



MAC VU360 Resting ECG Operational Efficiency Study

An observational study comparing the performance, usability and efficiency of four cart-based ECG systems.

Abstract

A double-blind observational research study comparing the performance, usability, and efficiency of four cart-based ECG systems was conducted by Healthcare Research & Analytics (HRA) following a formal protocol within the regulatory and engineering guidelines provided by GE Healthcare. The objective was to evaluate the operational efficiency and effectiveness of a new GE Healthcare ECG device against three others in common hospital use. The research provided solid evidence that the new system has meaningful advantages in operational efficiency and usability over the other devices tested.

Introduction

As hospitals face growing patient loads and pressure to reduce costs, efficiency and effectiveness become increasingly important. This applies to many routine tasks, including the capture of patients' ECG waveforms. ECG machines that are intuitive, easy to use, save time and reduce steps can help hospitals increase clinical efficiency. In particular, it is beneficial to deploy ECG devices that staff members can use with little or no assistance from a supervisor or cardiologist. This comparative study evaluated leading ECG devices against a newly introduced ECG system with features designed to enhance usability and efficiency.

Background/Objectives

GE Healthcare engaged Healthcare Research & Analytics (HRA) to conduct observational research comparing the performance, usability, and efficiency of four cart-based ECG systems. HRA is an independent and objective market research company with significant experience in conducting human factors and usability research. HRA analyzed the study results and documented the conclusions. The objective was to evaluate the operational efficiency of the new GE Healthcare MAC VU360™ resting ECG system in comparison to:

- GE Healthcare MAC™ 5500 HD
- Philips Pagewriter TC70
- Welch Allyn/Mortara ELI 380 ERGO and ELI 350

The MAC VU360 hardware and software were completely devoid of brand identification and the device was known to the study participants as Product X.

The four systems were tested and compared by a group of 20 participants comprised of nurses and ECG technicians. The comparisons included:

- Performance of a timed series of routine ECG tasks.
- Tracking of whether participants could complete tasks without assistance.
- Scores based on standard measures of usability and customer loyalty.
- Feedback on each machine's transportability, maneuverability and ease of cleaning
- A final ranking of ECG machines by preference

Methodology

The double-blind research study was conducted by HRA at Smith Research Facility, a third-party research facility, in Chicago, IL, March 26-30, 2018. Participants were screened to ensure a balanced mix of persons with experience using GE Healthcare systems, Welch Allyn/Mortara and Philips ECG devices in daily practice, and to ensure that participants had a wide range of ECG experience (Table 1). Seven registered nurses and 13 certified ECG technicians were recruited with ECG experience ranging from 1 to 27 years (average of 14 years) and with lower and higher frequency of using ECG machines in their normal employment. Nine participants came from academic hospitals and 11 from non-profit community hospitals. Clinicians were ineligible for the study if they or an immediate family member were consulting with or employed by a regulatory agency or medical device company.

The discussion guide and observations followed a formal protocol finalized by HRA, within the regulatory and engineering guidelines provided by GE Healthcare. After completing assigned tasks on each of four ECG machines[‡], the participants completed standardized usability survey instruments, as well as a Likert-scale survey.

Each respondent completed identical ECG tasks with each machine:

- Power the machine on and off
- Three manual new patient data entries
- Three 10-second resting ECGs^{**}
- 30-second rhythm strip
- Retrieve and print the first patient's 10 second ECG from the saved records file
- Delete a previous patient record
- Identify two randomly introduced artifacts for muscle tremor and respiration via simulator
- Multi-step and directional transport and maneuverability exercise
- Cleaning exercise on the machine and cart

Machines and respondents were video recorded, timed and observed by a trained, independent moderator during all the ECG tasks. All button pushes and touchscreen taps were recorded, as was the time it took each participant to complete each task on each machine. To avoid order bias, the moderator systematically rotated the order in which the products were tested.

Table 1

Distribution of participants, by main device used in daily practice and by ECGs performed per month*

Number of ECGs performed per month	Main device used in daily practice				Total Participants
	GE Healthcare	Welch Allyn/Mortara	Philips	Other	
Low (10-79)	4	2	1	1	8
Medium (80-120)	1	1	2	2	6
High (121-600)	2	4	0	0	6
Total Participants	7	7	3	3	20

* To be categorized as a user of a particular manufacturer's device, the respondent had to use that manufacturer's device exclusively in at least one department for at least 30 percent of the total ECGs they perform per month.

‡ The Welch Allyn/Mortara ELI 380 ERGO is the newest and flagship Welch Allyn/Mortara ECG unit; the ELI 350 is the unit used in a clinical setting by most participants classified as Welch Allyn/Mortara users. After being tested by seven study participants, the ELI 380 experienced a software error and malfunctioned. Because it could not be repaired and a replacement unit could not be accessed during the study timeframe, a Welch Allyn/Mortara ELI 350 was substituted. The majority of the GE users in the study tested the ELI 380 and therefore compared the GE MAC VU360 against Welch Allyn/Mortara's most recent device. The majority of Welch Allyn/Mortara users arrived for the study after the ELI 380 malfunctioned; this meant they tested on the ELI 350, which was the device they were accustomed to using in daily practice at their facilities. Two study participants were on site when the ELI 380 malfunctioned and thus were not able to test any Welch Allyn/Mortara device. This brought the total tests performed on Welch Allyn/Mortara devices to 18, rather than 20. Additionally, due to a time constraint, one respondent was unable to perform the tasks on the GE MAC 5500 HD, which was the last device in that participant's rotation. This brought the total tests performed on MAC 5500 HD to 19 rather than 20.

