

Ergonomic Principles Applied to the Design of the Microsoft® Office® Computer Keyboard

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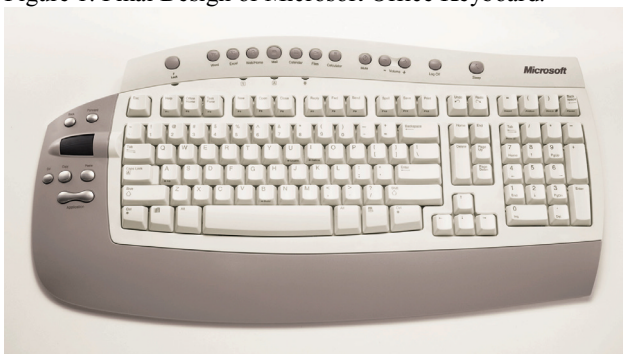
Ergonomic principles of human performance and human-machine interaction are applied to the design of a new, commercially available computer keyboard. Even though it is a primary means to connect people with computer applications, the keyboard has remained relatively static in design. This paper describes concepts and features implemented on a new computer keyboard, addressing negative performance issues as well as promoting new interaction between people and the desktop computer and its software. These concepts were evaluated using methods of design research to positively affect the empathy, efficiency, engagement, and creativity not only for consumption activities but also composition and communication experiences when utilizing the power of computers. The concept of bimanual action was applied to the design of a new left-side pod with a pallet of navigation and editing tools in the non-dominant, left hand. New, dedicated command keys offer one-step, quick action for the most common tasks traditionally performed by reaching and moving mouse or by hidden, awkward keyboard short-cuts.

INTRODUCTION

Computer keyboards have remained relatively unchanged as the computer itself has evolved in processing power, memory, and resolution. Some keyboards have looked at alternative layouts and arrangement of the main QWERTY keys (Lewis *et al*, 1997) and ergonomic designs such as split-angle keyboards (Honan *et al*, 1995; Marklin & Simoneau, 1996). Traditional computer keyboards exhibit vestiges of the general purpose computer, such as Function keys (e.g., F1-F12) and keyboard short-cuts or “hot keys” (e.g., Alt+Tab to “switch applications” and Ctrl+C for “copy”). Such keys are cryptic: neither “F11” nor “Alt+Tab” means anything to the typical computer user. They are also hidden: users have to rely on instruction or chance discovery to learn the short-cuts.

The principles of efficiency, bimanual control, biomechanics, and user-centered, empathetic design are evaluated using generative and iterative methods of product design research that lead to the new Microsoft Office Keyboard (Figure 1).

Figure 1: Final Design of Microsoft Office Keyboard.



Design Themes

Bimanual Control

Most persons are right-handed and the design of keyboards has reflected this fact. The integral number pad is located on the right side. The editing keys (e.g., arrow keys, page up, page down, etc.) are located on the right side. The mouse or other pointing device is often to the right of the keyboard. More than 95% of computer users use the mouse in the right-hand (Dennerlein, 2002). All of these actions overload the dominant hand for most of the population.

Yet, many tasks and actions are naturally accomplished using both hands. The non-dominant hand turns the pages of a book while the dominant hand takes notes. An artist holds a pallet of paint in the non-dominant hand while the dominant hand holds the paint brush. We explored this concept of bimanual control for a new computer keyboard.

One-Step Commands

Computer users frequently print, save, and create new documents; yet, these actions still cannot be performed obviously and quickly from traditional keyboards. A friend or colleague may have been looking over one's shoulder and shared the hidden key commands for Save (Ctrl + S) and other commands. However, these key short-cuts – like combinations to locks – must be memorized. So, why aren't these often performed actions – which users have done in the past and will continue to do in the future – given dedicated points of operation?

Engagement

Along a similar idea to one-step actions on keyboard, another objective of this project was to improve the interaction design to avoid repeatedly switching between mouse and keyboard for common, critical, or complex tasks, with the goal of maximizing engagement and minimizing

distraction. For example, computer users typically have more than one window (or application) open at a time; yet, they must reach for mouse (or use hidden, multi-step Alt+Tab keys) to switch between them, disrupting their thought processes or actions on screen.

Consumption & Creation

The internet and multi-media have been the focus of recent efforts in keyboard designs to improve the interaction between users' needs and power of computing. The boom of internet information has better connected people to information and services. For the most part, these activities are passive *consumption* where information is sought or brought to the person. Little action or energy is required on the part of the user.

Conversely, the historical power of the computer has been on the creation or *composition* activities: writing e-mail, formatting presentations, analyzing data, collaborating on reports, etc. These activities utilize the processing power of the computer and creativity of the person. This processing power has been the strength of the computer – to easily enter and edit or format content, displaying information and thoughts in ways previously unavailable by handwriting or typewriter. Modern keyboards need to effectively support both consumption and composition activities.

