A SURVEY ON USAGE OF TOUCHSCREEN VERSUS MOUSE FOR INTERACTION

Ibrar Hussain, Iftikhar Ahmed Khan,Imran Ali Khan, Syed Sajid Hussain and Attiqa Rehman.

Department of Computer Science, COMSATS Institute of Information Technology Abbottabad

ibrar.libra83@gmail.com, iftikharahmad@ciit.net.pk, imran@ciit.net.pk, sajidhussain@ciit.net.pk, attiqarehman@ciit.net.pk

ABSTRACT*— In the beginning of the personal computing era, the main input device to interact with machines was a physical keyboard. The introduction of the mouse as a point and select device revolutionized personal computers making them easier and faster to use. During the last decade, a new interface system based on touchscreen has made its debut especially among mobile phones and other handheld devices. In this survey paper, we performed a literature review of studies that compare the interaction of the mouse and the touchscreen. Specifically, we have surveyed the following aspects: how the users of different age groups use these devices? What is the effect of direct manipulation and indirect manipulation, on tasks and their variability? How does the experience with technology effect the efficiency? Which device helps to gain speed and accuracy under what circumstances? Based on these parameters, we concluded about the suitability of the devices under different circumstances.*

Index Terms—personal computing, Input device, Mouse, Touchscreen, direct and indirect manipulation.

I. INTRODUCTION

To increase access to information and communications around the world, different technologies are developed and improved [1].

In Human Computer Interaction (HCI), problems related to the input devices are fundamental [2].The effective interaction of human with system depends on the degree to which people interact with system - to perform an action, or to retrieve some information. This communication is usually by means of input devices such as keyboard, mouse, and touchscreen [3].Touchscreen technology is one of the latest advancement towards providing the ease to interact with a machine [4]. Touchscreen technology is increasingly being used because of its convenience. Touchscreen is used in industrial applications, products and services, kiosks in the airport and supermarkets, POS (Point of Sale), Heath care environment, tablet PC, control processes, system control and office automation [5]. A large number of studies are being conducted to study the usage of mobile devices with touchscreens in every-day life. These studies have presented new interaction techniques [6]. Since the direct manipulation is the superior pattern of interaction like touch devices, investigating the advantages of the interaction of these devices as compared to indirect devices received more attention [7].The touchscreen has caused a significant reduction in movement time, up to 35% to the mouse for the elderly, compared with only 16% of young, it also minimize the errors. Steering tasks, which were usually a problem for seniors on desktop computer has attained the extreme progress. However, dragging with the touchscreen has been relatively slow [8]. The research [9] indicated two factors that explain the faster time in selection of most important commands related to the menus which are accessed by the mouse. The first factor is motor operation of physical key press is substantially fast compared to a mouse. Second, menu use, requires a multi-step hierarchical process [9]. In traditional desktop screen configuration, there are some signs that on single point of contact task mouse input is equal or superior to the touchscreen input [10].

Each input device, whether touchscreen or mouse, offers a variable user experience and possibly lead to different results for the similar tasks [11]. Comparative study of the mouse and touchscreen, found that novice users perform best with touchscreen, while when talking about the accuracy, mouse is a superior option. The results indicated that the touchscreen input is the fast input mode and preferable for short tasks, such as the icon selection with low-resolution screens.

As this survey presents conflicting results due to this it is difficult to choose the suitable device in different conditions [12].Therefore, in this research we have focused on variables that could affect the operation of input devices. For example, does the choice of best input device depend on the tasks carried out? Does performance of an input device is affected by the age of the user? Does experience with the technology effects the performance? It is not new to recognize that one input device could be better than other input device for some specific tasks. To overcome the drawbacks of devices which are already exists the new input devices are designed. However, a systematic investigation of the interaction between the demands of the task, the user capabilities and characteristics of the input device is missing. In this research, we aim to cover this gap, by literature review and provide guideline.

The remaining paper is organized as follows**.** The related work is in section II, while methodology is in section III, section IV

discusses the results and the last section concludes this paper.

