Effects of distance on Hyfe performance

The Hyfe Team[1]*

Abstract

- Ideally, detection distance is limited so that ambient coughs are not confused with the user's coughs.
- We found that cough detections do decline with distance, but the effect is device-specific.
- On Motorola phones, detection rates drop by 15-20% at 1 meter.
- On iPhones, detection rates drop by the same amount at 3.5 meters.
- On Motorolas, peak loudness declines with distance much more rapidly, falling below Hyfe's loudness threshold at a closer distance.
- This threshold can be tailored strategically for each research project to manage the trade-offs involved.

[1] *www.hyfe.ai*
***Correspondence**: research@hyfe.ai

Introduction

Hyfe develops smartphone apps that use A.I. and passive listening to unobtrusively measure patterns and trends in a user's cough. Hyfe currently offers two apps: a public-facing consumer version entitled Hyfe Cough Tracker (hereafter, the Consumer app) and a research-oriented version optimized for clinical studies (the Research app). The former is available on both iPhone and Android; the latter is available only on Android.

Hyfe is designed for individual users. High performance means detecting all coughs from a nearby user and no ambient coughs from others in the distance. To achieve this, Hyfe uses various metrics to sort out the soundscape it is analyzing, filtering to loud noises that are potentially robust coughs from a nearby source. In the real-world, however, these circumstances are never binary. The intended user will be various distances from their phone and will be moving through various soundscapes.

To understand the spatial range of Hyfe performance, we designed distance trials in which smartphones provisioned with the Hyfe app are placed at various distances from a cough source. To ensure that each distance is assessed consistently and that separate trials can be compared to one another, we used a playback design in which the same sequence of pre-recorded coughs are played over high-quality speakers. These experiments allow us to assess the range at which a user's coughs can be monitored reliably.

Methods

Coughs were produced in front of an array of devices (one iPhone, two Android smartphones), which were provisioned with a mixture of Consumer and Research versions of the Hyfe app, at ten distances: 20 cm, every 50 cm between 50 cm and 3 m, then every meter up to 6 m.

Pre-recorded coughs were drawn from a cough screening study in which coughs were recorded in 5-second files (44.1 kHz, wav format) using a professional-quality microphone (see details here). At each distance, these 314 pre-recorded coughs were played in sequence. Sounds were played over a Kali Audio-6 6.5" desktop speaker (87 Hz - 25 kHz frequency response). The volume of the speaker was set to approximate that of a real person's cough based upon levels measured with a Gain SLM-24 sound level meter (www.gainexpress.com) at 1 m distance from the speaker (mean 81 dBA, sd 13 dB). Each cough was separated by a random interval ranging from 5 to 15 seconds. For each sound file, the exact playback time of its constituent cough was recorded to a log file along with the cough's associated metadata.

Cough detection data generated from the app were downloaded and synchronized to the "ground-truth" logs. Cough detections (defined as peak sounds with a cough prediction score greater than 0.50) that occurred within two seconds of a ground-truth timestamp were classified as a successful capture. Performance was scaled by that at the closest distance tested (20 cm).

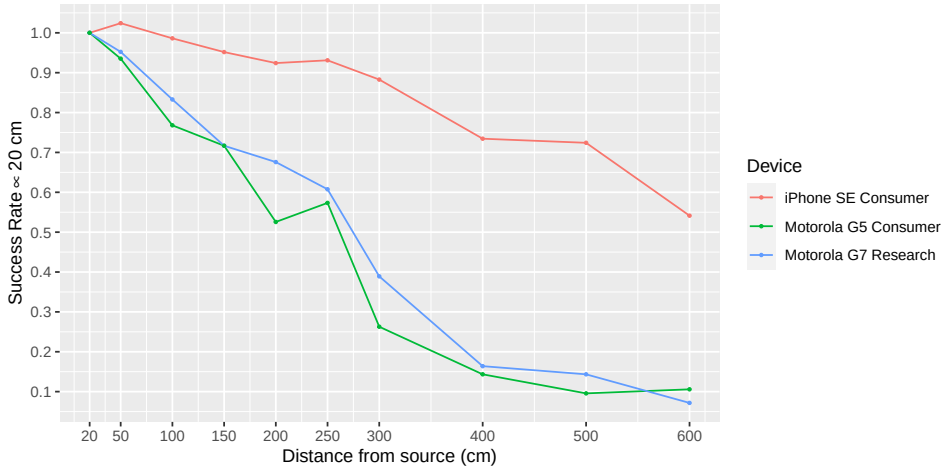

Figure 1. Results of playback distance trials by device, presented as performance relative to 20 cm results.