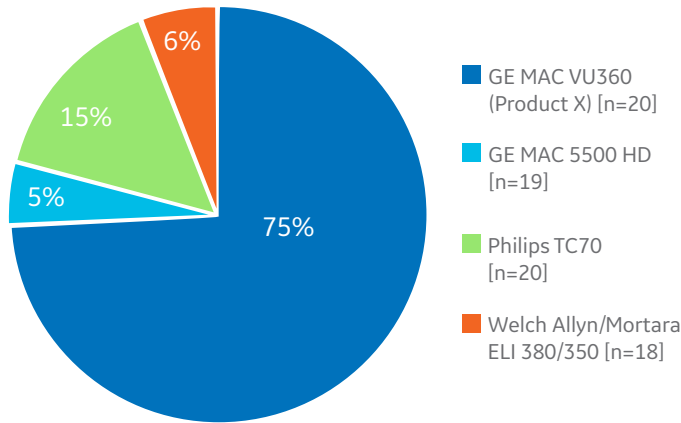
** On the Welch Allyn/Mortara devices and GE Healthcare MAC VU360, both of which have two acquisition modes, the first ECG was taken in the pre-acquisition (last 10 seconds) mode, and the second and third ECGs were taken using the Best 10 seconds mode on the Welch Allyn/Mortara devices and using SMART Auto ECG on the MAC VU360. The Philips TC70 and GE Healthcare MAC 5500 HD only have the one acquisition mode, capturing the last 10 seconds.

Study Findings

User preference

The moderator asked participants to provide an overall preference ranking of the ECG machines they tested, along with the rationale for the ranking. Among all respondents, **75 percent ranked the MAC VU360 as their number one preference** (Figure 1).

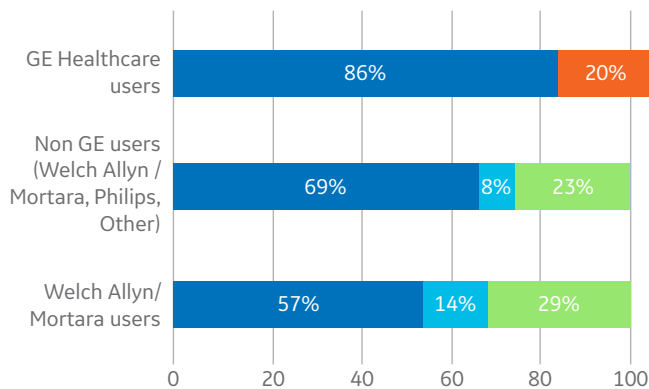
Figure 1
Preference ranking, percentage that selected each device as top choice*



* As 2 respondents did not test on the Welch Allyn/Mortara device and 1 did not test on the GE MAC 5500 HD, the percentages do not sum to 100%.

The MAC VU360 also had the highest percentage preference regardless of user group (Figure 2) or participants' frequency of ECG use.

Figure 2
Preference ranking (percentage that selected each device as top choice), by user group*



- % respondents that tested on Product X and ranked it 1st
- % respondents that tested on GE MAC 5500 HD and ranked it 1st
- % respondents that tested on Philips TC70 and ranked it 1st
- % respondents that tested on Welch Allyn/ Mortara ELI 380/350 and ranked it 1st

* As 2 respondents did not test on the Welch Allyn/Mortara device and 1 did not test on the GE MAC 5500 HD, the percentages do not sum to 100%.

“Anyone with a touchscreen phone or device would find [Product X] very easy to use. I also like that it gives you an image of the patient and tells you which leads are disconnected, what errors are occurring.”

ECG Technician, Welch Allyn/Mortara User

“Product X is easy to use. The new patient user interface is clean. I like the ergonomics of the machine and the ability to adjust to user height.”

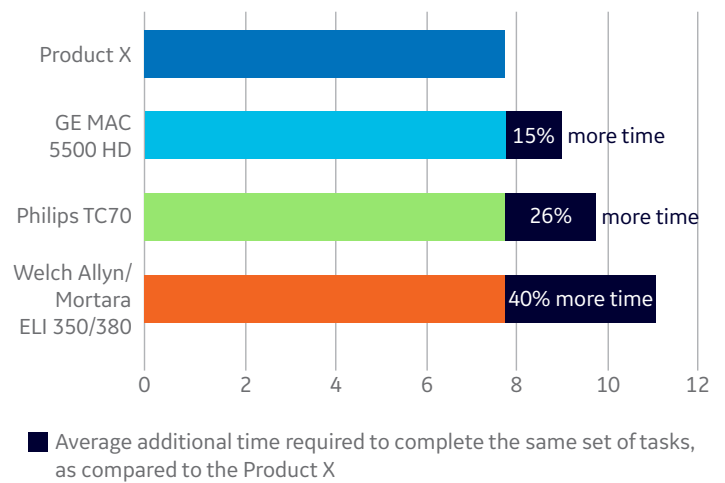
ECG Technician, GE Healthcare user

Workflow Efficiency

Timing of tasks

One measure of workflow efficiency is how quickly clinicians can complete their tasks. Study participants were timed on completion of all the listed ECG tasks on each of the four devices, and the times were totaled by device. On average, participants used the **least amount of time to complete the set of tasks on the MAC VU360, requiring 15 to 40 percent more time on the other devices** (Figure 3).

