Recall Test for Keyboard Layout

Stefanie, X.Q. Kang, Steve N.H. Tsang, Alan H.S. Chan, S.L. Liu

***Abstract*—In this study, the recall accuracies for different keys on a keyboard were studied and analyzed in a systematic way. It was found that alphabetic keys in the area of "Typing Keys" resulted in relatively lower recall accuracies than "Function Keys", "Control Keys" and "Numeric Keys". Besides, there was an absence of significant association between the relative use frequency of English letters and their recall accuracies, confirming to the general expectation that typing tasks rely on the processing of implicit memory rather than explicit memory. Regarding the recall accuracies for numeric keys, participants had higher recall accuracy for the keys located in "Numeric Keypad" than those in the "Typing Key" area. This might be the result of experience transfer from their daily interaction with devices of similar layout (ATM). Some useful suggestions were provided for the design of a more user-friendly keyboard layout.**

***Index Terms*-Keyboard Layout, Typing Performance, Recall Accuracy, Explicit Memory, Muscle Memory**

I. INTRODUCTION

THE ten-finger QWERTY keyboard has become a standard device for entering textual data into computers. Its influence is so pervasive that even in situations where ten-finger typing is not an option, such as cell phones and some military computers [1, 2], the keyboards are always arranged in a QWERTY layout [3]. A computer user or typist is easily surprised when first looking at the seemingly arbitrary arrangement of letters on a standard computer keyboard. Neither does the arrangement have any alphanumeric logical order nor is it optimized according to a high hit rate or ergonomic comfort. The keyboard was thought to be optimized to slow down typists to prevent the keys getting stuck.

Numerical typing is an error-prone daily task. Understanding human performance in skilled, perceptual–motor activities is very helpful for numerical typing study. Numerical typing errors can cause serious consequences in critical systems, such as medical databases or nuclear power plants. Besides, for transactional systems, numerical typing errors may lead to financial loss, the consequence of which could be more serious than frauds [4]. These problems are exacerbated by the fact that numerical typing errors are hard to detect.

The basic, single-plane QWERTY keyboard has long been the conventional keyboard used in the office environment. Despite the frequent use of telephones and calculator/computer keypads, individuals exhibit surprisingly poor memory when explicitly asked to reproduce the layout of numbers on these devices. For example, Rinck tested college students on their ability to correctly place the digits on a blank sheet using their memory for the layout of either a telephone or a calculator [5]. Accuracy for the correct placements of the digits 1 to 9 was 78% for the telephone versus 48% for the calculator layout. That is, approximately one-half of the college students tested could not explicitly recall the locations of the digits on a calculator keypad, as presented in Fig 1. In addition, Rinck found that when participants made errors, especially on the calculator layout, they reversed the layout (for example, entered the layout for numbers on a telephone when they were supposed to enter the layout of a calculator). Jones and Martin also found relatively low recall success for the calculator layout in their sample of college students [6]. Only about 25% participants in the control group, which was not provided with any strategies or explicit instructions, reproduced the calculator layout in its entirety with all the digits in the correct locations. In contrast, the same group of participants reproduced the telephone layout with near-perfect accuracy.

Why memorizing keyboard layout shows greater difficulty than performing normal typing task? In fact, recalling and typing tasks rely on two separate, viz., explicit and implicit, memory systems. Explicit memory system is involved when we need to consciously recall items/events, while implicit memory system is involved when we do not need to perform the recall task with conscious control or attention. It shows performance improvement of certain skill-based tasks (driving, typing) mainly by processing implicit memory system. Explicit and implicit memory systems seem to function quite independently from each other [7], but the question whether implicit and explicit memory depends on a single underlying system or multiple underlying systems remains unsolved [8].

In daily life, implicit memory (also known as long term memory) is being heavily dependent for performing various tasks in form of procedural memory, such as tying shoes and riding a bicycle, which do not require conscious effort and substantial attention to complete the tasks. Muscle memory is a form of procedural memory, in the presence of muscle memory, a motor task becomes automatic with minimal or no conscious effort through repetition or practice owing to the reduced need for

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attention and enhanced efficiency within the motor and memory systems [9].