II. RELATED WORK

Various review researches are conducted in context of input devices and their effectiveness. For example, the study [1] explored several studies regarding interaction methods for senior users by using touchscreen. Their finding showed that age-related changes, population, apparatus, tasks, screen size ,input techniques, prior knowledge with technologies, features of handheld devices and conditions of use are important factors to decide the use of input device . The research paper [13] investigated users opinions about touchscreens. Information from previous research studies, reports and papers were collected and analyzed. The collected information included: whether users liked touchscreen or not, the frequency of making mistakes and the time to learn the use of touchscreen. The authors also devised a questionnaire about traditional technique and touchscreens and conducted a survey. They concluded that respondents of younger ages are more likely to try touchscreens as their input mode and show more interest. Another study [14] examined the literature on input devices and their suitability for elder user. The authors summarized substantial findings from the evaluated studies

and outlined the strengths, weaknesses and suitable tasks for different input devices. On the bases of these findings the author proposes the design and selection of input devices. However, this study evaluated different direct and indirect input devices like mouse, keyboard, joystick and touchscreen only for elderly users.

Table1: Parameters of referenced studies

Study-Raf	Parameter discussed
[1]	Participants of different categories like age or skills, apparatus (touchscreens), tasks, data collection based on time and error, screen size.
[13]	Input mode preference, opinion of using touchscreen, making errors and time needed for learning, application that used touchscreens, comparison between touchscreen.
[14]	Older users, Input devices, keyboard, pointing devices, mice, trackball, joystick, touchpad, touchscreen light pen, and hands free input devices (foot, hand, eye brain and voice control devices).

The studies mentioned in the table-1 cover multiple parameters but these studies only focus input devices and their use by older people. There is no comparison between input devices to inquire which input device is better in which situations. These studies only focus older people and do not discuss the usage of input devices by children and young people. In this paper, we are going to target the parameters which are not focus by these studies.

III. METHODOLOGY

A set of keywords were identified to search appropriate related literature. The keywords were "comparison", "computer input devices", "interaction techniques", "computing", "direct device", "indirect device", "trackball", "mouse", "keyboard" "joystick", "touchpad", and "touchscreen". The different combination of these keywords was used with the terms such as "literature review", "survey" and "evaluation".

The search engine used for the first time was Google scholar. The research papers published in English were extracted from journals, and conference proceedings. Electronic resources searched included CHI Conference, Academic Search, ACM Digital Library, and Science Direct. Maximum searches were done highlighting the period from 2005 to 2016 to get the latest studies. During a preliminary analysis, duplicate references and studies having no or little relevance to the topic were discarded leaving only 38 research studies. This preliminary analysis involved reading title, abstract and conclusion.

IV. RESULTS

A. Comparison of young and old people on usage of mouse and touchscreen

In the studies [3] and [12], the subjects were inspected from questionnaire about literacy, age, education, typing speed, professional activities, and health conditions. In the studies [8,12,15,16] previous experience with the input devices, computers, or other use of electronic devices was an important criteria for subject selection. Two studies [2],and [17] examined the participants use of computer, mobile phone or touchscreen devices.

It was noticed that there was an enormous difference in number of users and their ages. Participant's age range was from 3 years to elementary level (children), young people from age 18 to 50 years, and older people from 60 to 80 years.

In the year 2000, only five countries had older people (65 years and older) more than youth (younger than 15) [14]. It was estimated that by 2030 all industrialized countries share the same demographics structure, some with more than two times more elderly than young people [14]. Jastrzembski research shows that old people have more visual problems than younger ones and demanding longer target acquisition times [18]. Older people have difficulty in recognizing small details of the icons and dynamic pointers used in graphical user interfaces (GUI). Generally older people and people having deficits in vision or having motor problems feel problems in Point-and-click tasks[18,19]. It was predicted that in 2020, approximately 18.2% of the US population suffers from arthritis, most of them 55 years old. In addition, 96% of cases of Parkinson's disease occur in people over the age of 50 [14]. Modern technology such as the touchscreen have frequent elderly user [20].

