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Ruggedized handheld device input effectiveness by generation: A time and error study

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ABSTRACT

The objective of this study is to determine whether ruggedized handheld scanning devices used for industrial purposes should contain one of the most prominent features provided on commercial smart devices: data entry via touchscreen as opposed to a physical keypad. Due to harsh environments, physical keys have been the preferred means of input for rugged handhelds. Advancement in touchscreen technology along with technology expectations brought about by the workforce demographic shift are influencing a notable shift to touch-only input for rugged equipment. Hypotheses expect there to be a difference in usability by worker generation and so 20 Gamers (Millennials) and 20 Baby Boomers performed manual data entry on ruggedized handhelds: one with physical keys and one touchscreen only. All participants took 19% less time on touchscreen than physical keys. Gamers were 31% faster than Boomers on physical keyed devices and 28% faster on touchscreen only. There was no significant difference in errors entered for either device by either age group; however, an 83% increase in permanent errors by Gamers on touchscreen was noted. Transitioning to a rugged device with touch-only input is recommended for industry as it could offer an increase in work productivity. This study presents timely insight into a new tool option for industrial workers.

Relevance to industry: This research describes the paradigm shift in the ruggedized handheld device market from physical keys to touchscreen only input and identifies real time productivity savings and error risks that can be expected by different generations of workers in the industrial workforce.

1. Introduction

Ruggedized handheld device solutions are used today by industrial, retail, and service-based organizations. Rugged devices are mobile computers that scan and perform data entry within locations that have environmental requirements or restrictions. Ruggedized computer devices are designed to operate properly in damaging, punishing environments and in extreme temperatures (between −20 °F and 140 °F). They have ingress protection against dirty environments and wet conditions ranging from bad weather events to complete submersion under water (IEC 60529, 2013). Also included in ruggedized device requirements is the ability to withstand a series of shocks and drops (four to ten feet in height) as defined by the military testing standard, MIL-STD-810G (US DoD, 2008).

Not only must ruggedized handhelds withstand extreme environments, they must also be usable by a diverse workforce that includes employees from differing generations. Baby Boomers, or Boomers, will continue exiting the workplace at a rate of 10,000 per day for the next 20 years (DePass, 2012). These retirees are being replaced by members of the Gamer Generation (or Millennials), someone 35 years of age or younger (Carstens and Beck, 2005) born between 1979 and 2000 (Burch and Strawderman, 2014). The two largest issues created by this demographic shift are employee retention (Sujansky, 2009) and knowledge transfer (Kapp, 2007).

Research has shown that employees in the Boomer and Gamer generations work differently. Modern technology adoption increases morale for Gamers and lessens their turnover (Cairncross and Buultjens, 2007). They learn best via their consumer technology (Kapp, 2007) and often bring their own solutions into the workplace (Blackburn, 2011) which should be encouraged (Tulgan, 2009). Bringing unfamiliar solutions into a mature work culture can be difficult and create time consuming issues (Schein, 1999) due to

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Boomers' lower desire to learn new technologies (Rogers, 2003) as well as their slower adoption rate of mobile technologies (Kurniawan et al., 2006). However, organizations can ill afford not to learn and adopt new technology in order to survive given how the external environment is changing ever more swiftly (Shih and Allen, 2007); therefore, a device must be usable by members of both generations. The intent of this study is to understand how changing a key component, the input method, of ruggedized handheld devices and mobile terminals affects usage between these two generations that bookend most workforce populations.

1.1. Data entry and physical keypads

Large organizations that purchase substantial quantities of ruggedized devices typically follow a five- to seven-year life cycle plan. The applications that run on these devices aiding worker job functions are generally developed in-house. No matter how anticipatory the applications become, manual data entry is always required and is used by field workers during their shift. Manual data entry may be regarded as one of the more time intensive interactions with the ruggedized device and, in logistical environments where every second counts, multiple manual entries could make the difference in on-time delivery.

