Global differences in industrial handheld device preference

Manuscript for submission to

Journal of Design Research

Reuben Burch, Shuchsnigdha Deb, Lesley Strawderman, & Katherine King

Department of Industrial & Systems Engineering

Mississippi State University

Abstract

One of the major concerns in managing a global organization is the potential difficulty that could arise due to different cultural preferences for technologies. This study provides evidence that cultural difference can influence ruggedized handheld device design preference. Field workers from different world regions of a worldwide service company responded to a survey expressing their choices on four potential handheld devices, five available features, and on the most influencing feature. The region of the world from which the workers were domiciled was impactful and showed significant influence on device selection as well as on all of the feature preferences.

Keywords: Handheld device, global organization, cultural difference

1. Introduction

The study of the design of creating tools for workers in an industrial environment that allows them to perform their job functions more efficiently and effectively has been around for some time in the form of a science called human factors. Since the beginning of man when implements were created for the first time, tools have evolved to better integrate with the needs of the user. Starting in the 1930's with the advent of computing technology, the tool design evolution for the common worker has increased at a rate that sees significant changes at a more frequent pace. This shifting landscape has led to the identification of the different generations of human factors as they pertain to the workforce and their tools. For example, industrial tools of today are currently in a cognitive fit state meaning that they: "harmoniously integrate humans, technology, and work to enable more effective systems" (Boff, 2006). In fact, Boff (2006) defined four generations of human factor guidelines specifically pertaining to tools aiding in humans' ability to perform work (Table 1).

Table 1: Four generations of human factors and ergonomics (Boff, 2006)

	Equipment Adaptation	**Description**	**Generational Current State**	**R&D Type as per Roussel *et al* (1991)**
Generation 1	Physical fit	Adapt equipment, workplace, and tasks to human capabilities and limits	Mature	N/A
Generation 2	Cognitive fit	Harmoniously integrate humans, technology, and work to enable effective systems	Growth	Incremental R&D
Generation 3	Neural fit	Amplify human physical and cognitive capabilities to perform work through symbiotic coupling with technology	Emerging	Radical R&D
Generation 4	Biological fit	Biologically modify physical and/or cognitive capabilities to maximize human effectiveness	Embryonic	Fundamental R&D

Regarding today's tools in the workforce, ruggedized handheld scanning solutions are a significant tool for industry that, until recently, have seen minimal innovations over the past decade. While the incremental changes that occur in each generation of ruggedized handheld devices are important and provide value, they have done little in past to bridge the gap between the current generation of tools and the next predicted step in the way humans and machines interact with each other to perform work. There should be a midpoint between today's ruggedized handheld computers (Generation 2) and the radical, emerging technology (Generation 3) envisioned by human factor future-state expectations.

The purpose of this study will be to use extensive field experience as well as expected advancement of human factors as defined by literature to predict and define requirements of this technological midpoint specifically for ruggedized handheld devices. This study will contribute to redefining state of art by surveying the broad multi-cultural scope of a global Fortune 100 company that is located in 220 countries and regularly replenishes hundreds of thousands of rugged devices on a reoccurring five- to seven-year equipment lifecycle. Another focus of this study is to assess a significant handheld design change: moving away from physical keys and using a touch-only interface. At the time of this study, there were no all-touch solutions with a MILSPEC 810G and IP (Ingress Protection) rating high enough to support extreme industrial use. Asking the participants to consider moving away from physical keys and a much heavier device was in anticipation of a new trend, one in which industry has slowly started moving toward. Therefor more than existing products were assessed in this study and future trends were part of the basis for this work.

1.1 Emerging Device Designs

Ruggedized computer devices are specifically designed to operate properly in damaging, punishing environments such as extreme temperatures (typically between -20°F and 140°F), dusty and dirty surroundings, and wet conditions that can range from moisture and humidity to bad weather events to complete submersion under water. Also, included in the requirements of a ruggedized device is the ability to withstand a series of shocks and drops (typically of four to eight feet in height). Five components of a handheld determine whether or not it qualifies as a ruggedized device: 1) the outer shell (casing), 2) the keypad, 3) the display, 4) the internal components (onboard computer), and 5) the accessories (Gooley, 2012). All five of these components will be discussed but the ones most important to this study are the outer shell (or form factor), the keypad (or touchscreen), and the display.

Ruggedized handheld scanning devices available in the market today meet the definition of Generation 2, or cognitive fit, based on Boff's (2006) human factors generational concepts as the humans and technology are integrated into effective systems. New device design iterations contain minor improvements to each of the five components from the previous ruggedized handheld but true innovation towards Generation 3—or neural fit between technology and the worker—of human factors is lacking. Industry markets tend to focus on their direct competition and how to maximize their current share in the marketplace as opposed to creating new products that truly revolutionize the way people do work (Paradis & McGaw, 2007); the type of innovation seen in a Radical R&D process (Roussel, Saad, & Erickson, 1991).