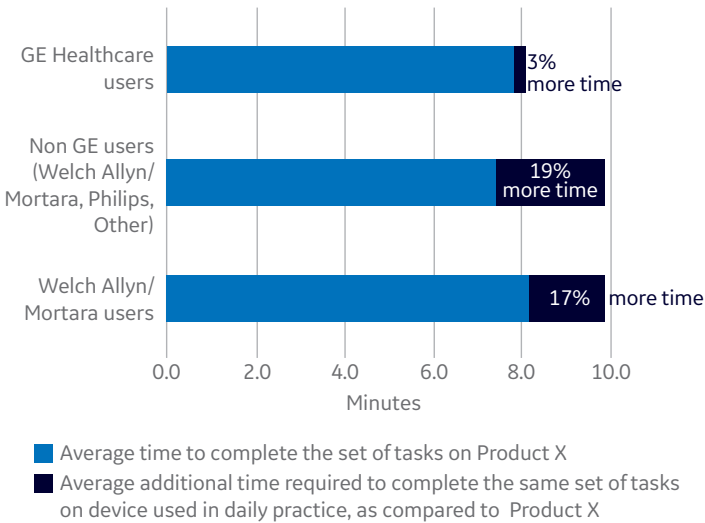
Figure 3
Average time to complete defined set of tasks (minutes)



■ Average additional time required to complete the same set of tasks, as compared to the Product X

Analyzing the results by user group, on average, **non-GE participants took 17 to 19 percent longer to complete the set of tasks on the device they used in daily practice than on the MAC VU360** (Figure 4).

Figure 4
Average time to complete defined set of tasks by user group (minutes)



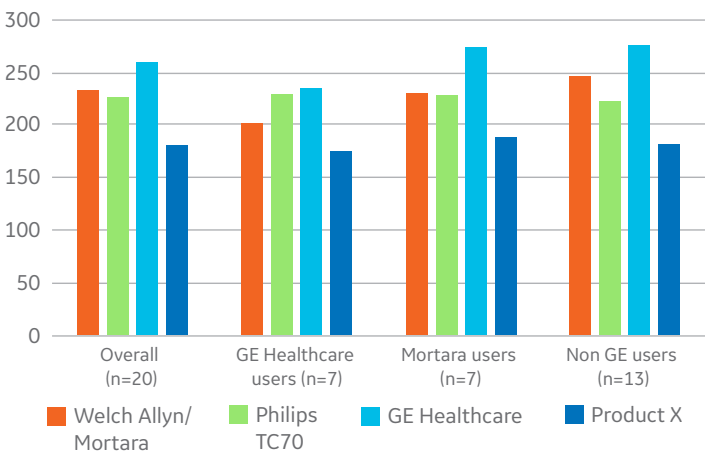
“Product X was very user friendly and fast. Best screen, most modern and up-to-date technology.”

ECG Technician, Philips user

Procedure steps

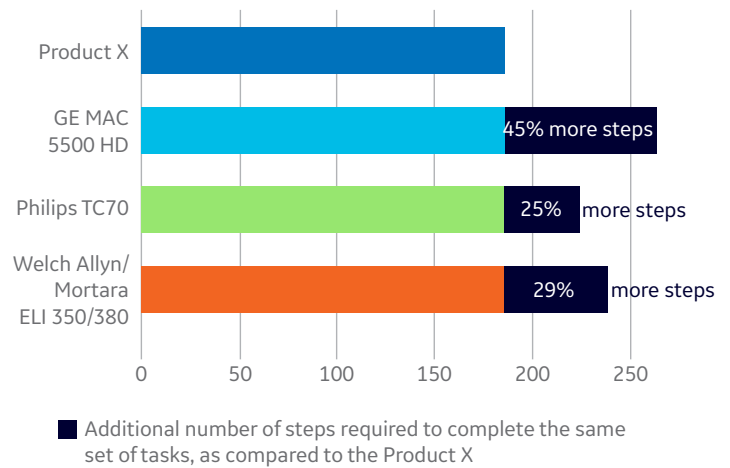
Another measure of workflow efficiency and ease of use is how few steps are required to complete procedures. The study moderator observed and recorded the number of button pushes and touchscreen taps each participant made in order to complete the set of ECG tasks on each of the four devices, and then summed the number by device. On average, respondents were able to perform the set of ECG tasks in fewer steps on the MAC VU360 than on any of the other devices, regardless of which device they typically used in day-to-day practice (Figure 5)