To date, most manual input into rugged handheld devices is performed through a physical keypad. Keyed rugged devices generally support touchscreen input but the screen display size ranges between 3.0 and 4.0 inches diagonal and isn't conducive to prolonged manual entry on a virtual keyboard given the small surface area of the keys. The physical keypads on these devices range in size and configuration. Keypads with larger keys are in alphabetical order and utilize a shift function to enter numbers. Physical keyboards with QWERTY configurations have smaller keys in order to achieve the same layout as a keyboard. The alphabetical keys in a QWERTY configuration are approximately half the surface area of the keys in alphabetical configurations. The numeric keys either are separate from the others and larger or a shift function is required. Alphabetically ordered keys cause a learning curve for new users and the QWERTY configuration is often too small for workers with large sized hands.

Physical keys on ruggedized handhelds have their disadvantages, such as becoming points of failure for extended use and they lack the flexibility of virtual keypads that can be designed to meet any button configuration. But physical keys have also been found to be a necessity when job tasks must be performed in cold weather while wearing gloves. Using a touchscreen with capacitive interaction has been found to be problematic in rain and snow or while wet.

1.2. Technology shift to touchscreens

In 2014, vendors began offering ruggedized handheld solutions that have touch-only input. Smartphone-like solutions will look to take market share by appealing to consumer-based expectations of the end users. These solutions will utilize stronger glass so that the display size can support an inch to two-inch increase in diameter without weakening the overall integrity of the device. New hardware and software capabilities within these touchscreen-only devices will create the sensation of key pushes, allow accurate key presses while wearing any pair of thick gloves, and will be usable with water on the screen. Industrial capability can now meet consumer expectations. In an ideal situation, software for the future devices will be written in such a way that minimal to no manual data entry will be required on the part of the end user as manual text entry decreases the competitive advantage of a full touchscreen interface (Kwon et al., 2009). Unfortunately, exceptions will always be required and in ever evolving work environments, the need to manually enter information must exist to some degree.

1.3. Touchscreen usability considerations

How users will hold and interact with a rugged device that has touchscreen-only input must be taken into consideration. As these touch-only rugged devices have a minimal presence in industrial environments at the time of this article's preparation, key insights can be drawn from their consumer counterparts. Studies performed on users of touch-only smartphones by Hoober (2013) have found that individuals prefer to hold their devices one-handed and with their right hand being the primary hand two-thirds of the time. When users cradle the device with one hand while performing data entry with the other, they perform data entry with their right thumb and hold the device in their left hand the majority of the time (Hoober, 2013). Holding the device vertically in portrait mode was shown to be most common where turning the phone horizontally for data entry only occurred about 10% of the time (Hoober, 2013). Studies also found that younger adults are better with multiple types of input including touch (McLaughlin et al., 2009). However, all participants are generally slower on smaller buttons (smaller buttons were more detrimental to older adults). Contrary to Fitt's Law, all participants were faster on buttons in the center as opposed to buttons of the left and rights sides of the touchscreen (Rogers et al., 2005).

Additional insights can be found in studies that simply evaluate physical keys versus touchscreen on other devices such as kiosks. Chung et al. (2010) found that numeric data entry via touchscreen was preferred over physical keys by both younger and older adults on devices typically used as automated teller machines (ATMs). While the mean entry time of the younger users was found to be faster than the older users, the older adults still operated more quickly on touch than on the physical numeric keypad (Chung et al., 2010).

1.4. Input preference versus reality

Is a shift from physical keys to touchscreens a productive one? Considering the generational component, members of the Gamer Generation are most engaged in learning complex skills and job functions when it's done via modern technology (Main and O'Rourke, 2011). But just because a worker desires a newer device form factor and may even be inclined to learn job processes more quickly while using it, there is no guarantee that there will be an actual increase in work productivity (Sonderegger and Sauer, 2010). Nor is there any concrete evidence to indicate that Baby Boomers, or Boomers, a cohort known to not be nearly as quick at adaption of new technology (Rogers, 2003), will lose productivity on technology that moves away from more traditional and familiar characteristics like physical key pads.

Putting preference aside, the goal of this study is to determine which input type, keypad or touchscreen, on ruggedized handheld devices is best for the generations leaving and entering the workforce, the Boomers and the Gamers. A future device must be accepted and useable by employees on both ends of the workforce spectrum in order for an industrial organization to receive the full benefit of a paradigm shift in mobile computing technology in a rugged environment. So while Boomers are leaving the workforce, a new device in the field must provide immediate benefit in order to cost justify making a change of this kind. Organizations can ill afford to wait until all Boomers have transitioned out of the work environment to evaluate new technology trends. Likewise, these companies also can't afford to keep devices used today in service for the next decade. Technology moves too quickly and devices used in harsh environment won't last long enough to not consider a possible competitive shift. This reasoning drove the decision to specifically include the dichotomy of Gamer versus Boomer productivity within this study.

