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Effect of Mechanical Keyboard Switch and Backlight Status on Typing Performance and User Experience

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Abstract: Mechanical keyboards are one of the most used keyboards in daily work, and as the core component of a mechanical keyboard, keyswitches' characteristics have been widely researched during the last several decades. Meanwhile, keyboards' backlight design has become an emerging market trend, even though its actual influence on user experience remains unknown. Our study investigated the influence of keyboard switch characteristics and backlight states on typing performance and subjective typing experience. Thirty-three participants were involved in an English-language typing task on keyboards with four typical switches (red, black, brown, and blue types). Software was used to automatically record typing speed and accuracy, and a 7-point Likert subjective scale was used to evaluate typing experience. Results showed that tactile characteristics performed better than linear switches in typing speed, accuracy, and subjective refresh feeling in pair comparison of blue and red switches, and turning on the backlight effect improved typing speed, refreshing feeling, and pleasure. Among six physical characteristics of switches measured in the experiment, pre travel, reset travel, make force, and bottom force contributed more to better typing performance and subjective experience. Our findings provide keyboard manufacturers and researchers with a reference to optimize users' typing experience.

Keywords: mechanical keyboard; keyswitch design; backlight effect; human–computer interaction

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1. Introduction

As an essential input peripheral of computers, keyboards have long attracted public attention. Working on keyboards means that fingers need to move across a certain area and perform the pressing action repeatedly, which may lead to some health problems, such as tendinitis in the hand and wrist, carpal tunnel syndrome, and tenosynovitis [1]. Previous studies show that repetitive movements when using a keyboard for a long time may cause musculoskeletal diseases [2]. Moreover, as a result of the widespread use of keyboards in electronic data systems, both employers and employees suffer from upper extremity injuries [3]. Decreasing the use of keyboards, such as by using voice recognition technology, might be an option, but may only be applicable in private working spaces. For people who are reliant on typing for their work in an office environment, keyboard typing performance and user experience undeniably influence their working efficiency and subjective feelings.

Desktop keyboards can be primarily classified into rubber dome and mechanical keyswitch keyboards. Compared with rubber dome keyboards, less muscle effort was observed on mechanical keyboards [4]. Additionally, owing to the relatively short lifespan and the flat clicking feeling while using rubber dome keyboards, more consumers prefer mechanical keyboards. The core component of a mechanical keyboard is the switch under the keycaps, as shown in Figure 1, which greatly influences users' clicking feeling.

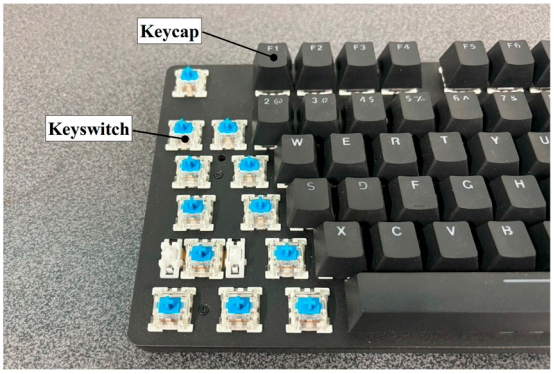


Figure 1. Keyswitches and keycaps on the keyboard.

Cherry is one of the most profitable keyboard switch manufacturers, prominent for its MX Series of switches [5]. The most common and classic keyswitches from this company are red, brown, blue, and black switches. One necessary point to mention is that the four colors mentioned above are just the names of the keyswitches, used to differentiate each from the rest; thus, they have nothing to do with the visual elements of the keycaps if they are installed. Table 1 lists some basic physical characteristics of the four mentioned switches. The differences between the four mentioned keyswitches have to do with their physical mechanism structure; thus, they have different force–travel curves, as shown in Figure 2.

Table 1. Physical characteristics of red, black, brown, and blue keyswitches from Cherry public product information [6].

Keyswitch	Red	Black	Brown	Blue
Switching Characteristic	Linear	Linear	Tactile	Tactile and audible
Make Force	45 cN	60 cN	55 cN	60 cN
Pre Travel	2.0 mm	2.0 mm	2.0 mm	2.2 mm
Total Travel	4.0 mm	4.0 mm	4.0 mm	4.0 mm

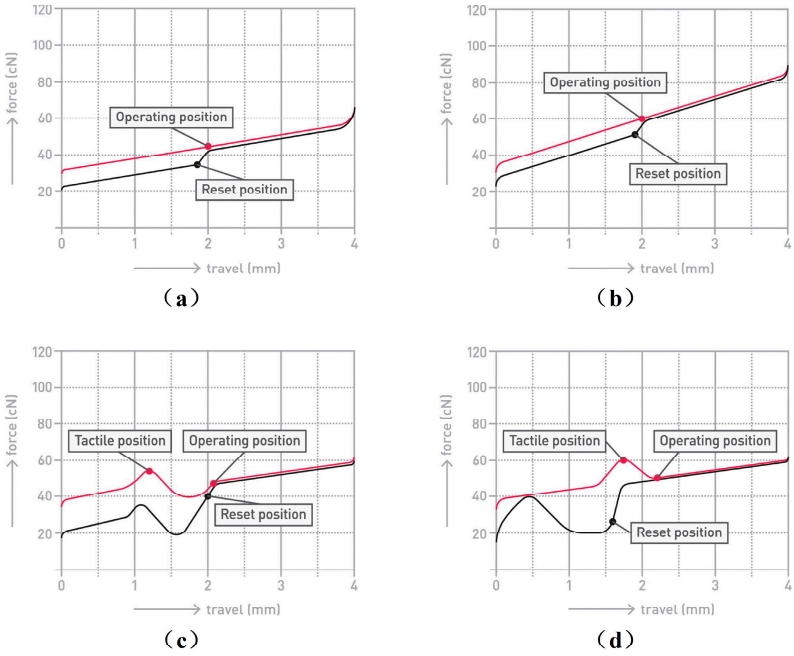


Figure 2. Red, black, brown, and blue keyswitches force–travel curves from Cherry public product information [6]. (**a**) Red switch; (**b**) black switch; (**c**) brown switch; (**d**) blue switch.