Figure 5
Total ECG task steps



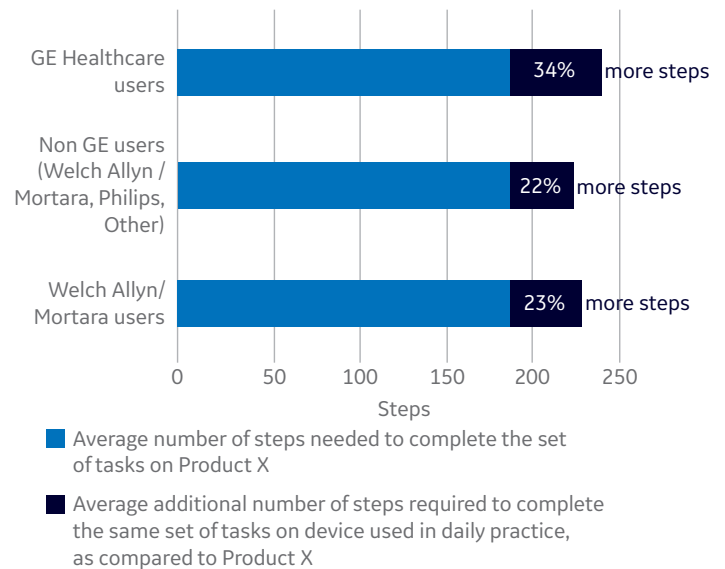
On average, participants required the fewest number of steps to complete the ECG tasks on MAC VU360, **requiring 25 to 45 percent more steps** on the other devices (Figure 6).

Figure 6
Steps required to complete the defined set of tasks



Analyzing the results by user group, on average, **participants required 22 to 34 percent more steps to complete the set of tasks on the device they used in daily practice than on the MAC VU360** (Figure 7).

Figure 7
Number of steps required to complete the defined set of tasks, by user group



“[On] Product X everything is in one place. It eliminates multiple steps for reprinting the ECG and deleting.”

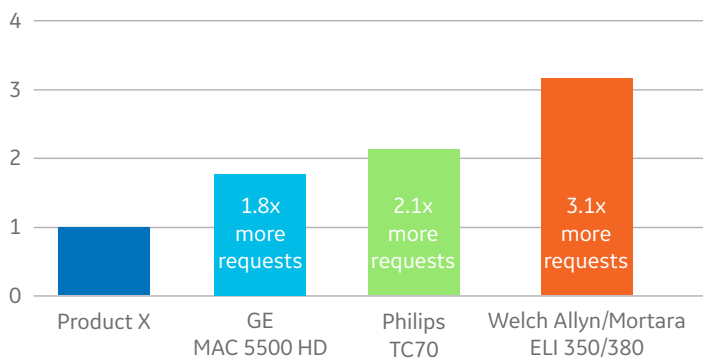
ECG Technician, GE Healthcare user

Need for assistance

The study was structured to determine to what extent each device's operations were intuitive, such that participants could perform the prescribed tasks without assistance. The moderator observed the participants at first and, if they struggled with a given task, allowed them to seek a resolution on their own. After one minute, the moderator would intervene. On average, **participants made significantly fewer requests for assistance to complete the set of ECG tasks when using the MAC VU360 as compared to the other products tested, which required approximately 2 to 3 times as many requests for assistance** (Figure 8).

Figure 8

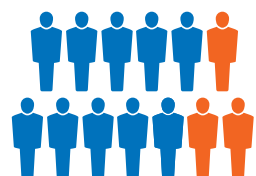
Average number of requests for assistance in completing the ECG tasks



SMART Auto ECG

Study participants were exposed to the alternative ECG acquisition modes on two of the devices. On the MAC VU360, the participants obtained two ECGs using SMART Auto ECG, an algorithm that immediately and automatically captures and displays the first clean, high-quality 10 seconds of ECG data. Similarly, on the Welch Allyn/Mortara devices, they obtained two ECGs using Best 10, an acquisition mode that selects the cleanest 10 seconds of the ECG data acquired.

Test participants responded favorably to the SMART Auto ECG acquisition mode on the MAC VU360 in comparison to the Best 10 acquisition mode on the Welch Allyn/Mortara devices.



Among the 13 respondents who expressed a preference between the Auto ECG and Best 10 acquisition modes, **77 percent preferred SMART Auto ECG.**

"I prefer [SMART] Auto ECG because the computer can get the best read the fastest for preview before printing. It gives me time, but also control"

Nurse, Welch Allyn/Mortara user

"I prefer [SMART] Auto ECG. It's computer driven, and there are a lot of non-ECG people using these machines. Best 10 takes an extra step to look and see if the best read is a good read."