Table 1. Results of playback distance trials by device, presented as performance relative to 20 cm results.

	Distance (cm)									
Device	20	50	100	150	200	250	300	400	500	600
iPhone SE iOS (Consumer)	1.00	1.02	0.99	0.95	0.92	0.93	0.88	0.73	0.72	0.54
Motorola G5 Android 10 (Consumer)	1.00	0.94	0.77	0.72	0.53	0.57	0.26	0.14	0.10	0.10
Motorola G7 Android 11 (Research)	1.00	0.95	0.83	0.72	0.68	0.61	0.39	0.16	0.14	0.07

Results

Detection rates declined with distance more quickly in the Motorola Android devices than in the iPhone SE that we tested (Table 1, Figure 1). With the iPhone, detections remained above 90% of maximum out to 2.5m, and was still above 50% at 6 m, the greatest distance tested here. With the Motorolas, in contrast, detections dropped below 90% at 75 cm, below 50% by 3 m distance, and below 10% by 6 m.

By counting the 'peak sounds' and coughs logged at each distance (Figure 2) it became clear that the decline was due to fewer peak detections rather than degradation in cough classification. The proportion of logged peaks that were classified as coughs remained roughly equal at all distances.

Based upon the sound metrics for peaks logged at each distance (Figure 3), the differential between iPhone and Motorola can be attributed to the loudness threshold. The signal-to-noise ratio (SNR) of peaks remained high at all distances, well-above the peak detection threshold of 18 used by Hyfe's algorithms. In contrast, the loudness (amplitude) of peaks detections dropped with distance more precipitously in the Motorolas, quickly falling below Hyfe's loudness threshold of 60 dbA.

Discussion

This preliminary trial indicated that the spatial range of Hyfe performance is driven by manufacturer specifications. Once Hyfe converts from static to dynamic peak detection thresholds (forthcoming), these device-driven differences will be minimized. Until peak detection becomes device-agnostic, research applications of Hyfe's apps should conduct preliminary trials, such as those outlined here, to understand the risks of missing participant coughs or detecting ambient coughs.

While it is important to understand the effect of cough distance on a particular device, interpreting that result can be difficult. Based on these results, which device is preferable: an iPhone or a Motorola? The former is better at detecting coughs when the user is not next to their phone, but it is also liable to detect ambient coughs from others. The Motorola, in contrast, is more likely to miss coughs even when the user is only an arm's length away, but its cough record will not be compromised by detections from others. Fortunately, Hyfe is able to adjust loudness and SNR thresholds for each research project separately, thus allowing partner investigators to navigate these trade-offs strategically.