Disparity regarding age affects which device is more appropriate for task. [3]. It appeared that use of touchscreen diminishes disparity regarding age for pointing task [8].It is found by a study that the older people initially got advantage of an indirect device, when pointing tasks is performed [1]. Overall performance of older adults is questionable if there is similarity between the characteristics of input device and input requirements i.e. Pointing tasks and ballistic tasks were thought most suitable to touchscreen and dragging tasks are difficult on touchscreen [21]. The extended coordination of hand and eye, which has exacerbated the operation of the mouse and in clicking tasks among seniors, age-related decay in motor abilities causes the low performance [14]. Touchscreen is used for displaying the direct input, which permits suitable hand and eye coordination and it is efficient as well as space is concerned. It is applicable for such circumstances when less typing is involve, i.e. for menu selection task, especially where training and practical is impossible such as people approachable information terminals [14]. Recommendation of touchscreen instead of mouse is due to its advantages, it diminishes the performance gap between young and old people by using different tasks such as by steering, dragging, pointing, clicking and crossing [1],[22]. This study concludes that the touch input is better than the mouse w.r.t throughput and movement time. However, a mouse is generally more accurate, compare to touch which do a large number of misses on small targets. [23]. Further it is concluded that touchscreen is better option for older adults.

B. Direct and indirect input devices

Direct and indirect input describes how data is entered into the system. Direct devices are often claimed more natural and fascinating to work than working with indirect input devices [15]. Actions of human body are translated into data by indirect devices, for example a mouse and joystick. These devices have various physical characteristics but have some common cognitive nature of mental interpretation between the machine and human body. For example, a cursor moves upward on screen when moving the mouse forward. The spatial interpretation required is indicated to be cognitively demanding, especially for the elder experiencing a normal age-related decline in spatial ability [21,24]. Mental translation is caused by indirect devices. A small movement of the device can be the cause of a larger movement on the screen. The physical distance moved by device is translated in virtual distance on screen and that translation influence the deliberate performance and attentional needs.[12].

Intermediary actions are not done by direct devices. In direct devices the motion of the body is translated into input of the machine. Touchscreen, light pen and voice recognition system are examples of direct devices. Cognitive mental translation is not required in the case of direct devices [3]. For senior users, the direct nature of the operation can result in rapid acquisition, operation, and accuracy with the interface. Direct devices not only have better performance, but sometimes they cause problems for the implementation of input tasks due to exhaustion, unintentional activation and lack of precision
[24].

In this related literature seven studies [8.10.16,23,24,25] and [26] were identified that compared touchscreen device with mouse. In addition, three Studies [9], [27] and [28] compared mouse with keyboard. Four studies [2,11,12,29] compared touch ,touch pad, mouse, pen and stylus. Two studies [3] and [24] compared touchscreen with rotary encoder . One study [30] compared finger and pen. In one study [31] ribbon commands are used and two studies[17, 32] compared tasks like point & click and drag & drop tasks. In one study [33] compared keyboard shortcuts with menus and tools.

It is concluded from these studies that to find the suitable input device the task and age of the user can influence. As compared to direct devices, indirect devices are more attention demanding due to the translation required. Touchscreen may have less cognitive processing as compare to the actions required with mouse.

C. Tasks and variability of tasks

In this literature review, we have categorized common interaction tasks into four types:

- Pointing.
- Dragging.
- Text or digit input.
- Drawing.

Earlier research efforts have rated input devices tasks into their effective comparison of devices and input requirements [3].Incompatibility between input device and input task, for example when a keyboard is used to control the sliding a pointer to a specific value, this incompatibility results in decreased performance. When an input device and the input task are compatible, such as in selection task, when we use touchscreen for selection of larger buttons, performance is improved as compared to the mouse, group difference between young and old is also minimized [8]. The concept of matching task with the characteristics of the input device is very important. A poorly explained feature of the tasks to the device is match /mismatch in terms of input requirements is due to attention. The mismatch between the features of the device and input needs are likely to be a source of enhanced intentional requirements [24]. It is represented to be influenced by age-related features of the user. Therefore, age should persist an essential anticipator is likely to become more essential when intentional demand is studied [24].