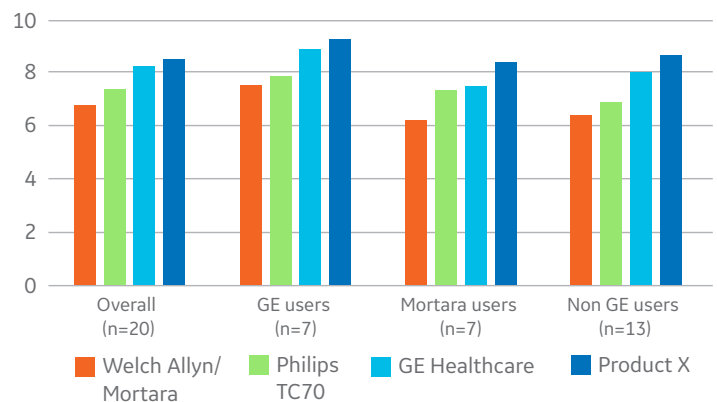
ECG Technician (and trainer for new ECG technicians),
Welch Allyn/Mortara user

Maneuverability

To test the ease of moving the devices from room to room, the participants were asked to maneuver each cart along a path that included turns, backing up, k-turn, turn from stop, and driving the cart with the non-dominant hand. They were then asked to rate the carts for maneuverability on a scale from 1 (lowest) to 10 (best). **The MAC VU360 achieved the highest average maneuverability rating of 8.4** (Figure 9).

Figure 9

Maneuverability ratings



"Product X was more modern, easy to move...lightweight and pushes well."

ECG Technician, Other device user

Comparative ratings

Participants rated the systems on an Agree/Disagree Likert scale on a series of statements related to quality, efficiency, and ease of use. **The MAC VU360 had the highest percentage of respondents strongly agreeing or agreeing with each statement - at least 85 percent across every statement** (Table 2).

Table 2

Survey results for each device, percentage of participants that strongly agreed or agreed with each statement

	Welch Allyn/ Mortara ELI 380	Welch Allyn/ Mortara ELI 350	Philips TC70	GE Healthcare MAC 5500 HD	MAC VU360 (Product X)
This system's design will help me optimize my workflow	57%	36%	45%	58%	85%
It is easy to quickly enter patient demographic information in this system	43%	55%	55%	45%	95%
This system's File Manager is easy to navigate	43%	18%	45%	37%	90%
This system's features would allow me to get a good quality ECG the first time, with infrequent need for retakes	71%	55%	65%	68%	90%
Most people familiar with operating ECG equipment would need minimal formal training to learn this system	43%	45%	65%	47%	85%
This system has a good ergonomic design	71%	27%	60%	47%	95%
All of the components of this system can be quickly and effectively cleaned	86%	64%	70%	89%	95%
This system's user interface is intuitive for a new/inexperienced user	43%	27%	55%	53%	85%

Quality and speed

- 90 percent of study participants Strongly Agreed or Agreed that MAC VU360's features would allow them to get a good quality ECG the first time with infrequent need for retakes, up to 35 percentage points higher than the other products tested.
- 85 percent Strongly Agreed or Agreed that the design of MAC VU360 would help them optimize their workflow, up to 49 percentage points higher than for the other devices.
- 90 percent Strongly Agreed or Agreed that the MAC VU360 File Manager was easy to navigate, more than twice the agreement than for the other devices.
- 95 percent Strongly Agreed or Agreed that on the MAC VU360 it is easy to quickly enter patient demographic information, approximately twice the agreement than for the other devices.

"Product X was better to use all around. Very easy to navigate between screens, like the menu of patients on the side."

Nurse, GE Healthcare User

Easy to learn

- 85 percent of participants Strongly Agreed or Agreed that most people familiar with operating ECG equipment would need minimal formal training to learn the MAC VU360. This was up to 42 percentage points higher than for other devices tested.
- 85 percent of participants Strongly Agreed or Agreed that the MAC VU360 user interface is intuitive for new or inexperienced users, more than 30 percentage points higher than for the other devices.

"Product X was self-explanatory, easy to use and you could find files easily especially in the fast-paced environment of an Emergency Department. The ECG prints out in bold text the name of the patient, which helps identify the patient clearly. I like the option of using the touch screen or the keypad interchangeably."

Nurse, GE Healthcare user

"Product X is the most intuitive. I like the touchscreen and the system is generally the most intuitive of the four machines."

ECG Technician, Welch Allyn/Mortara user

Easy to adjust

- 95 percent of participants Strongly Agreed or Agreed that MAC VU360 has a good ergonomic design, higher than for any other device tested.

“I like the ergonomics of the machine and the ability to adjust to user height.”

ECG Technician, GE Healthcare user

Easy to clean

- 95 percent of participants Strongly Agreed or Agreed that all components of MAC VU360 can be quickly and effectively cleaned, higher than for any other device tested.

“Product X is the best, easy to manipulate, figure out functions easily...cleaning was easy, not a lot of parts...”

ECG Technician, Welch Allyn/Mortara user

Measures of usability

Study participants rated all ECG systems tested employing three industry-standard measures of usability and customer preference.