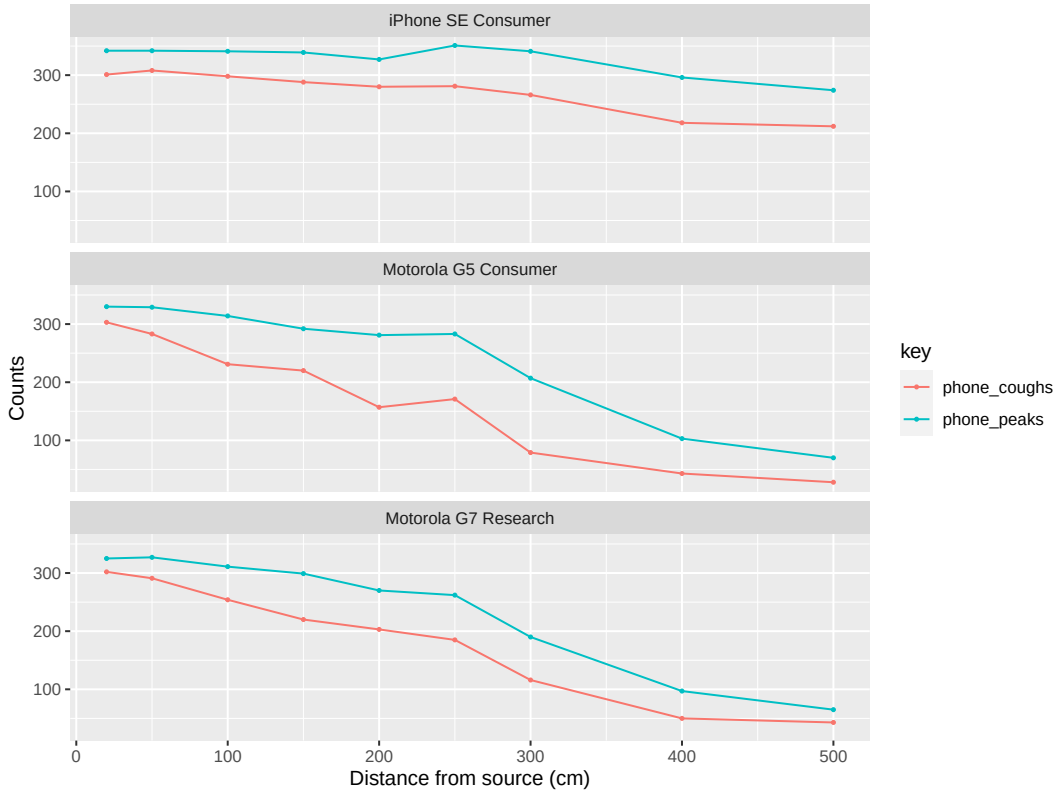

Figure 2. Counts of peak sounds and coughs detected during playback distance trials, by device.

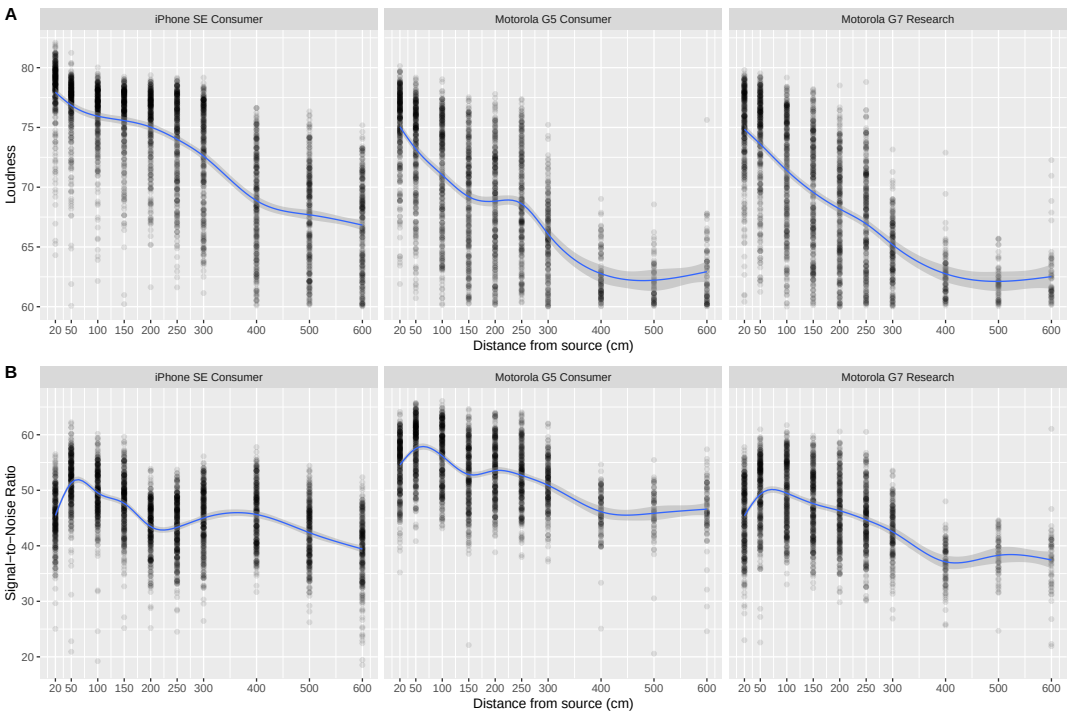

Figure 3. Detailed metrics for sounds detected during playback distance trials, by device. Devices were programmed to log sounds above a loudness threshold of 60 dBA and a signal-to-noise ratio threshold of 18.