We can conclude that input device characteristics and the match between task demands are essential. It is shown that young people can manage a mismatch even their attention is shared. Old people get benefited, when their attention is shared and there is match between device and task available. When less attention is required for performing a task the requirement of old people for match is enhanced. Attention is necessary for input devices. Few devices are better as compared to others but no single device is considered to be optimal for each task and application [12]. For both young and old population, if system needs to manage repetitive tasks like up-down buttons or move through a list, the rotary encoder is better choice. Similarly , if tasks are to be performed from drop down list boxes touchscreen considered to be optimal choice for both young and old people [3]. Older and younger people movement time reduced by 35% and 16% respectively, when shifted on touchscreen from mouse, on performing steering, crossing, dragging and pointing tasks. Dragging task consider to be slower when performing with touchscreen, while steering task is considered to be most difficult on mouse [8]. Ballistic and pointing tasks are more appropriate, when performing them with touchscreen whereas the precision and repetitive tasks are probably better performed with the help of mouse [24]. It is observed in study with younger adults that mouse is appropriate device for dragging tasks [12]. For point- and-click tasks the touchscreen is proved to be more appropriate for novice users. Touchscreen is not suitable for virtual alphabetic or numeric data entry [21].For dragging and radial selection tasks finger input is the slower method but faster for tapping tasks. For dragging and radial selections the stylus is the fastest input device , and for tapping selection it is the second [29]. The touch base interactions are less accurate than mouse base interaction for drawing tasks [16]. Performing a click task is faster than typing a numeric value. However, performing dragging task is most slowest method [32].

D. Experience with technology and speed & accuracy

Technology usage survey has proved that using computer and internet is not only refers to technology usage, devices like cell phone, CD players, laptops, tablets and digital camera is also the included in technology usage [34]. In 2016 it was estimated that 97% of all smart phones have touchscreen interfaces [35]. Mobile phones are playing a vital role nowadays in our society, both for older and younger groups. It was reported in 2009, by the ministry of internal affairs and communications in Japan that about 75% of the

population having age six years or more, more than 70% of having age 60-69 and 40% of people having age 70-79 had their own cell phones [36]. In the year 2014, On the occasion of US shopping day , 27% of online sales and 49% of online traffic was due to smartphones and tablets [37]. In 2013 it was reported that, 43% of Americans over 16 years has their own a tablet and 56% of Americans adults own a smartphone [6]. It was estimated that in terms of tasks about 28% of time on computer is consumed by the e-mail usage and 18% of time segment consumed on internet surfing [38].

For seniors, effectiveness and efficiency with input device, experience is an important factor. Overall, seniors who are habitual computer user are most accurate in their performance while using the mouse. For the choice of optimal input device, experience with the computer is acute issue. Seasoned users of technology are already familiar and feeling ease in using challenging indirect devices like mouse that is why mouse is the optimal choice as an input device [12,31]. If experience computer user wants to enhance performance he should increase their expertise with the mouse [1]. Children try to implement Drag and Drop (DnD) as a first choice. Why children first try to use DnD. Best possible explanation may be that children are more familiar and experienced with the DnD [17]. Practice reduces task time as well [9].It was estimated that for tapping task, practice of one week reduces the time completion of tasks by 7% and 9% for large and small devices, respectively. Similarly one week practice for dragging tasks reduces task completion time by 24% and 18% for large and small devices, respectively. If we talk about pinching task, practice of one week reduce the task completion time by 29% and 28% for large and small devices [36]. Hence the results of study suggest that practice improved the performance [27]. Touchscreen input is better than mouse in the aspect of throughput and movement time for tabletop interactive surfaces. However, a mouse is more reliable and accurate as compared to touch, as touchscreen makes large number of miss with small targets [23]. General observation is that the mouse is slower device as compare to touch. However, for all tested most of the tasks, the touchscreen is less accurate input device than mouse but the differences is usually insignificant [11]. Touchscreen is faster, but it is less precise as compared to mouse, for target selection and drawing tasks. Touchscreen interaction cause more errors than interaction with the mouse for drawing tasks.[16,25]. Touchscreen have almost double error rate than mouse on selection task. If we compare error rate of touch and mouse it is 8.5% compared to 4.1% respectively. For bimanual tasks like docking and resizing touch is better as 1.45 second than mouse 2.43 seconds. It was estimated that the mouse is more accurate, average error rate of 9.7% compared to using touchscreen18.9% [10].