In an attempt to be more innovative, there has been a shift to thinking that commercial devices should be used in an industrial setting. In some regards, commercial smart devices can be used but there are certain, costly limitations as they often can't survive exposure to vibrations, harsh environments, falls, and other impacts (Gooley, 2012). The initial low commercial device cost quickly becomes obsolete as replacements must be purchased at a much more frequent rate (depending on the environment) and the cost of being without a functioning device quickly outpaces the initial money saved. Another needed shift in the rugged handheld space is to focus on creating a future ruggedized device five years from now for the work force that will be in place five years from now, not to create a device in five years for the workers of today. Creating a device that anticipates the skillsets and needs of the future generation yet is backwards compatible with the previous generations in the workforce should be the goal that designers keep in mind as they set out on their R&D process. Striving to achieve Boff's (2006) Generation 3 of human factors design, or the neural fit, to solve problems of both today and tomorrow is an admirable goal. However, the culture and technology of industry today—and even five to seven years from now—isn't ready to blur the lines between where the human ends and where the tool begins, epitomizing the characteristics of Generation 3. Yet there must be some middle ground between Boff's (2006) Generation 2, cognitive fit, and Generation 3 that is obtainable and can drive innovation. Based on Boff's concept, this study designates the naming of the midpoint between generations as Generation 2.5. Generation 2.5 should take the next step in the industrial space by aiding cognitive capabilities through user experience in anticipation of the need of the user by systematically knowing the type of work being performed based on user location, time of day, or some differentiator like generational skillset. Following Boff's naming convention, Generation 2.5 equates to "the awareness fit". Radical R&D (Roussel, Saad, & Erickson, 1991) is the creative process needed to achieve this awareness fit.

Essentially, ruggedized handhelds should take the same path that consumer smart devices have proven are possible through the use of emotional design and Kansei Engineering by taking a marketing-oriented approach (Guo et al, 2014). Intuitive interfaces, anticipation capable devices, and exclusively touch driven input are enough to make workers faster and more efficient while enabling them to be creative. Creativity is a work necessity for the Gamer or Millennial Generation (employees born between the years 1979 and 2000) based on their work-driven, self-actualization needs (Espinoza, Ukleja, & Rusch, 2010). These changes could drive a positive industrial culture change.

To be ahead of the technology curve, Paradis and McGaw (2007) use “Era Maps” to spot emerging and converging trends and to define requirements. Era Maps create a contrast between past, present, and future trends in culture, competitive space, and most importantly, technology. This tool was used in this study to capture end user requirements for the preferred future ruggedized handheld device. For the Era Map provided in the next section in Table 2, each of the five major components of ruggedized handheld devices were analyzed.

1.2 Device Preference

Until a recent shift that started in retail chains in early 2015 and has since moved into large supply chain companies, rugged handhelds were largely “brick” shaped devices designed more to withstand a damaging environment than to be a seamless, ergonomic solution. (Figure 1 provides examples of globally-deployed, rugged handhelds with the brick form factor.)

While devices shown in Figure 1 are representative of commonly used ruggedized devices, they can often hinder the actual, physical work that needs to occur. For example, a common industrial and retail function is to physically lift, move, and set product of some kind from point A to point B. A scan of the product barcode by the rugged handheld typically occurs during this process as a part of asset tracking management. A device with an interface and a screen for viewing information is also usually needed more often than devices that perform single functions like scanners to support manual data entry. But due to the size of the device, the worker may have to set the device down, holster it, or attempt to hold the device while lifting and moving a product. All three of these scenarios decrease worker effectiveness by adding time to their work processes and possibly changing the state of the function on the device by inadvertently pressing a button on the physical keypad. Devices of this type may also add discomfort over prolonged usage given that the typical weight of these types of device is between one and 1.5 pounds.

Consumer products like smartphones typically have a cookie sheet form factor and are generally much small and lighter then rugged devices. Smartphones may be able to perform many of the functions of a rugged device with an imager but the environment will likely wear on the device over a much shorter period time rendering it inoperable.

Table 2: Era Map for ruggedized handheld devices based on Boff's Human Factors Generations

	Component Description	**Past**	**Present (Gen 2)**	**Near Future (Gen 2.5)**	**Future (Gen 3)**
Outer Shell	The outer casing of a ruggedized device protects the internal computer parts and also provides the user with the sturdy grip they need to hold and use the device.	Large and brick-like; requires one hand to hold and % of second hand for data entry	Medium to large; ergonomically shaped; requires one hand to hold and use	Medium to small; less than 100% of one hand needed to hold and perform data entry	Is a handheld required at all?
Keypad	The keypad is the main way in which the user will input data into the ruggedized device regardless of whether the work environment is rainy, snowing, extremely hot or cold, full of dust, bright or dark.	Larger, less durable and configurable keys	Smaller, more configurable and durable keys	Removal of all physical keys; touchscreen only	Shouldn't humans be the interface?
Display	The size of the screen display determines the size and readability of the information presented by the ruggedized device to the user. Screen size could also have an impact on the overall size and durability of the device.	Disproportionately small compared to the rest of device	Equal to proportionately larger than amount of key surface area	Comprises the entire front of the device	Couldn't a display be flexible and appear where the user prefers?
Internal Components	The internal components of a ruggedized handheld device include such things as computer parts, sensors for vibration feedback, antennas for the internet and making phone calls, and the battery.	Large, inflexibly sized components determine size of device	Small components allow ergonomic shaping, device still large	Even smaller device; careful to not be too small and thin becoming less rugged	Doesn't optimal form factor mean that only internal parts change; i.e. swappable guts?
Accessories	Ruggedized device accessories allow the same work function to be performed in multiple ways giving the user options and flexibility when performing their work tasks. Multiple options could also create more variability in how long it takes to get the same work completed.	No peripheral attachments	Some basic peripherals; may lack ruggedization	Device becomes a platform; many rugged peripheral options allowing for work flexibility	Are basic peripherals still needed; should device only pair to other devices?

