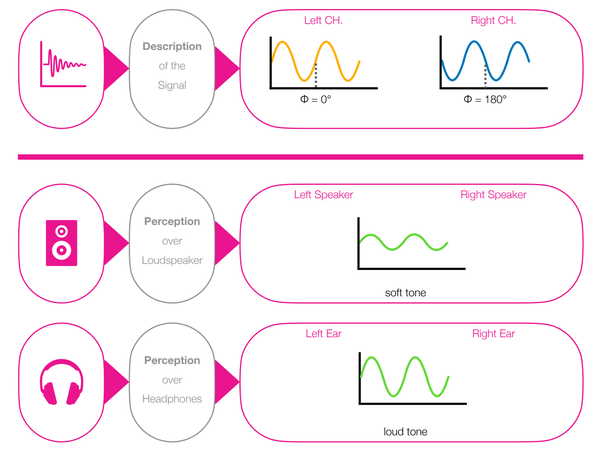
Test A (Interaural Time Difference)
(Bilsen & Raatgever, 2002)



Test B (Franssen Effect)
(Franssen, 1960)



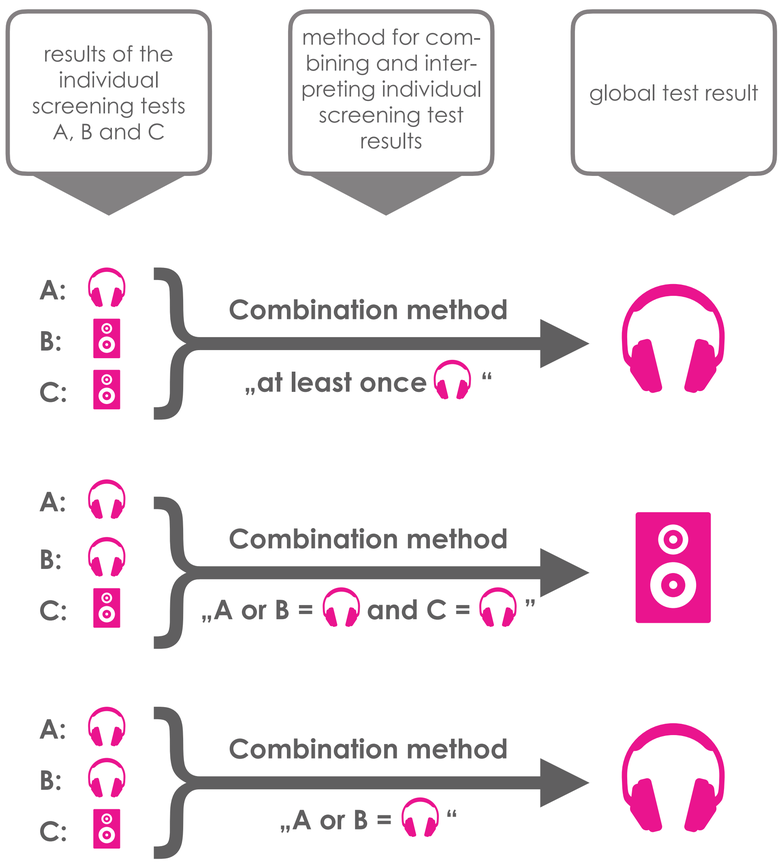
Test C (Destructive Interference)
(Woods et al., 2017)



4 Results

Combination of Screening Tests

Three different examples for the combination of the screening tests and their corresponding global results:



For different minimum numbers of correct answers (threshold), and 18 different methods, the sensitivity and specificity were estimated.
For a given base rate/prevalence for headphone users the overall utility (Treat & Viken, 2012) can be calculated to choose the optimal test combination and its thresholds.

Prevalence

In the trusted **unfiltered** sample (*N* = 1,194) *n* = 211 participants used headphones. This corresponds to a prevalence A of 17.67%, 95% CI [15.6%, 19.9%].
In the trusted **filtered** sample (no smartphones, tablets, monitors/ TVs; *N* = 211) *n* = 80 participants used headphones. This corresponds to a prevalence B of 37.92%, 95% CI [31.6%, 44.6%].
Prevalence A reflects the headphone usage in the studied population whereas prevalence B applies to a subset.

Sample Size Estimation

Model: The number of true headphone users *H* in a sample of *n* participants with a headphone test result can be conceptualized as random variable following a Binomial distribution. *p* is the probability that a participant used headphones given their headphone test result calculated from the prevalence and the test's sensitivity and specificity. ϑ is the probability of at least *k* true headphone users in the sample.

$$\vartheta := \mathbb{P}(H \geq k) = \sum_{i=k}^{n} \binom{n}{i} p^i (1-p)^{n-i}$$

Approximation: According to the De Moivre-Laplace theorem a Binomial distribution can be approximated by a Normal distribution (with Φ denoting the cumulative distribution function of the standard normal distribution). With a continuity correction we yield:

$$\vartheta \approx 1 - \Phi\left(\frac{k - \frac{1}{2} - np}{\sqrt{np(1-p)}}\right)$$

Calculating *n*: From the approximation follows for $\vartheta > 0.5$

$$n \approx -\frac{a}{2} + \sqrt{\left(\frac{a}{2}\right)^2 - b}$$

with

$$a = -\frac{1}{p}\left(2k - 1 + (1-p)\left(\Phi^{-1}(1-\vartheta)\right)^2\right)$$

$$b = \left(\frac{k - \frac{1}{2}}{p}\right)^2$$

Online Tool

- Determination of test combinations and thresholds in regard to the sample size estimation
- onfiguration of the Headphone And Loudspeaker Test [HALT] (R package)

QR code to Online Tool (click for link):

QR code to HALT R package (click for link):

QR code to HALT demo (click for link):

5 Conclusion

The low prevalence of headphone usage in web-based experiments indicates the central role of highly sensitive and specific screening methods. Considering the standards of signal detection theory (Treat & Viken, 2012) and epidemiology (Ahrens & Pigeot, 2014), it is insufficient to focus solely on sensitivity and specificity without obtaining information on device prevalence. Our findings can contribute to improve the data quality and efficiency of future online studies.

References

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