Empathy & Forgiveness

The Function keys (F1-F12) are meaningless to many persons, excepting the one or two F keys that the average user might be familiar with. Other rarely used keys may be equally inscrutable (e.g. SysRq and Pause|Break.) Furthermore, the keyboard is fraught with cryptic and dangerous keys. Thus, keyboards do not speak the user's language, and keyboard users are often fearful that they will accidentally hit a key or be left in a state where they cannot undo even an intentional a key strike.

RELATED WORK

Bimanual Control & One-Step Commands

As noted above, several current keyboards have dedicated multi-media and internet keys for quick access to actions associated with those activities. Even earlier, the Xerox Star's keyboard (Figure 2) included dedicated keys for generic commands: Move, Copy, Open, Delete, Show Properties, and Same (Copy Properties) (Smith *et al.*, 1982). Several of these command keys are located on the left side suggesting one of the first applications of bimanual control in keyboard design.

Several researchers have argued that the background task of navigating a document should be assigned to the non-dominant hand, while the dominant hand operates the mouse (Guiard, 1987; Hinckley *et al.*, 1998). Buxton and Myers report that a two-handed approach for compound selection and positioning task was easy to learn – done without prompting – and the speeds to complete tasks were quicker depending on how much of the tasks were done in parallel (Buxton & Myers, 1986). They also found that for navigation and selection in a word

processing task, two-handed operation was quicker than one-handed operation, with improvements seen among both experts and novices, yet more so for novices. View scrolling has been proposed to be better suited on the left-side of the keyboard for operation by non-dominant hand for most computer users (MacKenzie & Guiard, 2001). This project considered not only scrolling but also switching between open applications and back & forward keys – both navigation operations – and cut, copy, and paste buttons for editing.

Figure 2: The Xerox Star keyboard (circa 1981) with detail of the function key groups. Note that Copy is on the left.



METHODS

Several types of research methods were utilized in the design process of the Microsoft Office Keyboard. At the start, participatory design techniques were utilized to learn users' impressions and preferences for a large set of possible design changes, with some ideas well beyond the scope of the project as initially conceived. Brainstorming sessions were then conducted to enumerate the widest possible set of implementations where a single solution was not obvious for a feature. Then, non-functional models as well as functional prototypes were constructed for further iterative, evaluative user testing.

RESEARCH

Participatory Design

Participatory design research discerns persons' interest and desires in product ideas without building expensive models and prototypes. In the first of two studies, thirty participants worked in pairs to design their ideal keyboard, given rules of, for example, a maximum possible number of new keys. Each team was given the full range of design options in 2D full-size drawings pasted in magnetic sheets to be assembled like a jigsaw puzzle onto a magnetic white board. All total, 127 variables were explored with participants' ratings of preference and importance with discussions of optimal implementations. The variables explored need for existing keys and new command keys (e.g., Cut, Copy, Paste, Save, Print, New, Open, Close, etc.) and scrolling functionality. This participatory design study demonstrated users' desirability for new command keys.

A second participatory design study was conducted with six groups of four expert or competent keyboard users

– equal numbers of office and home users – evaluating three, 2D keyboard models showing alternative features on a new keyboard. Participants expressed their impressions and preferences for the keyboard features shown including those concepts that ultimately were designed and developed into the Microsoft Office Keyboard:

- Scrolling device.
- Device to move between open applications and windows within an application.
- Cut, Copy and Paste keys.
- Back, Forward, Undo, Redo, Print, Save, Help, Send, Reply, New, Open, and Close keys.
- Application Launch keys.
- Rearrangement of editing keys (Home, End, Delete, etc.) to save space.

Evaluative User Research of Models and Prototypes

After the participatory design studies provided a clear direction for content of the new keyboard, the next steps were a series of user studies utilizing non-functional models or functional prototypes evaluated in a laboratory setting with representative users and tasks.

Application Toggle

The project team brainstormed 20 ways to implement a means of switching between open applications or “windows.” The concepts were ranked based on ergonomic criteria (e.g., direction, range, and frequency of movement; postures assumed; physical load, accessibility, etc.) and heuristic criteria (e.g., skill, memory, user-centered, errors, feedback, etc.) to limit the building of prototypes and scope of research to four prototypes: rocker (or toggle), two horizontal buttons, one button, and a dial (or knob).

Using the four functional prototypes, a lab study with 9 participants determined that the horizontal rocker (Figure 3) was the preferred method for switching between open applications. Users preferred the rocker to their currently used method (most often mouse & task bar). Participants completed tasks that represented moving between open windows or applications. Participants appreciated the left-side location.

Figure 3: Application Toggle Prototype (1 of 4).