Figure 1: Ruggedized handheld examples with brick form factor

Because of products like the ones shown in Figure 2, devices that blur consumer product characteristics into the rugged experience of an industrial tool have started to penetrate the market. From a form factor perspective, these devices fit better in the workers' hands. They are lighter and more evenly weighted. They can be more comfortably held during the process of moving product without the risk of change of state due to inadvertent key press (as there are no physical keys). The screen is larger and may allow for more convenient data entry as well as many other benefits. Yet despite these opportunities for improvement, field workers may be hesitant to change to a new device because the device is simply different from what they are accustomed. Also, there may be a perception that, because the devices in Figure 2 now have consumer-like properties, the devices are more destructible in industrial work environments than the brick-shaped ones. There is a cultural bias and expectation that may need to be overcome in order to ensure the end user that—given that all rugged handhelds (including those with physical keys and touchscreen only) are subjected to the same testing as defined in MILSPEC 810G—the devices with consumer characteristics are at least as rugged as the brick-like peer devices.

Figure 2: Ruggedized handheld examples with cookie sheet form factor

Before such a significant change as input type and form factor is made, there needs to be a greater level of understanding of how end users respond to these types of changes. A wide-scale quantitative and hands-on test may not be practical given the global implementation that some industrial organizations may have. But a qualitative study of global geography that surveys the broad, multi-cultural expectations of future device preference is a very cost effective way to learn about the different cultural hurdles that a wide-scale device rollout may encounter.

1.3 Cultural Geography

Kirsch (2015) defines the term “cultural geography” as the science which engages with various components of geographic research that explore the significance of cultural processes and their geographies. Hofstede (1980) defines culture as “the collective programming of the mind that distinguishes the members of one group or category of people from another” (p. 25). Technological innovations, however, are breaking down the traditional barriers among different world regions and leading the world toward a unique culture (Harris & Moran, 1990).

Over the past several decades, the world has been moving toward the globalization of the market and the rapid diffusion of technologies (Held et al., 1999). However, even with this diffusion, the use of and acceptance for technology by different world regions is not a foregone conclusion. According to the investigation of several previous studies, the predictors of technology usage are generally focused on its usefulness, user comfort, and design features (Johns et al., 2002; Meuter et al. 2005; Zhu et al. 2007), as well as consumer demographical dimensions such as age, gender, and experience with the products (Dabholkar & Bagozzi 2002; Westjohn et al., 2009). The globalization of markets and corporate multinationalism create the necessity for more cross-cultural research (Applegate et al., 2003). When an industry grows its operations in the international arena, there is a need to build unity in terms of organizational structure, operations, and technology usage, both within and across countries. Hence, it is important for managers to learn, as much as they can, about the cross-cultural adoption and use of the technology they utilize. Based on the experience of the global company that aided in the data collection used by this study, it was common for each global region to utilize their own individual technology solutions causing increased difficulty in the support of and development for their end solutions.

Different cultures embrace technologies to varying degree. Researchers of past studies, concerned about cultural differences in technology usage, have divided the world into regions, based primarily on organizational structure (El-Mekawy & Rusu, 2011; He & Xiao, 2011; Frynas & Mellahi, 2015) and product or service provided by a multinational industry (Johns et al., 2002; Frynas & Mellahi, 2015). For this study, the researchers considered cultural distinction and technology use in a multinational industry and broke the world into seven regions: Asia, Australia, Canada, Europe, Latin America, Middle East, and USA (Figure 3). This grouping is similar to the regional indexing of countries reported by previous research conducted for multinational business industries which use handheld computing devices (Bombourg, 2012), cell phones and information technology (Johns et al., 2003). This grouping also matches exactly with the regions of the global company that participated in the study. The indexing used in this study follows the categorization of world regions by the United Nations Statistics Division (2013) for the Department of Economics and Social Affairs. The survey conducted for this study does not include any respondents from Africa. In addition, based on the technology use and service life of the industry, North America was divided into Canada and USA in order to get more accurate responses.

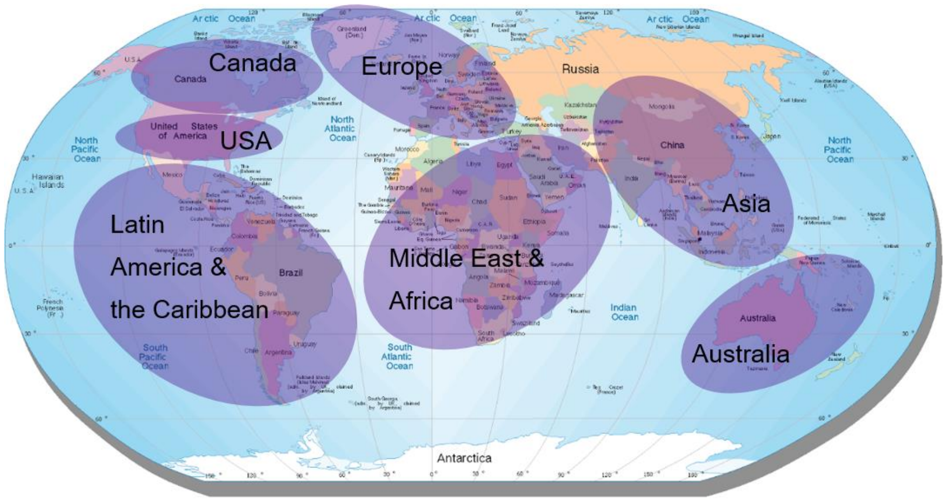

Figure 3: Seven global regions represented in the multi-cultural scope of this study

Designing products for a global audience involves more than including a translation of the features and the instructions. In fact, it requires a deeper understanding of the special needs of the target cultures. This research study was grounded in the belief that culture is a discernible variable which influences the usability of and preferences for product attributes. The aim of this research was to identify cultural influence on design preferences for a ruggedized handheld device of users from a multinational service industry.