2. Expected results

2.1. Time

Users experienced with touchscreen-only input are becoming more common in the consumer market so it can be inferred that more members of the present day workforce (or more certainly, members of the future workforce) are experienced with inputting information without the use of physical keys. Regarding a generational effect, gamers are more accustomed to entering information onto technical devices and have a higher likelihood to accept and adopt change in their work tools without having the burden of comparing present day tools to those used in the past. As such, this study expected members of the Gamer generation to take less time to enter data into a ruggedized device regardless of input type. Additionally, because of their average age and the quick progression of technology over the past decade, Gamers have more experience with or, at the very least, exposure to devices with touchscreen-only input. Based on this, the following hypotheses regarding time were tested:

- Hypothesis 1.a: Users will have a lower overall unit task time with a touchscreen than with a keypad.
- Hypothesis 1.b: Users from the Gamer generation will have a lower completion time for all input types (physical keypad and touch-only) than members of the Baby Boomer generation.

2.2. Errors

Where the first hypothesis set focuses on the differences in completion time, the second set of hypotheses focuses on error count during data entry. Gamers are likely to be more experienced with a touchscreen than they are with a physical keypad on handheld devices. Since the inception of most ruggedized handheld devices, the main input mechanism has been a physical keypad. In a work environment, Boomers' experience with a physical keypad is likely more significant than their experience with a touchscreen. This study expects error count when using a ruggedized device with a keypad to be comparable for both the Gamer and Boomer generations given Gamers' quick adaption of new technology (Rogers, 2003) and Boomers' longer experience with physical keypads. Therefore, the following hypotheses regarding errors were tested:

- Hypothesis 2: Users from the Gamer generation will make fewer errors with a touchscreen and users from the Baby Boomer generation will make fewer errors with a keypad.

3. Material and methods

3.1. Participants

Members of an industrial workforce were used in this study in order to increase external validity by using the target population. Results from real, experienced users will be more likely to identify true differences than if non-industrial workers or students participated. Based on recommendations from Lottridge et al. (2011), at least 10 participants per hypothesized subgroup are needed to detect significant differences between groups. Large samples between 20 and 50 participants should provide statistical power to test and identify new groupings. Given these guidelines, 40 participants from eleven unique locations around the continental United States were tested. This sample included 20 Gamers and 20 Boomers. In order to qualify, each participant had to have at least one year of ruggedized device usage experience including experience with the MC9500 handheld (Cannon et al., 2015). Rugged experienced was determined through participant self-reporting. Participants were representative of a workforce that performs daily industrial and logistical job functions. The average respondent age for Gamers was 28.1 years ($SD = 3.19$) and 53.2 years ($SD = 3.27$) for Boomers. Men represented 85% of the participants. This male to female ratio is somewhat representative of the gender breakdown for the company that provided study participants. Women represent a smaller portion of the field workforce (26%) with men making up a large majority (74%) for this company. Of the Gamer participants, all of them (100%) owned cell or smart phones. Most of the Boomers (85%) owned cell or smart phones as well.

3.2. Tools

There were three goals in the device selection process. First, the devices were to have similar characteristics (i.e. key surface area, height, and weight) to encourage participants to hold the two devices in a comparable way while inputting data. The second goal was to ensure that as few new variables were introduced into the study as realistically possible. The final goal was to use a keyed, rugged device with which participants were already experienced. With those goals in mind, the Motorola MC9500 (key) and the Motorola ET1 (touchscreen) were selected (Fig. 1). Because the participants in this study did not have any autocorrect features enabled on the rugged devices used in their day-to-day tasks, the auto-corrective features of these two devices were disabled during the study. Haptic feedback was turned on for the ET1 device based on results found by Chung et al. (2010) where tactile feedback is needed to increase accuracy. The Motorola MC9500 device was selected because all of the participants in this study used this exact device in their daily job functions. Also, the ET1 was the only rugged, all-touch device available at the time of this study with comparable key surface area matching preferred virtual key surface width between 0.7 cm and 1.0 cm (Park and Han, 2010). More recent studies show that 1.6 cm may be the ideal touch key size for achieving the desired 90%–99% touch hit rate (Jung and Im, 2015) but this simply wasn't achievable with a QWERTY key layout given the device's seven inch screen size. Even though the physical key layout on the MC9500 was alphabetically ordered—making it different from the QWERTY order of the virtual keys on the ET1—all participants in the study were familiar with this layout as the MC9500 is the device they use in order to perform their job tasks.