In this experiment, participants were given a paper with a typical computer keyboard on which the labels on the buttons were missing, and they were asked to recall the corresponding label for each button as many and accurate as they could. Recall accuracies for different keys were recorded and compared to give insight on the typing characteristics of the participants.

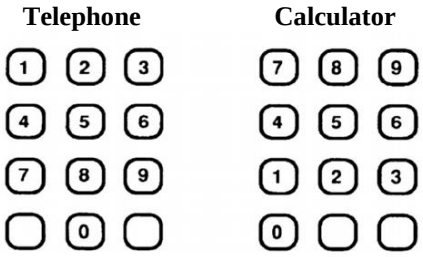

Fig. 1. The two alternative numeric keypads commonly used for the telephone keypad (left) and the calculator keypad (right).

II. METHOD

Ninety four Chinese students (26 female and 68 male) aged between 20 and 26 from City University of Hong Kong participated in this experiment. All of them had more than 3 years of computer use experience. They all gave informed consent before the start of the experiment and did not report any physical or health problem involving their brain and hands.

The experiment was conducted in a quiet room. Each participant was given a paper with the picture of a keyboard where all the keys were blank. They had 5 minutes to fill out as many keys (alphabet/number/function) on the blank keyboard as they could. The recall accuracy was recorded for subsequent analysis.

III. RESULTS

In order to facilitate the data analysis, the keyboard layout was divided into six sections, viz., control keys, function keys, typing keys, navigation keys, numeric keypad, and indicator lights, with reference to their control functions (Fig 2). However, the sections of "Indicator lights" and "Navigation Keys" were not subject to further analyses as the former did not refer to any input function while the latter was too easy to judge and distinguish by the spatial orientations (up, down, left and right) of the keys.

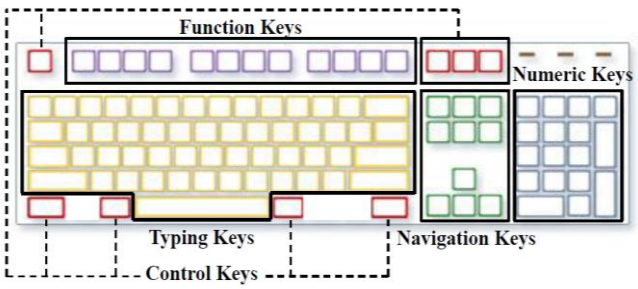

Fig. 2. Keyboard Position: Control-Function classification.

A. Control Keys

There are eight keys for "Control Keys", and of them, the keys "Esc", "Ctrl(left)", "Alt(left)", "Alt(right)" and "Ctrl(right)" obtained more than 70% recall accuracies, with the key "Esc" had the highest recall accuracy (97.87%). While for the keys "Print Screen", "Scroll Lock", and "Pause Break", their recall accuracies were 27.66%, 10.64%, and 1.06%, respectively (Fig 3). The relatively low accuracies could be the result of the little utilization of these keys in daily computer use.

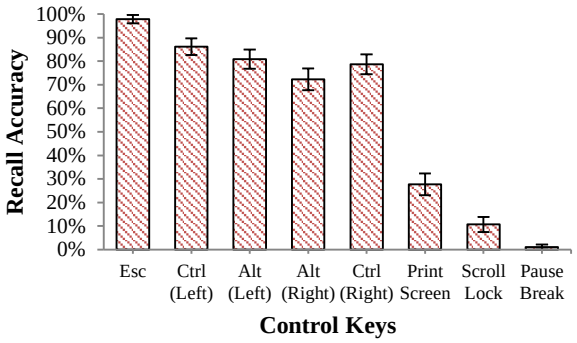

Fig. 3. Recall accuracies for "Control Keys".