2. Method

2.1. Participants

Current employees of an industrial-based, global company, who are targeted as having significant hands-on experience with rugged handheld devices, were given a survey to identify requirements and preferences for ruggedized handheld devices within their region. A total of 1171 employees of the industrial company responded to the survey from seven different regions of the world (as per the divisions defined by Department of Economics and Social Affairs identified in the previous section). Participants who answered incorrectly to the verification statement (indicating that they did not read the instructional text block prior to a verification survey question) or who had no experience with ruggedized handheld devices, did not represent the targeted demographic and their responses were excluded from the final analyses.

In this study, the workers were categorized according to the cultural attributes of the regions in which they work. This classification was performed by reviewing the worldwide locations where the industrial company serves and the cultural influences on handheld device design for those locations. Table 3 provides the demographic information of the participants including the region-based classification.

Table 3: Demographic information

	Statistics	
Demographics	Sample (N)	Percentage
Gender		
Male	854	72.93
Female	317	27.07
Region		
Asia	388	33.13
Australia	41	3.5
Canada	131	11.19
Europe	110	9.39
Latin America and Caribbean (LAC)	86	7.35
Middle East	9	0.77
USA	406	34.67
Experience with Touch-screen Device		
None or 0 years	32	2.73
1 year or less (≤1)	36	3.07
Between 1 and 5 years (1-5)	373	31.86
Between 5 and 10 years (5-10)	476	40.65
More than 10 years (>10)	254	21.69
Experience with Ruggedized Handheld Device		
1 year or less (≤1)	52	4.44
Between 1 and 5 years (1-5)	378	32.28
Between 5 and 10 years (5-10)	455	38.86
More than 10 years (>10)	286	24.42

2.2. Survey Design

The task to be performed by the participants was the completion of a 15-minute survey. This survey was designed to collect the following four types of information about the participants: demographics, future handheld device requirements, preferred final device selection, and key selection decision influencers. There were 12 questions, including one verification statement. The demographic questions (shown in Table 3) were asked about gender, region, experience with touch-screen devices, and experience with ruggedized handheld devices. The remaining three sections of the survey are descried in more detail below.

2.2.1. Future Handheld Device Requirements

Five questions were asked about the participants' design requirement preferences for the five major handheld features. The features were derived from the five components of a ruggedized handheld and were demonstrated via pictures and brief written descriptors. The pictures accentuated the specific feature in question and images of ruggedized and consumer devices already familiar to the participant were used in the survey to ensure a sense of familiarity. Each question was dichotomous, defined as level 1 and level 2 based on the Generation 2 and Generation 2.5 defined earlier. Both options for all five features are presented in Table 4.

Table 4: Different features with available options for a ruggedized handheld device

Features	Component Description	Level 1	Level 2
Casing Size	The size of outer casing of a ruggedized device	Small	Large
Display Size	The size of the display which determines the size and readability of the information presented by the ruggedized device to the user	Small	Large
Input Type	The mode by which the user will input data into the ruggedized device	Touch-screen-only	Touch-screen and full keypad
Internal Weight	The weight of all the internal components of a ruggedized handheld device	Light-weight; may lose some ruggedness	Heavy-weight
Multiple Accessories	Multiple accessory options which allow the same work function to be performed in multiple ways giving the user flexibility when performing their work tasks	Some basic peripherals	Many rugged peripheral options (holster case, scanner handle, hand strap, stylus)

2.2.2. Preferred Ruggedized Device Selection

Perceived desirability for different ruggedized handheld devices with various combinations of level 1 and 2 characteristics was also assessed. By selecting a ruggedized device based on pictures and specifications, respondents indicated which device they would prefer to use while performing their job functions in a chaotic environment. Four potential device options with their ancillary specification information which were provided to the respondents are shown in Figure 4. These four devices were selected for multiple reasons. Firstly, it was important to use devices currently familiar to the many regions in order to establish a baseline for preference.

Devices A and B are visual imitations of rugged devices actively used in all regions. Device C represents a more minimalistic device often used by the military and the oil and gas industry. Device D is representative of prototype designs by handheld vendors of an all touch device that, at the time, had not yet been released and was based upon field research findings for next generation handheld devices (Burch et al., 2016; Cannon et al., 2015). Secondly, device images were selected based on the different combination of Level 1 and Level 2 (Generation 2 and 2.5 respectively) features that they offered.

Device	Features			
	Input Type	Display Size	Casing Size	Weight
A	Touch + keypad	3.5”	5.8”H x 3”W x 1.3”D (smaller, narrow, not bulky)	0.8 lb
B	Touch + keypad	3.7”	9.2”H x 3.5”W x 2.0”D (larger, thicker, bulky)	1.4 lbs
C	Touch	3.2”	6.5”H x 3.8”W x 1.8”D (larger, thicker, bulky)	1.1 lbs
D	Touch	5.0”	6.4”H x 3.1”W x 1.0”D (smaller, narrow, not bulky)	0.8 lb

Figure 4: Potential device options provided to respondents in the survey

2.2.3. Key Decision Selection Influencers

The main features of the ruggedized handheld devices were assessed to determine the key factor influencing why participants selected one device over others. Respondents selected from casing size, display size, input type, internal weight, and multiple accessories to explain what influenced them in their ruggedized handheld device selection. While difficult to assess weight as a key decision influencer given that the pictures and associated weight values in the survey were all that the participants had to judge their selection upon, most participants of the study had hands on experience with devices comparable to A, B or both A and B. The reasoning of the researchers was that participants would understand the heft of each device and be able to associate like weight to Devices C and D. Color was not considered in the evaluated process as most rugged devices used in industry are either rebranded to match corporate colors and logos or are given a standard dark gray or black design. Brighter colors actually increase the manufacturing cost of the hardened mold exterior of the devices and so handheld vendors typically opt to minimize color variation outside of the keypad or minimal exterior features.