The participants were instructed to hold the devices in the same manner that they would while performing their job functions. The starting device used for each participant was alternated for counter-balancing purposes.

Additional tools were required to capture the responses from the participants as data was entered into the ruggedized handhelds (Fig. 2). A mobile usability testing tool, Mr. Tappy filming kit, was attached to the back of the handheld with an arm extending up and over the front of the device. A camera was fixed to the end of the arm. The camera, a Swann DIY Security Camera (color), faced the screen to record all data entered. Attaching the filming kit and camera to the devices allowed natural movement by the user. Fixing the device to an immobile surface would have skewed the results of the test by forcing participants into an unnatural typing position.

An A/V to USB converter was used to send video from the DIY Security Cameras into the laptop computer. PowerDirector movie

Fig. 1. The Motorola MC9500 [left] and Motorola ET1 [right] (Cannon et al., 2015).

Fig. 2. The complete tool setup for the study.

capture software recorded video for later analysis. Lastly, MiniTab v16 was used for statistical analysis of all data captured.

3.3. Procedure

The experimental procedure had three components: 1) a demographic and device preference questionnaire, 2) recorded data entry on the first device, and 3) recorded data entry on the second device (Cannon et al., 2015).

At the beginning of the procedure, prior to any data entry, each participant was asked a brief series of questions. The first question established which generation the participant was a member of: Gamer generation (born between 1979 and 2000) or Baby Boomer generation (born between 1946 and 1964). Gender was captured as well as their work function. Participants asked about cell or smartphone ownership and their experience level with consumer grade keypad and touchscreen devices. Participants then confirmed their years of ruggedized device experience.

Each participant was asked to manually enter the contents of a task list into a word processor application housed on the ruggedized device. The task list was provided on a sheet of paper and contained randomized container names and comments (Cannon et al., 2015) such as:

1. ake53190fx unload bulk to storage

The participant was then asked to enter each data entry task line onto the device in the follow manner:

ake53190fx

unload bulk to storage

Part of the job function performed by these participants is to observe text and copy it into the appropriate fields on their handheld device. Reformatting the text provided simulated part of the participant's work process while forcing a minimal level of concentration. This separated the participants who would normally concentrate from those who would not. One carriage return was required after each line. Two carriage returns were required between each entry set of container and comment. Notes were provided on the task worksheet reminding the participant of the carriage return rules. Each container name was comprised of three alphabetical characters, five numeric, and two alphabetic for a total of 10 characters to ensure both letters, numbers, and the shift key were utilized. Each comment was between 19 and 24 characters which is the average length of a comment generated for a barcode label. The sheet of paper with the 30 tasks was placed in front of the tester who could then move the list around as needed in order to read it and perform data entry onto the device. The lighting for all participants was equal consisting of general fluorescent lighting; no task lighting was used. Each participant was told to enter the data as quickly as possible while trying to be as accurate as possible. Fixing mistakes was encouraged. Each participant completed 30 tasks on each device. The middle 20 tasks were used for data analysis to account for warm up and device acclimation at the beginning of the test as well as fatigue at the end of the test.

4. Results

T-tests were used to analyze differences within a single population and ANOVA was used to analyze differences across populations. Cohen's d was used to suggest a moderate effect size for results that don't quite reach significance but should not be dismissed from an industry expert perspective.

4.1. Completion time

The authors expected that all participants, regardless of generation, would take less time with touch input than with a physical keypad. Most participants (78%) took less time with touch input (M = 670.63 s; SD = 150.82 s) than with physical keys (M = 828.40 s; SD = 271.33 s). A paired t-test of the time results (see Table 2) supports the hypothesis that significantly less time was needed to complete the input tasks with touch input for all users, $t(39) = 4.77$, $p < 0.001$.