It is concluded that each device has its own advantages and disadvantages. Hence, the optimal input device should be chosen based on what is needed and how it needs to be used. Choosing a device is a trade-off between performance and comfort [26].

V. CONCLUSION

An essential design claim confirmed by this study is that it is not appropriate to propose that an input device proved to be the best ever. The literature review suggests that before selecting an input device one must keep in mind the task requirement and age group of the user. In overall designing the input device, the age of the user should be given preference. Older people should choose the input device that is suitable for their required tasks. Indirect devices demand more attention as compare to direct devices because translation requires there. Direct devices such as touchscreen may involve less cognitive processing as compare to indirect devices such as the mouse.

Selection of devices (direct device or indirect device) depends on the requirements of the task. However, indirect device required more time for intermediate translation. So indirect devices are not suitable for older adults; however indirect devices are more accurate and easy to use for young experts that have technology experience.

This study shows that in steering, crossing, dragging and pointing tasks performance gap between older and younger people is reduce by touchscreen. With mouse steering task is difficult to perform. The dragging task is slower on the touch screen.

The optimal input device chooses depending on what is needed and how it should be used. The choice of a device is a trade-off between performance and comfort. This study and future studies will form the basis for developing user friendly interfaces. The touchscreen is easy to learn and the most natural of all input devices and even children can learn it easily.

Reviewed literature shows that several parameters should consider for designing the interaction system in which few are given below.

1. Experience with technologies (computer, laptop, tablet, mobile phones and handheld devices).
2. The different types of tasks used for interaction (pointing, text or digit input, drawing, dragging).
3. Age should be important parameter as old people has different requirements as compare to young.
4. Speed and accuracy tradeoff.

In this study we have evaluated thirty-eight research papers, which compared mouse and touchscreen. In future number of studies can be increased and comparison of other input devices like keyboard and trackball may be included.

REFERENCES

[1] L. G. Motti and N. Vigouroux, “Interaction techniques for older adults using touchscreen devices" : a literature review from 2000 to 2013,” *J. Interact. Pers.*, no. (to be published), pp. 125–134, 2013.

[2] S. Zabramski, D. Gkouskos, and M. Lind, “A comparative evaluation of mouse, pen- and touch-input in computerized version of the Torrance tests of creative thinking,” *Desire’11 Conf. Innov. Des. Oct. 19-21, 2011, Eindhoven, Netherlands. Assoc. Comput. Mach.*, pp. 383–386, 2011.

[3] W. a Rogers, A. D. Fisk, A. C. McLaughlin, and R. Pak, "Touch a screen or turn a knob: choosing the best device for the job.," *J. Hum. Factors Ergon. Soc. 47.2*, vol. 47, no. 2, pp. 271–288, 2005.

[4] D. Carvalho, M. Bessa, and L. Magalhães, "Different interaction paradigms for different user groups," *Proc. XV Int. Conf. Hum. Comput. Interact. - Interacción '14*, no. September, pp. 1–6, 2014.

[5] M. R. Bhalla and A. V. Bhalla, "Comparative Study of Various Touchscreen Technologies," *Int. J. Comput. Appl.*, vol. 6, no. 8, pp. 2–8, 2010.

