Measuring steps at the ear: How My Steps improves accuracy

White Paper

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signia

Introduction

For many years, Signia hearing aids have used motion sensor technology in their signal processing algorithms to improve communication in everyday listening situations. Most recently, Signia implemented an integrated accelerometer to improve the performance of its directional microphone system (Branda & Wurzbacher, 2021).

An added advantage of the integrated motion sensor is that it provides data that can be used for step counting. In recent years, research has shown a relationship between hearing loss and other harmful conditions such as diabetes and dementia (Besser et al., 2018). Along with an increased awareness of these comorbidities, some hearing aid wearers have focused more of their attention on their own health and well-being. To this end, a step-counter functionality integrated into a hearing aid provides the wearer useful information about their physical activity levels, a key component of good health.

Signia has introduced the My WellBeing solution as part of the Signia app, allowing the wearer to track key parameters related to hearing loss and general health, such as steps, physical activity, hearing-aid wear time, and the frequency with which they engage actively in conversations (Jensen & Taylor, 2022). The step-counting feature, My Steps, allows the hearing aids to perform as a step counter worn at the ear level. The integrated motion sensor detects walking and counts the wearer's steps. The data are accessible via the app, showing daily, weekly and monthly step counts (see Figure 1).

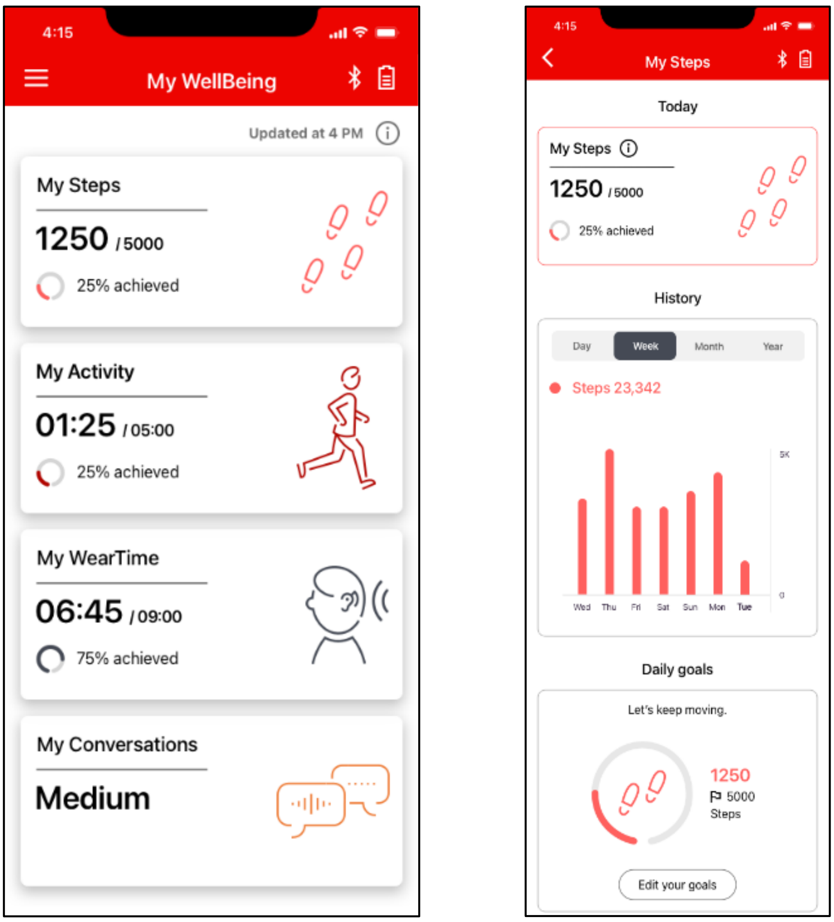

Figure 1. The opening screen of My WellBeing, left, provides a quick overview with the status of the four tracking features. When entering the My Steps screen, right, more detailed information is made available, including the history of daily, weekly and monthly step counts.