As expected, Gamer participants took less time with both input types (touch: M = 559.80 s; SD = 75.78 s, physical key: M = 678.65 s; SD = 178.78 s) than Boomer participants (touch: M = 781.45; SD = 122.97, physical key: M = 978.15 s; SD = 269.54 s). The ANOVA shows that Gamers take significantly less time than Boomers on both touchscreens, $F(1, 38) = 47.16$, $p < 0.001$, and keypads, $F(1, 38) = 17.27$, $p < 0.001$.

While all users collectively took significantly less time on touch input than with keypad input, further analysis indicates that each individual generational cohort takes significantly less time between devices. Gamers took significantly less time completing their input tasks on a touchscreen than on a physical keypad, $t(19) = 3.25$, $p = 0.004$. Likewise, Boomers took significantly less time completing their tasks on touchscreen than on a keypad, $t(19) = 3.60$, $p = 0.002$. In addition to finding that both generations were faster on touchscreen, an F-test for equality of variances showed that the variance in time to complete the task was significantly lower for the touchscreen (SD = 150.82) compared to keys (SD = 271.33) across the sample, $F(19,19) = 3.24$, $p < 0.05$. This suggests that the touchscreen was not only faster but also generally easier to use.

Table 2
Mean and standard deviation for all times for all participants (in seconds).

	Key input (s)				Touch input (s)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
All	828.40	271.33	437	1227	670.63	150.82	431	1072
Gamers	678.65	176.78	437	1491	559.80	75.58	431	728
Boomers	978.15	269.54	580	1491	781.45	122.97	579	1072

4.2. Number of errors

Table 3 provides mean and standard deviation calculations of the totaled error data by generation and for all generations. Overall, there was not a significant difference in the total errors for touch input (M = 34.68; SD = 22.06) compared to physical key input (M = 30.65; SD = 30.37).

The authors expected that Gamers would make fewer errors with touchscreen input than with a physical keypad. However, Gamers actually made a larger number of errors on touch input (M = 40.65; SD = 22.59) compared to physical keypads (M = 29.15; SD = 19.2). While this difference was not statistically significant, $t(19) = -1.65$, $p = 0.116$, $d = 0.54$, indicates that further research should investigate factors affecting errors across device types. Expectations were that Boomers would make fewer errors with a keypad than with a touchscreen. However, the analysis did not provide evidence of a significant difference between input types, $t(19) = 0.50$, $p = 0.623$.

Additional analysis revealed no evidence for a significant difference between generations for total errors on the keypad, $F(1, 38) = 0.10$, $p = 0.759$. However, additional research with a larger sample size should be pursued to further investigate total errors on the touchscreen as Gamer participants had a higher average number of errors than Boomer participants $F(1, 38) = 3.09$, $p = 0.087$, $d = 0.57$.

Table 3
Mean and standard deviation for total errors for all participants.

	Key input (errors)				Touch input (errors)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
All	30.65	30.37	3	165	34.68	22.06	5	98
Gamers	29.15	19.20	5	66	40.65	22.59	11	87
Boomers	32.15	38.99	3	165	28.75	20.34	5	98

Table 1
Experience with devices by generation (cell values = number of participants).

Gamers					Boomers			
Experience with:	<2 years	2–5 years	5–10 years	>10 years	<2 years	2–5 years	5–10 years	>10 years
Devices with touch input only	4	7	9	0	9	9	2	0
Devices with physical keys	0	5	9	6	1	6	3	10
Ruggedized handheld devices	2	10	7	1	1	2	1	16

4.3. Error type

The observed error types included the standard categories of insertion, omissions, and substitution (Kano and Read, 2009) and were identified at an individual character level. Errors were categorized as resolved errors and permanent errors. Resolved errors were errors initially made by the participants but eventually corrected. Permanent errors were errors made by the participant and never corrected. While no error is ideal, resolved errors ultimately result in a time or productivity penalty but final process outcomes are correct. Permanent errors, however, are a big concern from a business perspective as they result in lost or incorrect inventory and parcels.