B. Function Keys

The "Function Keys" involve the keys F1 to F12, all of which had very high accuracies with the values ranging from 91.49% to 96.81% (Fig 4). With the sequential order of the "Function Keys", there was slight decline in recall accuracies for the keys from "F10" to "F12".

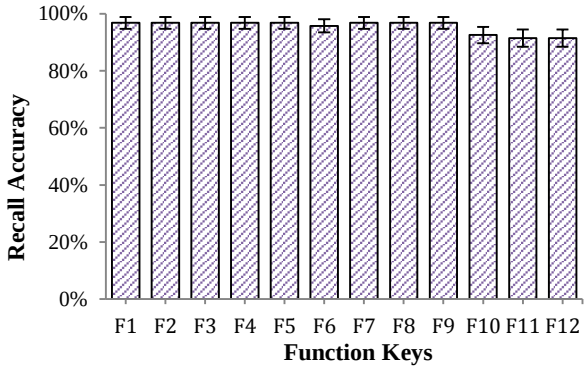

Fig. 4. Recall accuracies for "Function Keys".

C. Typing Keys

Most of the keying tasks are performed with the keys in this section. These keys include alphanumeric keys, punctuation keys and some function keys. Among these keys, there was a general trend that recall accuracies dropped from left to right on the keyboard (Fig 5). For instance, the recall accuracies decreased drastically from "QWERT"…to… "{,}, and \", with the values dropping from 81.91% to 15.96%. In general, the average recall accuracy for function keys (Backspace, Tab, Enter, Shift, and Space) was the highest, followed by alphanumeric keys, and the average recall accuracy for punctuation keys was the lowest among all the keys in this section.

D. Numeric Keypad

As shown in Fig 6, the recall accuracies for the numeric keys were much higher than those for the non-numeric keys.

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Within the non-numeric keys, the keys "Num Lock", "+", "Del/." and "Enter" attained higher recall accuracies than the numeric operator keys "/", "*", and "-". For example, the recall accuracies for "Enter" and "Del/." were 84.04% and 77.66%, while those for "/" and "*" were 21.28% and 30.85%, respectively. The results imply that participants in general had better memories on the locations of the numeric keys on the numeric keypad, due very likely to its calculator-like layout which they commonly encounter in daily life activities.

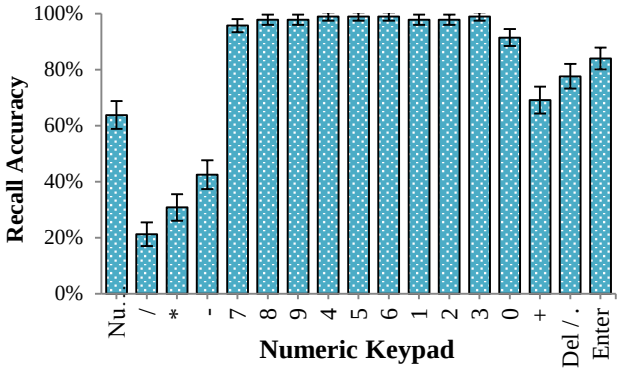

Fig. 6. Recall accuracies for "Numeric Keys".

E. Comparisons in recall accuracies for numeric keys

On the keyboard, there are numeric keys both in the areas of "Typing Keys" and "Numeric Keypad" (Fig 7). Fig 8 shows the recall accuracies for the numeric keys in these two areas. For all the numeric keys, the recall accuracies for numbers in "Numeric Keypad" were much higher than those in "Typing Keys". Subsequent analysis with the Wilcoxon Signed Rank test showed that all the differences in recall accuracies between the numeric keys in these two areas were significant at the level of p's < 0.01. The findings somehow reflected that numeric keys located in "Numeric Keypad" could be more easily recalled than those located in "Typing Keys" section.

Fig. 7. The numeric keys between "Typing Keys" and "Numeric Keypad".