A variety of step counters are available in the marketplace. They often are worn on the wrist, but they also can be worn at the hip, around the neck, and even integrated into smartphones. Given the multiple placements and designs of step counters, it is not surprising their accuracy has been called into question.

Several investigations have looked at the accuracy of step counters. Husted & Llewellyn (2017) showed a large variety of results among different pedometers, with some of the more expensive being the least accurate. Ehrler et al. (2016) reported that pedometers can perform more accurately at higher walking speeds, although wrist-worn devices may be a more reliable option at slower walking speeds.

It is fair to assume that for regular walking, most devices are relatively accurate, but some variability can be expected. Importantly, one must consider not only if they are accurate at counting each footstep of the wearer but if they are also subject to other variables that could generate artifacts and false step counts.

It is believed that wrist-worn step counters are prone to errors because they sometimes falsely detect arm motions as steps, even when the wearer is stationary. Further, when a step counter is worn on the ear, due to its sensor placement, it may be more accurate (fewer falsely counted step counts) than a wrist-worn device. Researchers have tested the accuracy of step counters to other locations on the body. In a comparison of wrist-worn and hip-worn step-counting devices, Nelson et al. (2022) showed higher accuracy on a treadmill (normal walking) for the wrist-worn device, but overall higher step counts during at-home daily living activities for the wrist-worn device due to falsely detected steps caused by arm movements. Another study by Case et al. (2015) showed that wrist-worn devices were not as accurate as devices positioned at the hip level. These studies cast doubt on the accuracy of wrist-worn step counters for certain activities.

With the launch of Signia's My Steps feature, it was important to compare the step counter worn at the ear level to those worn on the wrist. This study addressed three questions:

1. Does My Steps provide an accurate (or more accurate) step count compared to wrist-worn step counters when the wearer is walking?
2. Does My Steps provide a more accurate step count compared to wrist-worn step counters in activities involving arm and body movements but no steps?
3. Do false step counts, due to arm movements, result in lower (but more accurate) step counts in real life for My Steps compared to wrist-worn step counters?

Methods

In this study, 10 participants were recruited to compare My Steps to two premium, commercially available wrist-worn devices with step-counting functionality. Participants consisted of four males and six females with a mean age of 45 years. Hearing loss was not a consideration for candidacy, as the focus of the study was strictly on step counting. The protocol was reviewed and approved by an external ethical review board.

The hearing aids used were Signia Pure Charge&Go AX with open, non-occluding domes. Programming was not a critical parameter because amplification was not an area of investigation and open fittings provided necessary access to environmental sounds. Programming adjustments were not required or requested by any of the participants. The wrist-worn devices were an Apple Watch Series 7 and a Fitbit Versa 3 Smartwatch. The comparative devices were selected as being current, premium offerings from well-known manufacturers of wrist-worn products with step-counting functionality.

Five tasks were designed to compare the accuracy of the step counters. Four of the tasks were controlled lab tasks, while the final task was a daily-life activity task. For all the tasks, participants were asked to wear their hearing aids in the correct position on their ears. Participants could choose which arm would be used for the wrist-worn devices; however, both devices needed to be worn on the same arm. If at any point in the study a participant needed to remove a device, all devices needed to be removed to ensure the same situations were monitored by the hearing aids and the two wrist-worn devices.

For the lab tasks, steps were recorded immediately prior to beginning the task, and then recorded again following the task. Participants remained still prior to each recording of the data to allow the recording devices to display the most current counts.

The tasks were designed as follows:

Task A: Walking 200 steps. Participants walked 200 steps at a normal walking pace. No restrictions were placed on arm or head movement while they walked. Participants were asked to count each step to establish the true 200-step count.

Task B: Walking up/down stairs. Participants walked up and down 200 stairs. At the top or bottom of the flight of stairs, participants were asked to do an about-face to continue the count. They were able to rest in a stationary position as needed. There were no restrictions placed on pace, arm movement, or head movement, including how participants used safety rails.

Task C: Loading/unloading a dishwasher. Participants were asked to keep their feet stationary while loading and unloading a dishwasher to a countertop for a period of five minutes. No restrictions were placed on arm or head movement. However, participants were asked not to favor one arm over the other to ensure same activity from both arms.