[6] R. D. Vatavu, L. Anthony, and Q. Brown, "Child or adult? Inferring Smartphone users??? age group from touch measurements alone," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 9299, pp. 1–9, 2015.

[7] K. Wolf and N. Henze, "Comparing pointing techniques for grasping hands on tablets," *Proc. 16th Int. Conf. Human-computer Interact. with Mob. devices Serv. - MobileHCI '14*, pp. 53–62, 2014.

[8] L. Findlater, J. E. Froehlich, K. Fattal, J. O. Wobbrock, and T. Dastyar, "Age-related differences in performance with touchscreens compared to traditional mouse input," *Proc. SIGCHI Conf. Hum. Factors Comput. Syst. - CHI '13*, p. 343, 2013.

[9] R. C. Omanson, C. S. Miller, E. Young, and D. Schwantes, "Comparison of Mouse and Keyboard Efficiency," *Proc. Hum. Factors Ergon. Soc.*, pp. 600–604, 2010.

[10] C. Forlines, D. Wigdor, C. Shen, and R. Balakrishnan, "Direct-touch vs. mouse input for tabletop displays," *Proc. SIGCHI Conf. Hum. factors Comput. Syst. - CHI '07*, p. 647, 2007.

[11] S. Zabramski, S. Shrestha, and W. Stuerzlinger, "Easy vs. Tricky: The Shape Effect in Tracing, Selecting, and Steering With Mouse, Stylus, and Touch," *" Proc. Int. Conf. Mak. Sense Converging Media. ACM*, pp. 99–103, 2013.

[12] E. Wood, T. Willoughby, A. Rushing, L. Bechtel, and J. Gilbert, "Use of Computer Input Devices by Older Adults," *" J. Appl. Gerontol.*, vol. 24, no. 5, pp. 419–438, 2005.

[13] K. M. Luo, Er, "Experience of Touchscreens A study of usage of touchscreen among different age groups in Gavle.," no. June, 2012.

[14] D. Taveira and S. D. Choi, "Review Study of Computer Input Devices and Older Users," *Int. J. Hum. Comput. Interact.*, vol. 25, no. 5, pp. 455–474, 2009.

[15] T. Sasao, S. Konomi, M. Arikawa, and H. Fujita, "Touch Survey: Comparison with Paper and Web Questionnaires," *Int. Symp. Cartogr. Internet Ubiquitous Environ.*, p. 4, 2014.

[16] E. R. Hooten and J. A. Adams, "Comparing input error for mouse and touch input," *Conf. Proc. - IEEE Int. Conf. Syst. Man Cybern.*, pp. 2853–2858, 2011.

[17] W. Barendregt and M. M. Bekker, "Children may expect drag-and-drop instead of point-and-click," *Proc. 2011 Annu. Conf. Ext. Abstr. Hum. factors Comput. Syst. - CHI EA '11*, p. 1297, 2011.

[18] T. Jastrzembski, N. Charness, P. Holley, and J. Feddon, "Input devices for web browsing: Age and hand effects," *Univers. Access Inf. Soc.*, vol. 4, no. 1, pp. 39–45, 2005.

[19] A. M. Piper, R. Campbell, and J. D. Hollan, "Exploring the Accessibility and Appeal of Surface Computing for Older Adult Health Care Support," 2010.

[20] T. Page, "Touchscreen mobile devices and older adults : a usability study Touchscreen Mobile Devices and Older Adults : A Usability Study," 2014.

[21] N. Caprani, N. O'Connor, and C. Gurrin, "Touch screens for the older user," *Assist. Technol.*, no. 1, p. 95/118, 2012.

[22] A. Steinert, M. Haesner, J. L. O. Sullivan, and E. Steinhagen-, "Difference in operation of Mouse and Touchscreen in older adults," *" Int. J. Serious Games*, vol. 2, no. 4, pp. 93–99, 2015.