User Experience Questionnaire (UEQ)

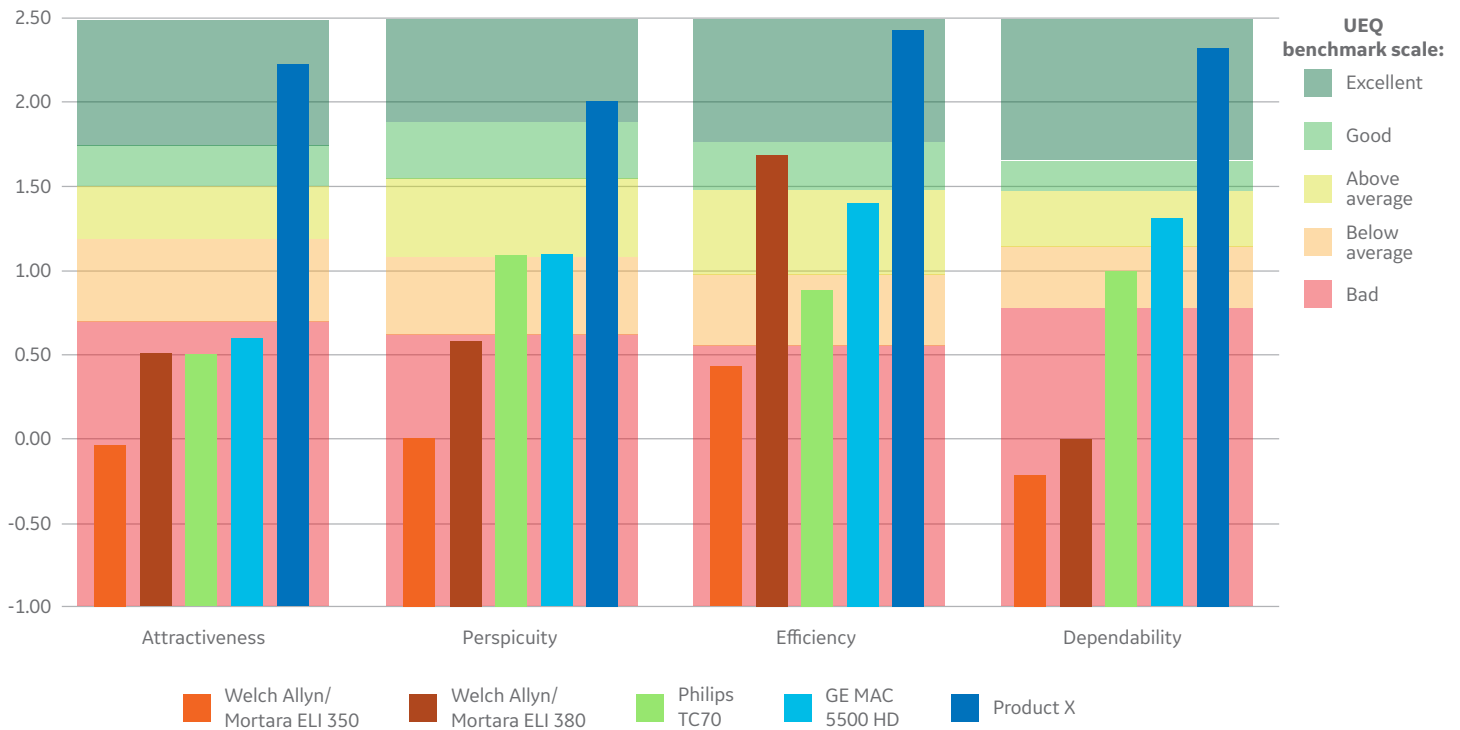
Each participant completed a User Experience Questionnaire evaluating the devices on four standard scales of usability. The UEQ was developed in 2005 and has been benchmarked through use in more than 240 studies with over 9900 participants. The questions are asked on a bipolar semantic scale; scoring is on a -3 (extremely bad) to +3 (extremely good) scale, although it is extremely difficult to obtain aggregate values above +2 or below -2.¹ The scores are combined to form composite scores pertaining to these attributes:

- Attractiveness:** Overall impression of the product; do users like or dislike it?
- Perspiciuity:** Is it easy to get familiar with and learn how to use the product?
- Efficiency:** Can users do their tasks without unnecessary effort? Does the product react fast?
- Dependability:** Do users feel in control of the interaction? Is it secure and predictable?

The **MAC VU360 received scores of 2 to 2.4, placing it in the Excellent range** on all four metrics of the UEQ. This represents the top decile, demonstrating higher perceived usability than over 90 percent of all benchmarked products, and significantly higher than the other ECG systems tested (Figure 10).