Task D: Placing/removing items in a shelf. Participants were asked to take items from a countertop and place to or remove from a shelf at head level while remaining stationary for five minutes. No restrictions were placed on arm or head movement. However, participants were asked not to favor one arm over the other to ensure some activity from both arms.

Task E: Daily activities. Participants were asked to wear the hearing aids and wrist-worn devices while completing their daily activities at work or at home throughout the course of one day. No restrictions were placed on activities, arm movements, or head movements. Again, if at any point a participant needed to remove one device, all devices were to be removed at the same time. The duration of the day and the types of activities varied among participants.

Results

The mean number of steps registered with each step counter in each of the four lab tasks are plotted in Figure 2. Each plot also indicates the true step count in the task. For Tasks A and B, the true step count for each task was 200 steps. For Tasks C and D, as the activities were stationary, the true step count was zero steps.

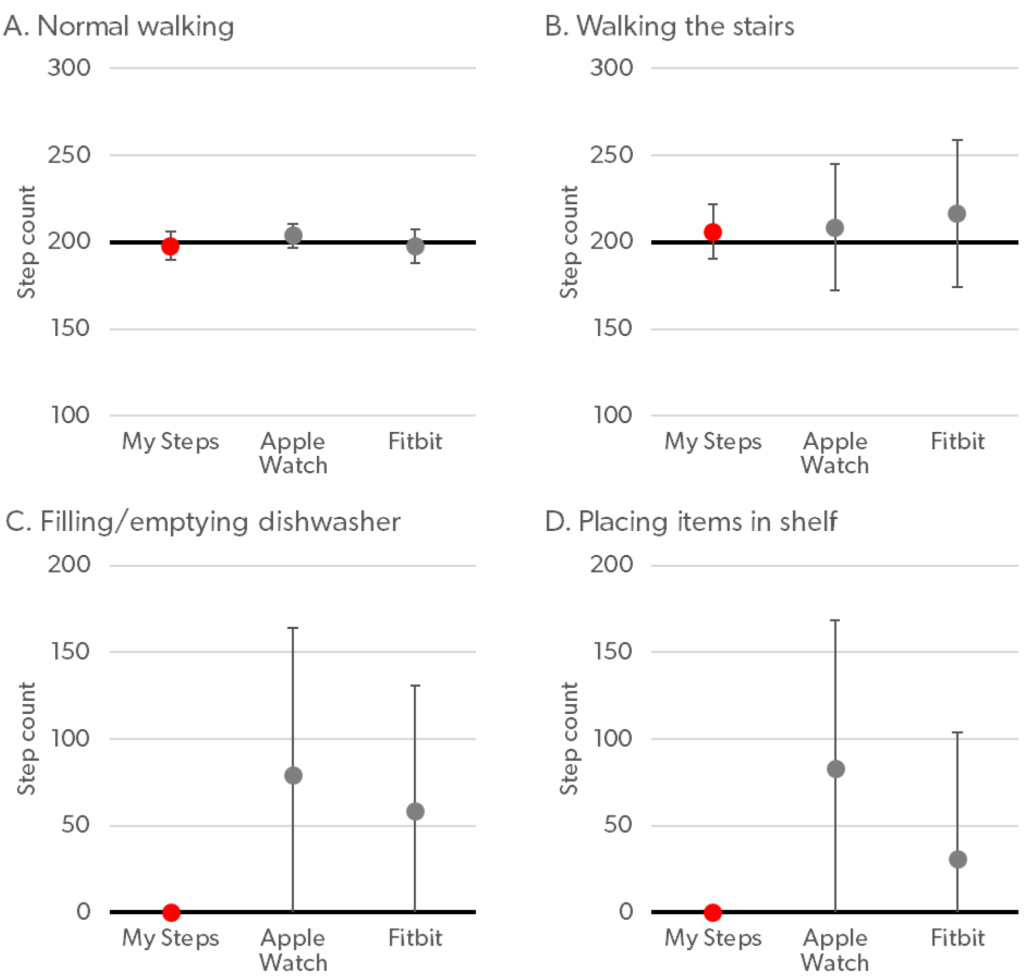

Figure 2. Mean step count for the 10 participants, registered by My Steps and two wrist-worn step counters (Apple Watch and Fitbit) in four tasks: A) normal walking (with normal arm movements), B) walking the stairs (with normal arm movements), C) filling/emptying dishwasher (without moving the feet), and D) placing items in a shelf (without moving the feet). Error bars indicate ±1 standard deviation. The true step count in each task is indicated by a bold line.