[23] F. Sasangohar, I. S. MacKenzie, and S. D. Scott, "An Evaluation of Different Input Techniques for a Tabletop Display Using Fitts' Reciprocal Tapping Task," *Proc. HFES 2009 53rd Annu. Meet. Hum. Factors Ergon. Soc.*, vol. 53, no. 12, pp. 839–843, 2009.

[24] A. C. Mclaughlin, W. A. Rogers, and A. D. Fisk, "Using Direct and Indirect Input Devices: Attention Demands and Age-Related Differences," *ACM Trans. Comput. Interact. 16.1*, 2012.

[25] S. Zabramski, "Careless touch: A comparative evaluation of mouse,pen, and touch input in shape tracing task," *Proc. 23rd Aust. Comput. Interact. Conf. ACM*, pp. 2–5, 2011.

[26] R. Senanayake and R. S. Goonetilleke, "Pointing Device Performance in Steering Tasks," *Percept. Mot. Skills*, vol. 122, no. 3, pp. 886–910, 2016.

[27] R. C. Omanson, C. S. Miller, and S. V Joseph, "Effects of Item Grouping on Selection Efficiency," *Proc. Hum. Factors Ergon. Soc. Annu. Meet.*, no. 2011, pp. 1526–1530, 2014.

[28] K. Ollila, "Are mouse gestures better way to interact with PC compared to shortcuts and direct manipulation ?," pp. 1–3, 2012.

[29] A. Cockburn, D. Ahlström, and C. Gutwin, "Understanding performance in touch selections: Tap, drag and radial pointing drag with finger, stylus and mouse," *Int. J. Human-Computer Stud. 70.3*, vol. 70, no. 3, pp. 218–233, 2012.

[30] L. G. Motti, N. Vigouroux, and P. Gorce, "Drag-and-drop for older adults using touchscreen devices: Effects of screen sizes and interaction techniques on accuracy," *26th French-Speaking Conf. Human-Machine Interact. HMI 2014*, pp. 139–146, 2014.

[31] J. Scarr, A. Cockburn, C. Gutwin, and A. Bunt, "Improving command selection with CommandMaps," *Proc. 2012 ACM Annu. Conf. Hum. Factors Comput. Syst. - CHI '12*, p. 257, 2012.

[32] J. A. Husser and K. E. Fernandez, "To click, type, or drag? Evaluating speed of survey data Input methods," *Surv. Pract.*, vol. 6, no. 2, pp. 1–7, 2013.

[33] D. M. Lane, H. A. Napier, S. C. Peres, and A. Sandor,

"Hidden Costs of Graphical User Interfaces: Failure to Make the Transition from Menus and Icon Toolbars to Keyboard Shortcuts," *Int. J. Hum. Comput. Interact.*, vol. 18, no. 2, pp. 133–144, 2005.

[34] N. C. Katherine E.Olson , Marita A.O'Brien , Wendy A.Rogers, "Diffusion of Technology:Frequency of Use for Younger and Older Adults," vol. 36, no. 1, pp. 123–145, 2012.

[35] L. Skrypchuk, M. A. Williams, M. J. Pitts, and L. Skrypchuk, "Comparing the User Experience of Touchscreen Technologies in an Automotive Application Comparing the User Experience of Touchscreen Technologies in an Automotive Application," *Proc. 6th Int. Conf. Automot. User Interfaces Interact. Veh. Appl. ACM*, no. September, 2014.

[36] M. Kobayashi, A. Hiyama, T. Miura, and C. Asakawa, "Elderly User Evaluation of Mobile Touchscreen Interactions .," 2011.

[37] S. A. Brasel and J. Gips, "Interface Psychology: Touchscreens Change Attribute Importance, Decision Criteria, and Behavior in Online Choice," *Cyberpsychology, Behav. Soc. Netw.*, vol. 18, no. 9, pp. 534–538, 2015.

[38] K. Taylor, "An analysis of computer use across 95 organisations in Europe , North America and Australasia," no. August, p. 12, 2007.