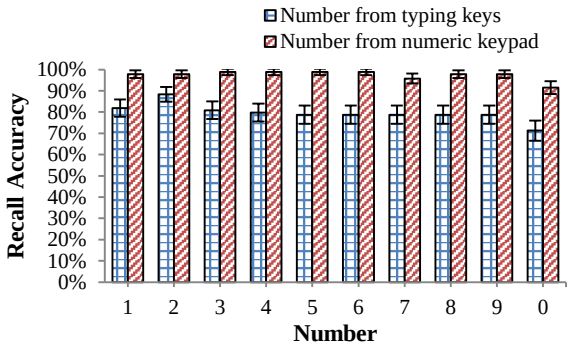

Fig. 8. Comparisons in recall accuracies for numeric keys between "Typing Keys" and numeric keypad.

F. Comparisons in recall accuracies for repeated control keys

Another comparison is for the recall accuracy of repeated control keys on the left and right hand sides of the keyboard (Fig 9). Except for the key "Shift", participants attained higher recall accuracies for the keys "Ctrl", "Alt", and "Enter" on the left hand side than the same keys on the right hand side. Subsequent analysis with the Wilcoxon Signed Rank test indicated that the differences between the left and the right keys "Ctrl" ($p = 0.05$), "Alt" ($p < 0.05$), and "Enter" ($p < 0.01$) were significant.

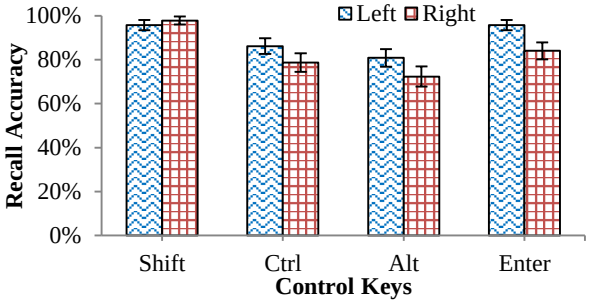

Fig. 9. Comparisons in recall accuracies for control keys on the left and right hand sides of the keyboard.

G. Correlations between relative frequencies of 26 letters in English writing and their recall accuracies

Fig 10 and Fig 11 show the relative frequencies of 26 letters in English writing and the recall accuracies for each letter. In English writing, "e", "t", "a", "o", and "i" are the five letters with the highest frequency of use. Fig. 11 shows that "a", "q", "s", "w", and "z" are the five letters with the highest recall accuracies. Spearman rank order Correlation test showed that there was an absence of significant association between frequency of use and recall accuracy of the English letters ($p > 0.05$), implying that the letters with higher frequency of use did not facilitate participants to recall their spatial locations on the keyboard.

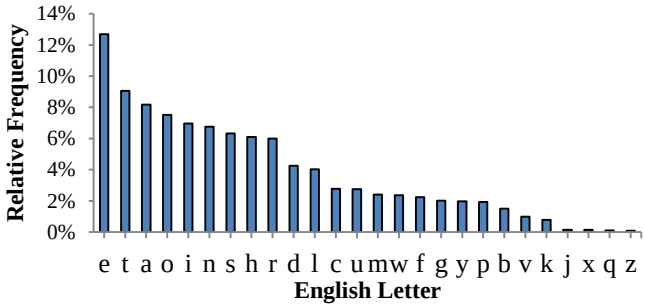

Fig. 10. Relative frequencies of 26 letters in English writing.

Fig. 11. Recall accuracies of 26 English letters.