Per the results shown in Tables 4 and 5, Gamers saw an increase in average number of permanent errors from the physical keys ($M = 9.90$; $SD = 14.05$) to the touchscreen ($M = 18.15$; $SD = 15.89$). While this difference in permanent errors for Gamers was not statistically significant, $t(19) = -1.93$, $p = 0.069$, $d = 0.55$, an 83% increase in permanent errors from physical key input to touchscreen input for a relatively small sample of Gamers warrants further investigation given the impact of permanent errors.

Permanent errors for the Boomer participants were not significantly different, $t(19) = -0.81$, $p = 0.425$, from the keypad ($M = 19.20$; $SD = 29.63$) to the touchscreen ($M = 14.80$; $SD = 15.01$).

4.4. Survey

Results from the participant survey revealed that the majority of participants (83%) preferred touch input. Gamers preferred touch input over input with physical keys (85%) as did Boomers (80%).

5. Discussion

5.1. Time analysis

The first goal of the time component of this study was to explore that, on average, members of the workforce would take less time to complete input tasks on a ruggedized handheld device with a touchscreen versus a rugged device with a physical keypad. While this study correctly anticipated that ruggedized handheld users who are Gamers would prefer and be better at touch input than physical keypad input, the Boomer users' preference for and skill with touchscreen input was sorely underestimated. Not only did both generations of ruggedized handheld users take significantly less time performing their input tasks on a touch screen than on a keypad, both generations strongly preferred touch over keys. Separately, each generation took significantly less time with touch input than with the keypad.

The second goal was to test the assertion that the youngest members of the workforce who had grown up immersed in technology as digital natives (Prensky, 2006) would in fact be more acclimated to all devices regardless of input type. Analyses revealed that Gamers took significantly less time with their input tasks on both devices, physical keys and touchscreen, than their Boomer colleagues who have more ruggedized handheld experience. This appears to support the theory that Gamers are already adept at using modern technology from their personal lives in the workplace (Tulgan, 2009). Also, the age of the Baby Boomers and the potential of being less dexterous due to age could also be a factor in why Gamers had faster data entry times.

Table 4
Mean and standard deviation for resolved errors for tasks 6 to 25.

	Key input (errors)				Touch input (errors)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
All	16.10	12.43	2	58	18.20	11.85	2	39
Gamers	19.25	12.03	5	51	22.50	12.66	8	57
Boomers	12.95	12.32	2	58	13.90	9.44	2	39

Table 5
Mean and standard deviation for permanent errors for tasks 6 to 25.

	Key input (errors)				Touch input (errors)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
All	14.55	23.37	0	107	16.48	15.35	1	68
Gamers	9.90	14.05	0	46	18.15	15.89	2	54
Boomers	19.20	29.63	0	107	14.80	15.01	1	68

5.2. Error analysis

The first goal of the error analysis portion of this study was to help identify whether Gamers would make fewer errors with an input type they were more familiar and comfortable with. However, there was not a statistically significant difference between error rates on the two devices. While there wasn't a significant difference, further analysis showed that much of the error count increase was due to permanent errors. Permanent errors have a greater negative impact on performance and warrant further consideration. There remains the possibility of higher error rates on touch that demand further research with a larger sample size to further explore the relationship between Gamers and data input on touchscreens. Should a negative relationship be found in Gamer error rates on touch, this could pose a business problem for industrial organizations looking to move to touchscreen-only ruggedized devices. One possibility for an increase in permanent errors is that, just as Gamers have grown up never knowing a time when there wasn't technology (Kapp, 2007), so too have they not known a time when there wasn't corrective logic in word processing applications. A Gamer has gone their entire adult life using auto-correct, auto-complete, spell check, and other anticipatory communication logic. Auto-correct and auto-complete on smartphones have become more accurate at predicting what the user is attempting to type that a Gamer may actually expect the device to detect and correct the most important errors which obviously did not occur for this test as corrective logic was turned off.

The second goal for error analysis was to determine if Boomers would make fewer errors with the keypad as they would, in theory, be more familiar with the ruggedized device with physical keys than with a touchscreen. However, Boomers had no difference between input types. Boomers are likely to be longer-term employees and may be more cognizant of the true productivity loss to their job function and overall cost to the company when errors are made. Also, it is possible that auto-correct and auto-complete software has not had the same level of influence on the Boomers that it has had on the Gamers.