3. Results

3.1 Descriptive Statistics

The results show that large percentages of all respondents from all regions chose device A (36.21%) and device D (44.32%). Device B was selected by 13.83% of the respondents, while device C was chosen by only 5.64%. The survey also revealed the influence of different design features on device preference. Table 5 summarizes the responses on the influence of different design features and also the level preference for each individual feature. This summary shows that device preference was mostly dependent on casing size, display size, and input type. For level preference, extremes were observed in the cases of casing size and internal weight, especially followed by the cases of display size and multiple accessories. According to the results, input type was not strongly differentiated between the "touch-screen only" and "touch-screen and full keypad" options.

Table 5: Summary of survey responses for preferred design features

Survey Responses	Percentage (N=1171)
Influencing feature	
Casing Size	31.62
Display Size	28.63
Input Type	23.08
Internal Weight	11.62

Multiple Accessories	5.05
Casing Size	
Smaller	74.40
Larger	25.96
Display Size	
Smaller	30.06
Larger	69.94
Input Type	
Touch-Screen Only	42.36
Touch-Screen and Keypad	57.64
Internal Weight	
Lighter	73.87
Heavier	26.13
Multiple Accessories	
Included	66.10
Not Included	33.90

3.2 Inferential Statistics

Table 6 presents significant associations between demographics and survey responses. Statistical analyses revealed that of the four demographics (gender, region, touch-screen experience, rugged-screen experience), region showed significant associations with all the responses except input type. Gender was found to have influence on input type preference. Input type was also associated with touch-screen experience.

Table 6: Significant associations between demographics and responses

Demographics	Response Variables	χ^2 statistics (p value)
Gender	Input Type	8.7888 (0.003)
Touch-Screen Experience	Input Type	18.109 (0.001)
Region	Device Preference	32.359 (0.018)
	Casing size	16.736 (0.010)
	Display size	20.600 (0.002)
	Internal Weight	75.269 (0.000)
	Multiple Accessories	33.303 (0.000)

3.3. Device Preference by Region

The percentages of device preferences reported by workers from the seven different regions of the world are summarized in Table 7. The summary shows that workers from each region primarily preferred devices A and D. For the workers in Europe and Australia, device B was also a strong preference, about twice as much as any of the other regions. On the other hand, device C was always found to be preferred the least in each of the regions; in fact, in the Middle East, none of the workers chose device C as an option.

Table 7: Device preference made by region

Device	Percentage of device preference by region						
	Asia	Australia	Canada	Europe	Latin America	Middle East	USA
A	35.31	36.58	39.70	31.82	40.7	66.67	35.47
B	10.31	26.83	11.45	21.82	13.95	11.11	14.53
C	4.12	7.32	3.05	6.36	8.14	0	7.14
D	50.26	29.27	45.80	40	37.21	22.22	42.86

When considering the inferential statistics according to region, only one region, the Middle East showed significant association (χ^2 =15.276, p =0.004) between touch-screen experience and device preference.

3.4. Features Influencing Device Preference Worldwide

In order to identify the factorial structure of the influencing features, Principal Component Analysis (PCA) with oblique rotation was carried out on all five features for the responses from all the world regions. The Kaiser–Meyer–Olkin measure of sampling adequacy was satisfactory (0.64); Bartlett's test of sphericity was significant (0.000). A cut-off point of 0.40 was used for feature-loading values. The scree plot from this PCA (for responses from all the world regions) indicated that the data best fit a two-component solution, which accounted for 51.82% of the total variance. Two components with eigenvalues >1 were identified. The first component, which included casing size and internal weight, explained 21.09% of the total variance. The second component, which included display size and input type, explained 21.814% of the variance. Table 8 displays the results of the PCA (for all the world regions) with feature loadings for all participants (N=1171). The high positive loading for each feature illustrates the fact that the workers favored either smaller sized-lighter weight device or larger screen-touch type input.

Table 8: Principal components for influencing features throughout the world regions

Feature	Loading	
	Component 1	Component 2
Casing Size	0.764	
Internal Weight	0.789	
Input Type		0.678
Display Size		0.757

3.5. Features Influencing Device Preference by Region

The features that played an important role in selecting a device varied from region to region. The PCA was carried out on each of the five features for each individual region and tested for the assumptions. As was the case with the worldwide PCA result, casing size and internal weight were the first component for each individual region. The workers from Europe and Australia showed resemblance in their component formation. For Canadian workers, multiple accessories had no influence in device selection. The Latin American and Middle East workforce included four features in the first component and had only multiple accessories in the second component. The workforce from USA and Latin America were the only ones who preferred the inclusion of multiple accessories in their ruggedized handheld devices. All the PCA results are presented in Table 9 with pertinent factor-loadings and the percentage of influence of each feature by region.

Table 9: Influencing features for device preference by region

Region	Features	Percentage of influence	Loading	
			Component 1	Component 2
Asia	Casing Size	24.80	0.750	
	Display Size	32.38	-0.606	
	Internal Weight	14.88	0.757	
	Input Type	27.68		0.729
	Multiple Accessories	0.26		-0.702
Australia	Casing Size	43.59	0.861	
	Display Size	20.51	-0.434	0.431
	Internal Weight	7.69	0.674	
	Input Type	17.95		-0.591
	Multiple Accessories	10.26		-0.887
Canada	Casing Size	31.00	0.732	
	Display Size	31.78	-0.703	0.631
	Internal Weight	7.76	0.842	
	Input Type	27.91		0.889
	Multiple Accessories	1.55		
Europe	Casing Size	26.67	0.793	
	Display Size	30.48	-0.715	0.437
	Internal Weight	8.57	0.777	
	Input Type	32.38		0.607
	Multiple Accessories	1.90		-0.680
LAC	Casing Size	38.82	0.703	
	Display Size	17.65	0.521	
	Internal Weight	16.47	0.747	
	Input Type	24.71	-0.650	
	Multiple Accessories	2.35		0.941
	Casing Size	22.22	0.669	
	Input Type	66.67	-0.773	