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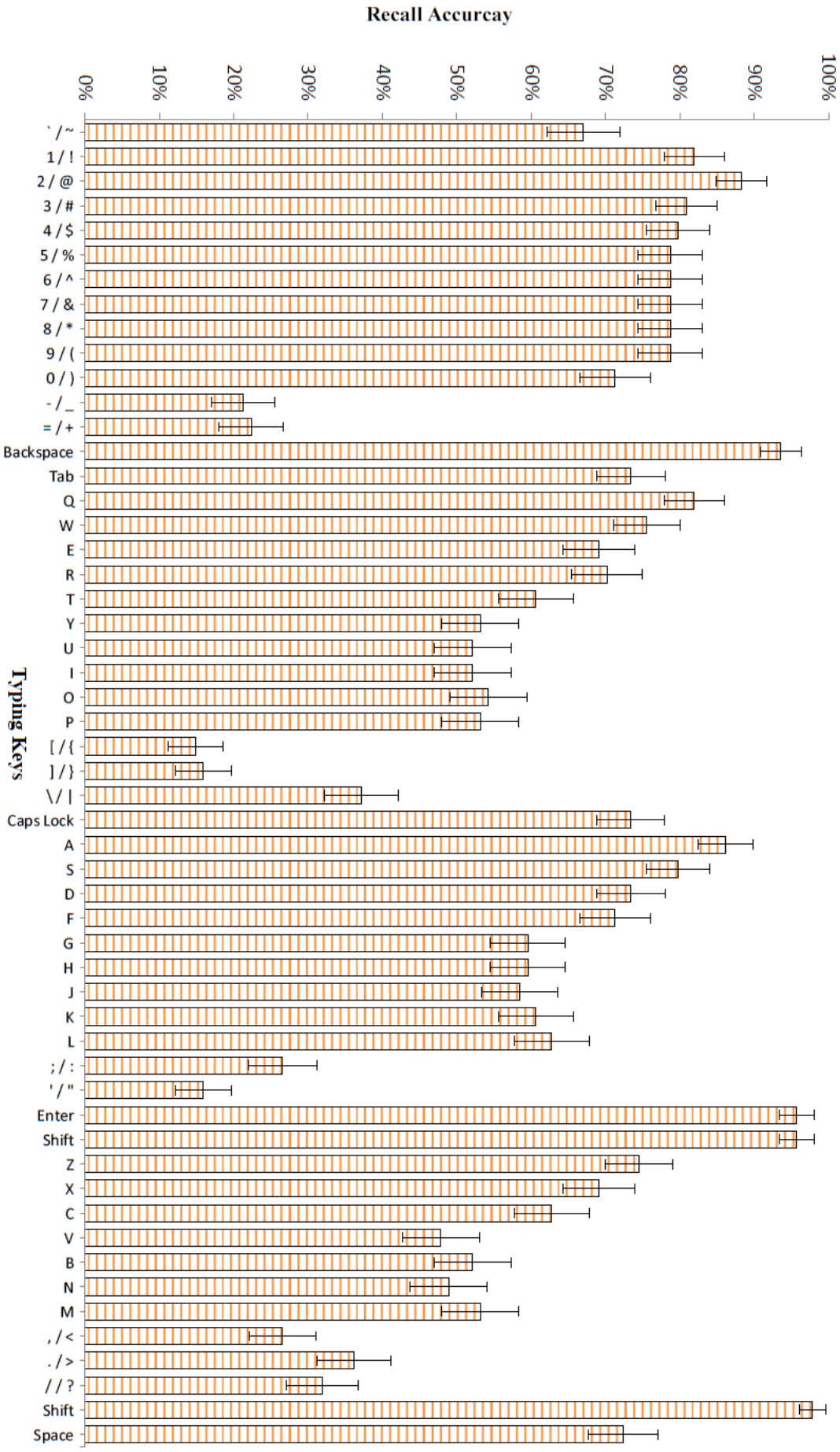

Fig. 5. Typing Keys correct percentage

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IV. DISCUSSION

A. Control Keys

Among the control keys, the recall accuracies for "Print screen", "Scroll Lock", and "Pause Break" were significantly lower than those for the other control keys. As the functions of these keys are rarely used for normal computing exercises nowadays, it would be difficult for the participants to recall the labels of these keys. In a subsequent interview after the experiment, some participants even reported that they did not realize the functions of "Scroll Lock" and "Pause Break". In fact, "Pause Break" was a useful function to stop the running of a program in the DOS era. However, with the advanced computer operating system, this function is not very much in use now.