Panel A in Figure 1 shows that all three step counters were consistently accurate for normal walking (Task A). My Steps provided the mean value closest to the true value, but the differences among devices were small. All mean values were within four steps (2%) of the true step count (200), with low variance across participants, and analysis of the data using a mixed model analysis of variance (ANOVA) showed no significant effect of device type (p = .13). The average walking pace was 0.9 meters per second, which is consistent with an average gait (Studenski et al., 2011).

Panel B shows the results from walking the stairs (Task B). Compared to normal walking, the observed mean deviations from the true step count were slightly larger, but all mean values were within 20 steps (10%) of the true count, with no statistically significant differences between the mean values, according to a mixed model ANOVA (p = .56). However, it is still worth noting that My Steps provides the most accurate mean step count and a substantially lower variance across participants. The latter observation indicates that the individual deviations away from the true value were smaller for My Steps.

The results from Tasks C and D, where participants did not walk but only moved their arms, are shown in panels C and D in Figure 1. The two plots show basically the same pattern. In both tasks, a clear difference between My Steps and the two other devices was observed.

Benefitting from the sensor position at the ear, My Steps did not make any (false) detections of steps for any of the participants, resulting in a mean step count (and standard deviation) of zero steps. In comparison, Apple Watch registered an average of 79 and 83 steps, respectively, in the two tasks, while the Fitbit device registered an average of 58 and 31 steps.

Due to a skewed distribution of data points, which reached the lower limit of zero, the data were analyzed using a non-parametric statistical test. A Wilcoxon matched pairs test showed that the mean counts made by the two wrist-worn devices were significantly higher than the My Steps counts in both tasks (all $p < .05$). As shown by the error bars in the plots, a large variation across participants was registered for both wrist-worn devices, because, in part, the number of arm movements made during the five-minute test varied across participants. The mean difference between the two wrist-worn devices was only significant in Task D ($p = .03$), while it was non-significant in Task C ($p = .08$). In just three cases (all observed for Fitbit in Task D), a correct step count of zero was observed with a wrist-worn device.

For the daily activity (Task E), the mean number of steps registered by the three devices is plotted together with the standard deviation in the bar graph in Figure 3. The figure shows that the mean step count made by the two wrist-worn devices were substantially higher than the mean count made by My Steps. The Apple Watch count (4,276) was 38% higher than the My Steps count (3,096), while the Fitbit count (4,800) was 55% higher, and in both cases the difference was statistically significant, according to a mixed model ANOVA and Tukey HSD post-hoc test ($p = .03$ and $p = .002$, respectively). The difference between the two wrist-worn devices was not statistically significant ($p = .44$).