Figure 10

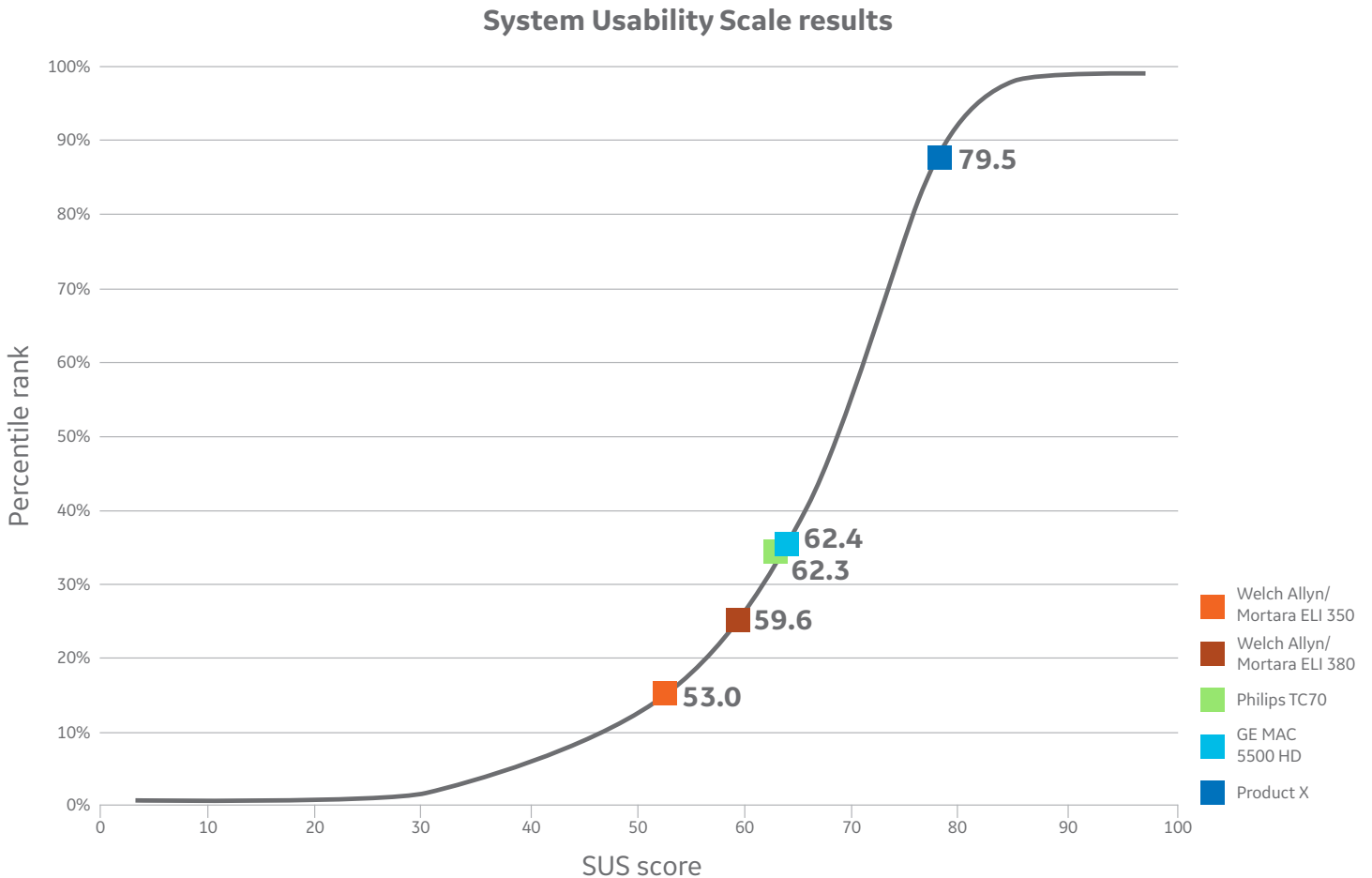
User Experience Questionnaire results



Systems Usability Scale (SUS)

Each participant completed the Systems Usability Scale questionnaire, an industry-standard assessment tool, created in 1986 and recommended by the U.S. Department of Health and Human Services as a reliable tool for measuring usability.² The ten-item Likert-Scale produces a score between 0 and 100. Based on the SUS database of 500 studies, a score above 68 is considered above average and anything below 68 is below average.³ **The MAC VU360, with a SUS score of 79.5, achieved a higher usability rating than approximately 90 percent of the products on which the scale is based.** The MAC VU360 also significantly outperformed the other ECG devices tested, which received SUS scores of 53 to 62.4, placing them in the below-average benchmarked range (Figure 11).

Figure 11

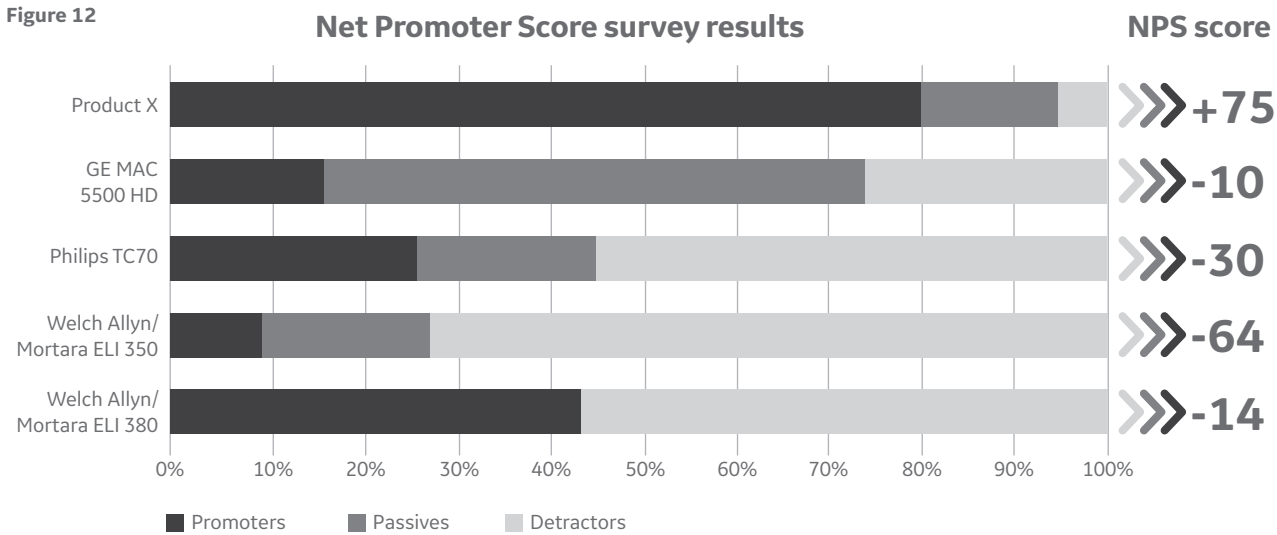


Net Promoter Score (NPS)