Scrolling and Internet Back / Forward Navigation

The project team brainstormed 17 ways to implement scrolling on a keyboard. Again, the concepts were judged using ergonomic and heuristic criteria to prioritize the concepts and then limit the building and testing of four

prototypes: touchpad, two vertical buttons, and two types of wheels. Alternative locations of the Back and Forward navigation keys were also considered in separate models during this same study.

Using working prototypes in the lab, twelve participants appreciated the touchpad scrolling method as well as a scrolling wheel (Figure 4). Users liked using both the touchpad and the wheel, but the scrolling wheel was the most recognizable and approachable scrolling device.

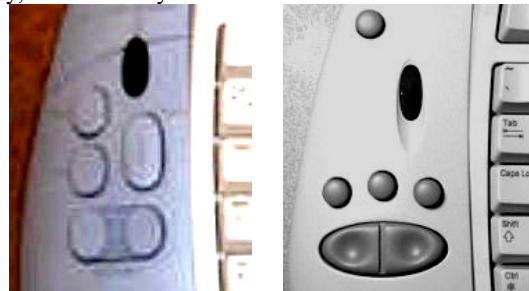
Figure 4: Scrolling Prototype (1 of 4) of Wide Wheel.



Command Keys

A separate lab study with eleven participants focused on the top portion of the new keyboard including dedicated application launch buttons for word processing, spreadsheets, web/home, e-mail, calendar, files, and calculator; limited multi-media controls; and new command keys where old Function keys were located. The content of the new Command keys were prioritized with Spell (Check), Save, Print, New, Open, Close, Reply, Forward, Send, Undo, and Redo rising to the top participants' rankings of 20 possible new Command keys over the old Function keys. The new F Lock key provided easy access to functionality under old Function keys if necessary or preferred.

Figure 5: Left-Pod Models. Both models have Application Toggle on the bottom. *Left:* Triangular arrangement of Cut, Copy and Paste keys. *Right:* Single-row arrangement of Cut, Copy, and Paste keys.



Left-Side Pod

Two separate studies were conducted to determine optimal arrangement of features on left-side. One study with 10 participants utilized three mechanically but not electronically functioning models (e.g. Figure 5, left). The second study with 9 participants used three functional prototypes constructed with various arrangements for cut, copy, paste, application toggle, and scrolling device (e.g.

Figure 5, right). After a brief introduction to the study, participants evaluated and ranked the designs based on visual impressions. Participants then performed tasks using each of the keyboards: 1) scrolling and then copying and pasting with the left pod (right hand on the mouse), 2) scrolling and switching applications with the pod (right hand on the mouse), 3) typing and scrolling (using the left pod), and 4) typing and then copying and pasting with the left pod. The participants' feedback showed that implementing a wide scroll wheel was preferred to a narrow scroll wheel; cut, copy, and paste should be horizontally arranged; and the scrolling mechanism should be equally accessible for consumption and composition activities. Feedback was also garnered to improve users' experiences when using points of operation based on size, location, spacing, shape, and surface design.

Figure 6: Final design of the left pod of the Office Keyboard (with image of entire keyboard for context).



DISCUSSION

Participants do understand and appreciate the concept of bimanual control as represented by the Back & Forward buttons; Scroll wheel; Cut, Copy, & Paste buttons; and Application Toggle (Figure 6). Quantitative data showed that users can perform some operations faster with left-side pod compared to other methods (McLoone *et al*, 2003). The horizontal arrangement of Cut, Copy, and Paste buttons matches the horizontal presentation of fingers of the hand, and the frequency of use of these three buttons corresponds to the dexterity and strength of the respective fingers: most often performed Paste action on the index finger; second most often Copy action on the middle finger; and the least often performed Cut action on the ring finger. The dedicated buttons for Cut, Copy, and Paste not only reduces motion of the mouse to select icons representing these actions but also reduces the awkward, twisted finger postures to complete the action one-handed when using keyboard short-cuts.

Keyboards should express empathy and forgiveness of user error by reducing the likelihood of common errors, removing or deemphasizing keys which are meaningless to the lay person, making commonly used functions available through clearly labeled and efficient means, and allowing the user to easily undo mistakes. The goals of empathy and forgiveness are exemplified in several

ways on the new keyboard. The dedicated Undo and Redo keys provide clear means to return text or objects back to where or what they were before the most recent action. The vertical arrangement of the editing keys saves space of the keyboard on the crowded right side, giving more room and closer proximity for the mouse or other external input device – more often used than the number pad or editing keys. All keys have default actions with clear legends. Lastly, empathy is given to persons who use the old Function keys. All previous keyboard keys are still available – none have been removed.

Many common actions present on the keyboard by dedicated keys reduce the need to reach for the mouse to complete an action. For example, users can open their e-mail provider, start a new e-mail message, and send it without reaching for the mouse. Engagement is met directly with commands at persons' finger tips.

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