In a subsequent analysis on the recall accuracies for the repeated control keys "Shift", "Ctrl", "Alt", and "Enter", the results showed that there were no significant differences in recall accuracies between the left-right keys of "Shift", "Ctrl", and "Alt". However, significant difference was observed for left-right key of "Enter", with the recall accuracies for left "Enter" being significantly higher than that for right "Enter". It may be partly explained by the fact that the left "Enter" is located in the main typing area which is of much higher frequency of use than the right "Enter" clustered in the numeric keypad area.

Also, the results showed that the recall accuracies for these control keys were comparatively higher than that for the alphanumeric keys in close proximity. These might be the results of the salient positions of these keys at the edge of the keyboard layout as well as their different sizes and shapes as opposed to the uniform size of the other typing keys.

B. Function Keys

The recall accuracies for "Function Keys" were all above 90% and significantly higher than the recall accuracies for "Typing Keys" and "Control Keys". It might be due to the fact that the twelve function keys (F1 to F12) occupy a relatively independent area which could be easily differentiated from other parts of the keyboard, such that participants could readily recognize and recall the corresponding meanings of the keys. In addition, the arrangement of the function keys conforms to the general expectation of incremental values moving from left to right [10, 11]. The immediately adjacent key could therefore provide a useful hint for participants' prediction of the meaning of the next key in the same row.

C. Typing Keys

It should be noted that among the alphabetic keys, the recall accuracies decreased gradually from left to right for each row of keys. As the general reading habit for English writing is from left to right and it is expected that the best reading and memorize area should be in the left corner of the keyboard, and the key located closer to the upper left corner, the higher recall accuracy should be achieved [10, 11]. Also, the absence of significant association between the relative frequency of use of English letters and their recall accuracies provided partial evidence that the typing task relies heavily on implicit rather than explicit memory for processing. Thus, as participants utilize muscle memory for typing, they could subconsciously locate the desired key. However, when they were asked to recall the location of each typing key on a blank keyboard, they had to search from their explicit memory on which the typing task does not usually depend, such that on average relatively low recall accuracy was resulted for the alphanumeric keys which cluster in the main area of the keyboard, as opposed to the function and control keys which are with more salient locations.

D. Numeric Keys

In this study, the recall accuracies for numeric keys on "Numeric Keypad" were significantly higher than those on "Typing Keys". As the isolated numeric keypad has a calculator-like layout with which we commonly operate in daily life, such as the Automated Teller Machine (ATM), participants could easily transfer their experience from their familiar layout to the recalling for the numeric keys on the "Numeric Keypad" here [12-14]. Also, the numeric keys on "Numeric Keypad" are arranged in a logical and sequential order which could facilitate the recalling for the numeric keys, resulting in significantly better recall accuracies than the recalling for the alphabetic keys. It should be noted that the numeric operators "/", "*", and "-" on "Numeric Keypad" had comparatively lower recall accuracies, due very likely to their low utilization rate in normal typing tasks.

V. CONCLUSION

The results of this study showed that participants had relatively lower recall accuracies for the alphabetic keys. Such finding is in agreement with the general expectation that typing tasks are very much dependent on the processing of our implicit memory (or muscle memory) rather than explicit memory. As the sample sizes of male and female participants are substantially different, the authors did not conduct any statistical analyses of differences in performance between them. The recall accuracies for different keys on the keyboard were systematically analyzed and compared. Some useful recommendations for more user friendly keyboard design were provided.

A. A tactile cue should be added to the first and the last key of "Function keys" (i.e., F1 to F12) and numeric keys in "Typing keys" (i.e., 1-0) to help the users locate the keys.

B. Some keys such as "Scroll Lock" and "Pause Break" are rarely used nowadays and should therefore be removed to allow a more compact design of the keyboard.

C. Keyboard designed in a way resembling to the devices of our daily operation could facilitate the transfer of use experience and enhance the recall accuracy for typing tasks.

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