Middle East	Display Size	11.11	-0.686	
	Internal Weight	---	0.888	
	Multiple Accessories	---		-0.910
USA	Casing Size	39.44	0.774	
	Internal Weight	10.94	0.765	
	Multiple Accessories	5.34	0.453	
	Input Type	15.27		0.811
	Display Size	29.01		0.759

4. Discussion

This study was conducted to report the influence of different cultures on the selection of ruggedized handheld devices. The study tested this association for four ruggedized handheld devices, considering two different levels for available features. The researchers worked with a worldwide industrial-based company conducting a survey in seven regions of the world. The workers were asked to express their choices on the devices and the available features. They also selected the feature that influenced their device preference the most. The findings of this study explained that the device preference of workers from all over the world was highly dependent on casing size (smaller), display size (larger), and input type (touch-Screen and keypad). The less influencing features were found to be internal weight (lighter) and multiple accessories (included).

The innovation of advanced technology in the design of handheld devices made several options available for input. The invention of the touch-screen replaced the necessity for different input-output space, with the advantage of a larger screen. This, in turn, reduced device size and weight. Nevertheless, some participants still preferred to have the physical key option along with touch-screen input. In an empirical study, Page (2013) found that users with no touch-screen experience require longer input time, which may, therefore, make them uncomfortable with touch-screen-only devices. Previous studies also found significant influence of gender for touch-screen preference (Weiss, Möller, & Schulz, 2012) and for touch-screen user performance (Lai & Wu, 2012; Chourasia et al., 2013). Interestingly, touch-screens were preferred by females (Weiss, Möller, & Schulz, 2012), but their accuracy with touch-screen usage was found to be less than males (Lai & Wu, 2012; Chourasia et al., 2013). As noted, this study also saw findings that gender had influence on input type preference as did touch-screen experience. Statistical analysis to investigate the influence of different demographics of the workforce on the device selection process confirmed the influence of cultural differences. The region of the world from which the workers came showed significant influence on device selection as well as on all of the feature preferences except input type.

Although a large percentage of the workforce (>30%) from all the regions showed inclination for device A, workers from the Middle-East showed much higher preference for it (66.67%) than workers from any other region. The workforce of that region expressed significantly different device preferences based on their touch-screen experience. Most of the respondents from the Middle East had five to ten years or more than ten years of experience with ruggedized handheld devices and relatively less experience with touch-screen devices. That could be a reason why they preferred devices with both touch-screen and keypad given their lack of familiarity with touchscreen-based consumer devices. In addition, the reluctant attitude across the different cultures toward device C would also be the reaction of this lack of experience with touch-screens, a condition which may be reversed in future. Although the likely reason is that Device C didn't offer enough physical key input options and the screen didn't take advantage of the additional real estate on the front of the device providing little advantage to either keyed or touch-only input. A wider design for this device could also have created a negative impression toward its selection. More than 20% of the total workforce from Australia (26.83%) and from Europe (21.82%) selected device B as their preference. These respondents made a trade-off between a larger display size and a large, heavy device, and avoided the touch-screen-only option in selecting their preferred ruggedized handheld device. Based on feedback from the engineers of the participating company, this is a common trend that has been identified in past technology selections processes were Europe and Australia often share similar behaviors. For Europe, the desire to retain physical keys was explained by engineers in that reason to be based upon the colder climates and the fear that touchscreens won't be interactive enough with thicker gloves. Australia (specifically Sidney) has a humid subtropical climate and so the weather and glove reasoning of Europe doesn't match despite the similarity in participant responses.

The PCA revealed that the workforce from all the world regions preferred ruggedized handhelds based on either component 1 (casing size and internal weight) or component 2 (display size and input type). These components explain the reasons for preferring each of the four devices. According to the results for device preference, most of the people selected device A and D. These devices are smaller in size and lighter in weight. One of them (device A) has smaller display and both touch-screen and keypad options for input, while the other (device D) has a larger display with a touch-screen-only option. In selecting these two most preferred devices, component 1, which explains most of the variance, had the most influence. On the other hand, those who preferred device B were influenced by component 2 and were not dissuaded by the larger and heavier device. The larger and heavier device C has a touch-screen input type within minimal physical key functionality and a smaller display size, which therefore did not fit into any of the component categories. This device was, as would be expected, not chosen by a significant number of respondents. Due to the variations in final device selection and feature preference by region, PCA results also varied across the regions.

Asian and Canadian workers made their choice for devices based on a smaller and lighter weight device and a smaller display size. These criteria, included in component 1 of PCA related to these regions of the world, explain the preference for device A (35.31%). However, component 2, for which input type (touch-screen-only) is the most prominent feature for these regions, influenced these workers to choose device D (50.26%). For Canadians, this result is further supported by the inclusion of a larger display size in component 2. In the case of Australian and European workers, device B was selected for a negative factor-loading of input type meaning that the workers preferred both a touch-screen and a keypad. From the same component (component 2), a positive factor-loading for display size (large) influenced the workers to choose device D. For the Latin American workforce, as most of the features (four out of five) were in component 1, they not only showed preference for device A and D (as did all other regions) but also showed noticeable preference for device B and especially for device C. Preference for device C was the highest in Latin America. The Middle East workers also formed component 1 including four features except accessories, but with negative factor loading for display size (smaller) and input type (both touch-screen and keypad). These criteria led this population to prefer device A the most. The workers from USA made their choice on device A (35.47%) based on component 1 from the PCA and device D (42.86%) based on component 2.