Further analysis confirms that both Gamers and Boomers have comparable error rates on the device with the physical keys. Both generations of testers use the Motorola MC9500 on a daily basis and so their experience level, while not equal given the extra work experience of the Boomers, appears to have created similar device usage abilities. Likewise, results show that there was no significant difference in error rates between workforce generations; however, the Gamer error rate on the touchscreen appeared higher than the Boomer's rate and warrants further investigation. From an industrial expert perspective, the error results alone could indicate that making a change from physical keys to a touchscreen input leads to a productivity increase for the older generation but not for the youngest generation in the workforce as one might have originally expected.

6. Conclusions

There appears to be a time advantage for using ruggedized handheld devices with touch input over devices with physical keys. While this is of little surprise for Gamers, performance by the Boomers with touchscreen was better than expected. Also unexpected was the possible increase in total and permanent errors made by the Gamers via touch. Mitigating higher Gamer error rates via software aid will need to be considered by designers. This study recommends a move to touchscreen-only ruggedized handheld devices in the industrial space with caution that careful incorporation of spell check, auto-correct, and auto-complete be placed into software applications running on the device. Training on the use of the device is always an option as is continued removal of manual input requirements. A mean increase in 9.90 permanent errors by the Gamers on physical keys to 18.15 permanent on touch is a concern for industry but it's also correctable if organizations are aware and plan for problem mitigation.

Field worker device preference and the most time-productive device appear to be the same for both generations. Regarding errors, Boomers appear to benefit immediately with no notable drawbacks. Therefore, touchscreen input is recommended for the future design of ruggedized handheld devices.

Limitations for this study include diversity of the participants. Six women out of 40 participants isn't enough to determine gender-based differences. Also, the mean age for Boomers was low considering that the Boomer age range currently spans between 50 and 68 years of age and the majority of field workers employed by the participating organization are Boomer-aged (43%). Gamers are the second highest generational cohort of field workers (29%) employed by the participating company. Future studies used to determine which industrial technology should be deployed to a population of workers could include Generation X cohort members; people born between 1965 and 1978. The researchers in this study made the assumption that, based on technology experience and capability, Generation X results of time and error would fall somewhere between the results of the Boomers and the Gamers. However, because this wasn't tested, including Generation X could be helpful when evaluating the productivity of a subset of people that represent the entire workforce.

Another limitation of this test was that there wasn't a good way to evaluate the finger dexterity of the participants in order to baseline text entry skill and capability. This is important when analyzing the differences in usability between people of vastly different ages. Because there was a significant difference between the time it took each generation to perform data entry, it's possible that older participants were less dexterous than the younger participants therefore influencing the results of the timed portion of the test. Future studies should look to find way to baseline usability in order to determine how much age factors into data entry.

The total number of participants ($n = 40$) was sufficient enough for most variables but the borderline results with error rates suggest further investigation should be performed with a larger population sample to determine if there is a generational or device-driven difference. Also, there weren't enough participants in the study that represent the bottom tier of workplace performance. Field testers were sometimes identified as potential participants by their management largely as a reward for good performance. High performers aren't likely to represent the lower tier in work performance. Different tiers of quality output in the workforce are believed to be part of the reason behind such high variability in errors for each generational group and should be investigated further as well.

Next steps for this study include understanding the role screen size has in input time and error rate. Future ruggedized handhelds won't have a screen matching the size of the ET1. Instead the screen will be smaller (between 4.7 and 5.5 inches). Also, another study will need to evaluate how effectively users can input information on future handheld touchscreens while wearing gloves with varying degrees of thickness. Furthermore, as industrial tools continue to merge with consumer products and expectations, User Experience (or UX) design considerations will be for more critical for software. Past studies have identified the need for UX quantification but only focused on consumer-grade tablet devices (Park et al., 2013). UX quantification for the industrial workforce on rugged mobile devices is important for the future prediction of productivity over a large scale enterprise. Lastly, further analysis of the types of errors that occur on a touchscreen and why they occur warrants investigating. Likewise, analyzing errors based on content type (letter and numbers combinations versus basic words and phrases) is valuable in understanding what errors are most likely to occur. This additional research will allow application developers to mitigate touch-based risks.

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