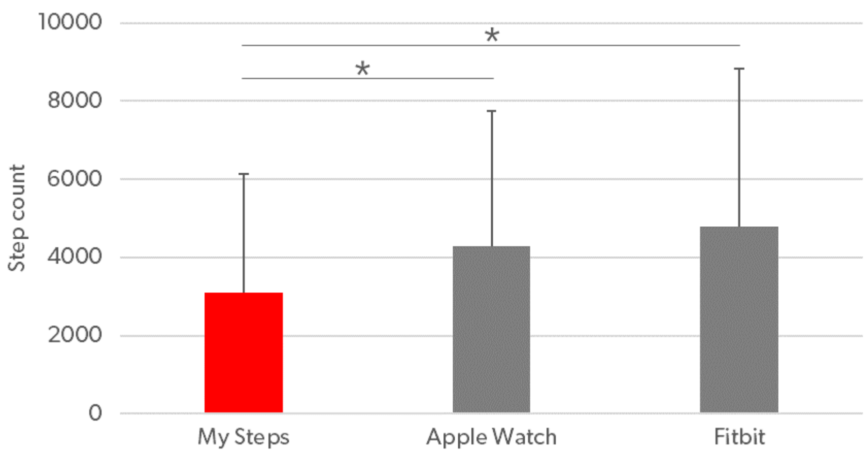

Figure 3. Mean step counts by My Steps and the two wrist-worn devices (Apple Watch and Fitbit) when worn simultaneously for one day (Task E). Error bars indicate one standard deviation. Asterisks indicate statistically significant pairwise differences (p < .05).

The large variance observed for all three devices in Figure 3 indicates that the number of steps taken during the daily-life task varied considerably across participants. The observed differences in the mean counts suggest that the false step detections made by the wrist-worn devices (cf. the results from Tasks C and D) may accumulate to a substantially large number and add a significant error to the total daily step count when these devices are used in the real world.

Discussion

As expected, for activities that involved normal walking, the ear-level hearing aids performed consistently with the other established step-counting products worn on the wrist. This was apparent in Task A (walking 200 steps), where the final mean results were not significantly different. For Task A, all three step-counting devices accurately measured the true 200 step count at an ordinary gait.

For Task B, walking up and down the stairs, there was no significant difference between devices, although My Steps provided the mean step count closest to the true count. For all three devices, the overall count was slightly higher than the true count. This could be a result of how participants managed the flight of stairs and reversing direction. It is possible that extra steps (not counted by the participant) may have been taken during the turning process. However, in this case, any additional steps appear to have been counted by all three step counters.

For Task C and Task D, the two stationary activities, it was expected that participants' feet would remain still, and no steps would be counted. During both these stationary activities, which involved bending and reaching, the ear-level hearing aids accurately detected that no steps were taken. Although no steps were taken, the other devices inaccurately detected several of the arm motions in both stationary activities as steps.

These results suggest that My Steps more accurately counts steps during stationary activity, as the two wrist-worn step counters mistook arm and hand movements as steps in these conditions. This finding was confirmed in the final task (Task E), where higher step counts were erroneously detected with the wrist-worn devices.

The magnitude of the error depended on the activities performed during daily life. People performing activities involving more arm movements, like Tasks C and D, had significantly overestimated step counts when using a wrist-worn device. For individuals who like to track the number of daily steps taken as precisely as possible, these results demonstrate that My Steps is more accurate than two popular wrist-worn devices.

A variety of pedometers are available in addition to the wrist-worn devices, such as app-based smartphone step counters, which could be worn on other parts of the body, as well as hip-worn step counters. Of course, to obtain accurate step counts, the wearer must carry the step counter in the appropriate position during daily situations. This may not always be an option with hip-worn devices, and smartphones are often placed on a table or in a bag.

Using My Steps in comparison to devices worn on the hip or in a pocket offers the practicality of the step counter being convenient to wear and not so cumbersome. Ultimately, for those seeking to include step counting as part of their daily health regime, My Steps offers a reliable solution as part of the Signa AX platform.

Summary

Our investigation, which compared ear-level step counters to wrist-worn step counters, confirmed three outcomes about Signia AX's My Steps feature of the My WellBeing app:

1. For tasks involving ordinary walking and walking a flight of stairs, our results confirmed that the My Steps ear-level step-counter is as accurate as wrist-worn step counters.
2. For tasks involving stationary activity, My Steps is more accurate than wrist-worn step counters. During routine kitchen activities, use of My Steps resulted in no false step counts, as opposed to both wrist-worn devices.
3. For measures of step counts during daily activity in the real world, My Steps is more accurate than wrist-worn devices. This statement is based on data indicating wrist-worn devices tend to falsely detect arm motions as steps.

Given the growing interest by individuals who desire to lead a healthier lifestyle and to track their physical activity levels, My Steps is an outstanding choice. This study demonstrates it is accurate and precise. For Signia AX wearers, My Steps offers additional functionality that contributes to their overall health and well-being.

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