The Net Promoter Score, introduced in 2003,⁴ is used to gauge customer loyalty, or preference. Study participants were asked how likely they would be to recommend the system to their colleagues, on a scale of 0-10. Responses of 9-10 are promoters, 7-8 are passives, and 0-6 are detractors.

Any NPS score above zero is considered adequate, 50 or higher is excellent, and 70 or higher is world-class.⁵ **The MAC VU360 achieved an NPS of 75, which is in the world-class benchmark category.** The other products' overall NPS scores were all below zero (Figure 12).

$$\text{NPS} = \% \text{ Promoters (9-10)} - \% \text{ Detractors (0-6)}$$



When analyzed by user group, the NPS scores for MAC VU360 ranged from 43 to 86, which was higher than the score the user group gave to the product they used in daily practice (Table 3).

Table 3 **Net promoter score results, by user group**

User group	Devices			
	Welch Allyn/ Mortara ELI 350 and 380	Philips TC70	GE MAC 5500 HD	GE MAC VU360 (Product X)
GE Healthcare users	+20	-43	+43	+86
Welch Allyn/Mortara users	-42.9	0	-28.6	+43
Non-GE users	-69.2	0	-41.7	+69

Conclusions

The testing provides compelling evidence that the MAC VU360 ECG system has meaningful advantages in operational efficiency and usability over the other devices tested. In particular:

- MAC VU360 ranked best among devices tested for average time and number of steps to complete the assigned ECG tasks.
- MAC VU360 had a much higher percentage of respondents strongly agreeing or agreeing on a Likert scale on a series of efficiency and performance questions than the other tested products.
- MAC VU360 achieved high ratings for usability and customer preference against standard measures (UEQ, SUS and NPS) and exceeded the composite scores for every other machine tested.

- 75 percent of participants selected MAC VU360 as their most preferred product. Only 15% of study participants preferred the Philips Pagemwriter TC70, and only 6% of those who used the Welch Allyn/Mortara ELI 380 chose it as their most preferred product.[‡]

[‡]Among those that tested on ELI 380, 14% chose it as their top preference.

Appendix

Special instructions given to participants for each device tested

Welch Allyn/Mortara ELI 380 ERGO and ELI 350	Acquisition unit is wireless and needs to be powered on Two acquisition modes will be tested: <ul style="list-style-type: none">• Pre-acquisition/last 10 seconds: Uses the most recent 10 seconds of data on screen when you push the ECG button• Best 10 seconds: Uses the best 10 seconds of all the data collected in the last 5 minutes.
Philips Pagewriter TC70	Acquisition unit is wired and does not need to be powered on One acquisition mode will be tested: <ul style="list-style-type: none">• Pre-acquisition/last 10 seconds: Uses the most recent 10 seconds of data on screen when you push the ECG button
GE MAC 5500 HD	Acquisition unit is wired and does not need to be powered on One acquisition mode will be tested: <ul style="list-style-type: none">• Pre-acquisition/last 10 seconds: Uses the most recent 10 seconds of data on screen when you push the ECG button
Product X (GE MAC VU360)	Acquisition unit is wired and does not need to be powered on This device is height adjustable with a lever on the right side Two acquisition modes will be tested: <ul style="list-style-type: none">• Pre-acquisition/last 10 seconds: Uses the most recent 10 seconds of data on screen when you push the ECG button• Auto-ECG: System monitors ECG data quality and will automatically press the ECG button and provide a preview when it sees the first 10 seconds of good quality.

1. Shrepp, Martin. User Experience Questionnaire Handbook V3..2017. www.ueq-online.org
2. <https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html>
3. Sauro, Jeff.2011. Measuring Usability with the System Usability Scale. <https://measuringu.com/SUS>
4. Reichheld, Frederick F. "The One Number You Need to Grow". Harvard Business Review. December, 2003.
5. <https://www.promoter.io/blog/good-net-promoter-score/>

Imagination at work



©2018 General Electric Company.

General Electric Company reserves the right to make changes in specifications and features shown herein, or discontinue the product described at any time without notice or obligation. This does not constitute a representation or warranty or documentation regarding the product or service featured. The results expressed in this document may not be applicable to a particular site or installation and individual results may vary. This document and its contents are provided to you for informational purposes only and do not constitute a representation, warranty or performance guarantee from GE Healthcare.

GE, the GE Monogram, MAC, MAC UV360 and imagination at work are trademarks of General Electric Company.

GE Healthcare, a division of General Electric Company.

JB59982XX