In determining the requirements and preferences for designing a future ruggedized handheld devices, which would be used throughout the world, it would be recommended to the manufacturer to consider the different cultural expectations. Table 10 summarizes the design specifications for ruggedized handheld devices for different world region considering the cultural influences. A key similarity for device design seen across all regions is the focus on device casing which includes the ergonomic form factor of the device. While not all regions agreed on what this design should be, they all agreed that it is important. Another feature identified as important to all regions (except the Middle East) was the display size. With this research, a trend has been identified that rugged handheld manufactures can further analyze in their future design of device casing and screen dimensions.

Table 10: Design specifications for ruggedized handheld devices by world region

Region	Preferred Influencing Factor	Design Specifications
Asia	Display Size	Small casing, small display, light-weight, and touch-screen-only device without including multiple accessories
Australia	Casing Size	Small casing, small/large display, light-weight, and both touch-screen and keypad input device without including multiple accessories
Canada	Casing Size and Display Size	Small casing, small/large display, light-weight, and touch-screen-only device
Europe	Input Type and Display Size	Small casing, small/large display, light-weight, and touch-screen-only device without including multiple accessories
LAC	Casing Size	Small casing, large display, light-weight, and both touch-screen and keypad input device including multiple accessories
Middle East	Input Type	Small casing, small display, light-weight, both touch-screen and keypad input device without including multiple accessories
USA	Casing Size	Small casing, small display, light-weight, and touch-screen-only device including multiple accessories

For larger industrial companies present in multiple regions (including the global company that participated in this study) the different regions typically perform their own, independent device selection for many reasons both financial and cultural creating a technology gap that further distances the regions from each other. By taking an approach that allows all regions visibility into and participation in the future handheld device selection process, many regions are able to see for the first time that they actually share many of the same priorities.

5. Conclusion

If the design decision for a future, globally distributed, ruggedized handheld were based solely on the preferences identified in this study, a next generation device would be designed smaller but with a larger screen and it would still have a physical keypad. Given that the front surface area of today's brick form factor devices are already at capacity due to the inclusion of both a touchscreen and a keyboard, a design that matches overall global preference would be difficult to make. A smaller device with a larger screen leaves little room for effectively usable physical keys.

With a shift already in progress toward all-touch, rugged handheld solutions, two of the three overall preferences are being met with the third preference for physical keys indicating where the biggest challenge and training opportunity exists. If in fact a reluctance on the part of the worker to use a touch screen is due to the loss of physical feedback, then technology that is comparable to or a replacement for physical keys will need to be integrated into the touchscreen user experience. For example, the simplest solution may be to include haptic vibration that can be used upon key press to provide an indication that the device recognized an interaction and responded. Likewise, for workers who may be familiar with no-look data entry on a physical keyboard, audible response and predictive keypad placement could be employed. While not plausible for this upcoming generation of rugged devices, additional technologies such as interface advancements from Tactus that place a disappearing physical keyboard on all-touch devices that raises out of the flat screen when virtual keys are present (Tilley, 2015) could be built into devices, addressing concerns identified from certain global regions. Additional concerns regarding lower accuracy could be addressed via predictive software solutions that learn the work force cultural preferences as well as the corporate culture and language. So given the recent and upcoming advancements made in mobile technology, all-touch rugged solutions appear to be the best future option based on global majority preference for smaller devices with larger screens.

From a managerial perspective, there are a number of noted benefits that can be realized upon the global implementation of an all-touch, ruggedized solution. For one, selecting a device that is largely preferred across many of the regions reduces the need to purchase multiple physically keyed solutions from different vendors. With physical keys, the challenge exists in that the keyboard layouts likely differ due to vendor specific, proprietary device production resulting in software application for keyboard mapping. With an all touch solution, the differences that can exist (at the surface level) between device inputs are reduced regardless of the vendor selected to supply the device. Secondly, with less variability comes the reduced dependence on and cost of specialized, per-device training. The cost of maintenance and support of the devices are also reduced due to the removal of approximately 30 points of mechanical failure (the keys themselves). Another consideration is the preference by newer employees for a more familiar, all-touch solution given the penetration of smartphones in consumer lifestyles. A more familiar work tool may provide some advantages when industrial companies attempt to attract and retain those newer employees. Lastly, cultural acceptance of a new tool by a work culture is a common management challenge that is compounded when working with the different geographic cultures. Identifying a single solution that is accepted by the overall work culture as well as the distinct geographic cultures improves the implementation speed of the new solution while creating cultural champions who can advocate for the user of the new tool.

There were limitations identified for this study; the foremost being the language barrier. The company selected for this study requires some level of understanding of the English language for all employees regardless of the region in which they are domiciled. Also, pictures were mostly used in the survey to reduce the need for written explanations. Despite the measures that were taken, it is likely that a percentage of participants made design preference decisions based on incorrectly understanding the survey questions. Another limitation was that there were only nine participants from the Middle East region. Likewise, Australia and LAC had less than 50 and 100 participants respectively. So while this study may have correctly captured and reported preference for many of the regions, there is risk that such a small sample size is not reflective of the preference of the entire population. Lastly, only ~27% of all participants were female. While this gender percentage breakdown is reflective of the worker population of the company used for this study, having more women participants would have been helpful especially with the noted difference in preferred device input type.

While this qualitative study of device preference is helpful in understanding what to expect from different cultures' device acceptance in the event of global handheld distribution, a quantitative study to determine which device type workers are best at using is a needed complement to these results. As in other rugged device studies, future work for this study should include physically visiting each of these regions and observing the different device types in use in the field (Burch & Strawderman, 2014). Along with this additional work, understanding how the elements affect device usage (i.e. extreme cold or precipitation) would be important to understand as user preference for physical keys might be based of environmental challenges that they face today. Also, a deeper understanding of how different cultures respond to technology changes in the commercial world as well as the effect that "technology skips" has had on different geographic regions of the world. Lastly, further research should expand upon the five basic characteristics of a handheld used to define the methodology of this study and include the evaluation of the many human interface elements (HIEs) defined within Kansie Engineering (Guo et al., 2014). HIEs that need to be included in future methodologies include functional and non-functional attributes such as ratio of length and height, thickness, curvature and transfer, hue, gloss, logo attributes, and so forth as identified by Guo et al. in their research of digital cameras (2014).

References

Applegate, L. M., Austin, R. D., & McFarlan, F. W. (2003). Corporate information strategy and management: text and cases. New York, NY: McGraw-Hill Irwin.

Boff, K. R. (2006, July). Revolutions and Shifting Paradigms in Human Factors & Ergonomics. Applied Ergonomics, 37(4), 391-399.

Bombourg, N. (2012, April 24). Global Handheld Computing Devices Industry. Retrieved from PR Newswire: http://www.prnewswire.com/news-releases/global-handheld-computing-devices-industry-148856905.html

Burch, R. F., & Strawderman, L. (2014). Touchscreen Versus Keypad: Ruggedized Handheld Device Input Effectiveness by Generation. In Y. Guan, & H. Liao (Ed.), Industrial and Systems Engineering Research Conference. Montreal: Institute of Industrial Engineers.

Burch, R. F., Strawderman, L., & Carruth, D. (2016, Jun). Ruggedized Handheld Device Input Effectiveness by Generation: A Time and Error Study. *International Journal of Industrial Ergonomics, 54*, 146-153.

Cannon, A. B., Strawderman, L., & Burch, R. F. (2015, May). Evaluating Change in User Error When Using Ruggedized Handheld Devices. *Applied Ergonomics*(51), 273-280.

Chourasia, A. O., Wiegmann, D. A., Chen, K. B., Irwin, C. B., & Sesto, M. E. (2013). Effect of sitting or standing on touch screen performance and touch characteristics. *Human*

Factors: The Journal of the Human Factors and Ergonomics Society, 0018720812470843.

Dabholkar, P. A., & Bagozzi, R. P. (2002). An attitudinal model of technology-based self-service: Moderating effects of consumer traits and situational factors. Journal of the Academy of Marketing Science, 30(3), 184–201

El-Mekawy, M., & Rusu, L. (2011, January). Organizational culture impact on business-IT alignment: A case study of a multinational organization. In System Sciences (HICSS), 2011 44th Hawaii International Conference on (pp. 1-11). IEEE.Espinoza, C., Ukleja, M., & Rusch, C. (2010). Managing the Millennials: Discover the Core Competencies for Managing Today's Workforce. Hoboken, NJ: John Wiley & Sons.

Frynas, J. G., & Mellahi, K. (2015). Global strategic management. Oxford University Press.

Gooley, T. (2012, May 14). The What, When, and Why of Rugged Handhelds. Retrieved February 25, 2013, from dcvelocity.com: http://www.dcvelocity.com/articles/20120514-the-what-

Guo, F., Liu, W. L., Liu, F. T., Wang, H., & Wang, T. B. (2014, Jun). Emotional Design Method of Product Presented in Multi-dimensional Variables Based on Kansei Engineering. *Journal of Engineering Design, 25*(4-6), 194-212.

Harris, R. P., Moran, R.T. (1990). Managing Cultural Differences. Gulf Publishing, Houston, TX.

He, C., & Xiao, X. (2011). Geography of Multinational Corporations and Functional Specialization in Chinese Cities. Symphonya. Emerging Issues in Management, (1 Global Cities and Knowledge Management-1).

Held, D., McGrew, A., Goldblatt, D., & Perraton, J. (1999, March). What is Globalization? Retrieved from Global Transformations: https://www.polity.co.uk/global/whatisglobalization.asp

Hofstede, G. (1980). Culture's consequences. Beverly Hills.

Johns, S. K., Smith, M., & Norman, C. S. (2002). How culture affects the use of information technology. In Accounting Forum (Vol. 27, No. 1, pp. 84-109).

Lai, C. C., & Wu, C. F. (2012). Size Effects on the Touchpad, Touchscreen, and Keyboard Tasks of Netbooks 1. *Perceptual & Motor Skills*, *115*(2), 481-501.

Meuter, M. L., Bitner, M. J., Ostrom, A. L., & Brown, S. W. (2005). Choosing among alternative service delivery modes: An investigation of customer trial of self-service technologies. Journal of Marketing, 69, 61–83 (April).

Page, T. (2013). Usability of text input interfaces in smartphones. *Journal of Design Research*, *11*(1), 39-56.

Paradis, Z. J., & McGaw, D. (2007). Naked Innovation. Chicago, IL: IIT Institute of Design.

Roussel, P. A., Saad, K. N., & Erickson, T. J. (1991). Third Generation R & D: Managing the Link to Corporate Strategy. Boston, MA: Harvard Business School Press.

Tilley, A. (2015, Feb 12). Phorm Brings Physical Touchscreen Buttons To The iPad Mini. San Francisco, CA: Forbes.com. Retrieved Dec 7, 2015.

United Nations Statistics Division. (2013, October 31). Composition of macro geographical (continental) regions, geographical sub-regions, and selected economic and other groupings. Retrieved from http://unstats.un.org/unsd/methods/m49/m49regin.htm