Force–displacement curves have been widely used to discuss keyswitch characteristics, which describe the relationship between the pressing force and the switch displacement. According to the curve shape, mechanical switches can be divided into linear switches and tactile switches. The force–travel curve of a linear switch seems like an approximate straight line, such as with the red and black switches shown in Figure 2, while the tactile switch presents a more irregular curve with some fluctuation, such as in the brown and blue switches. These differences lead to the different pressing feelings of the linear and tactile switches. Linear switches have a top–down straight-through feeling and have little tactile and auditory feedback, while tactile switching involves a snap feeling when clicked and has clearer haptic and auditory feedback.

The curves also indicate some technical terms of switches. Make force, activation force [7,8], and operation force [2,9,10] have the same meaning, representing the force needed to activate a key. Both the operating position, as shown in Figure 2, and the pre travel relate to the displacement corresponding to the make force, which is the same as the activation force and operation force. Total travel means the displacement to the bottom of the switch and the pressing force at this point is named as the bottom force. During the resetting process, the displacement where the switch regains an inactivated status is called the reset displacement (presented by reset position in Figure 2), which is associated with reset force. Tactile position is the unique parameter of tactile switches, which means the peak force preceding a distinct drop in force during key travel, as shown in Figure 2c,d. To avoid potential confusion, make force, bottom force, reset force, pre travel, total travel, and reset travel were adopted as the names of the switch parameters in this research.

Keyswitches have received extensive attention from researchers. Characteristics of switches are categorized as various forces and travels [1], which have been widely researched. A higher make force has been found to be associated with increased muscle activity [11]. Thus, a make force lower than 0.47 N is recommended [12]. A longer key travel can decrease pressing forces [13]; however, it comes at the cost of higher peak muscle activity [8]. As for classification, linear switches are less preferred than tactile switches [14,15] and the former perform worse than the latter in terms of typing performance [8]. Switch interaction feedback is also discussed, as typists prefer switches with clearer haptic and auditory feedback [1] and these switches have better typing efficiency [16].

Mechanical keyboard manufacturers have provided colorful onboard backlight designs. Currently, onboard backlight effect design has gained popularity among keyboard users for exhibiting personal taste and identity, which has been a crucial design element and an emerging trend in the mechanical market. Therefore, keyboard backlight design can play an effective role in addressing the issue of typing performance and user experience and is worth researching.

2. Related Work

2.1. Overview on Keyboard Research

Keyboards have piqued the interest of researchers from many fields. Some researchers have investigated the influence of the keyboard layout and shape. Three keyboard design features (lateral inclination, rotation, and slope) have been found to have no significant impact on the discomfort and fatigue of users [12]. Negative slope keyboards are geometrically superior to traditional keyboards in terms of typing performance and user preference [3]. An ergonomical keyboard design can significantly influence typing speed and error rate with a proper training effect [17]. The Dvorak and QWERTY layouts were summarized as two commonly used keyboard layouts, and the former could improve typing speed with more keystrokes on the middle row of the keyboard [18]. With the GEM (Guided Evaluation Method) to estimate the training typing performance among novices, the OPTI layout was concluded to outperform the traditional QWERTY layout [19]. A layout comprising rectangular buttons with separate number keys has been shown to lead to higher typing speed, user comfort, and reception, whereas square buttons are associated with higher accuracy [20]. The concept of a single-line keyboard called One Row Keyboard

(ORK) has been proposed to simplify the keyboard layout [21]. A dynamic virtual keyboard layout called Keydrop was proved to be helpful for improving typing speed and reducing typos [22]. Some studies have compared physical and virtual keyboards. Physical keyboards (on laptops and desktops) have an advantage over virtual keyboards in terms of typing speed, accuracy, and user preference, but require higher finger muscle activity [9]. Similarly, typing speed on a physical keyboard is significantly higher than on a virtual keyboard, but no difference in accuracy was observed [23].

2.2. Keyswitch Characteristics

As one of the key factors on a keyboard, the keyswitch has received considerable attention from researchers. Keyswitches' physical characteristics can be measured by a force–travel curve. Thus, many studies have investigated the influence of these two factors. For force-related research, after evaluating the muscle activity when typing, it was found that keyswitches with a make force of 0.47 N or less should be preferred over those with 1.02 N [12]. Additionally, after comparing keyswitches with a make force of 0.28 N, 0.72 N, and 0.83 N, significantly higher subjective discomfort and more muscle activity were observed on 0.83 N keyswitches [11]. Pressing force and finger joint torque generally increase with make force; however, this relationship is not monotonic [10]. People tend to press a keyswitch with a force that is two to seven times greater than required, which denotes the make force [1]. Regarding travel, it has been found that keyswitches with longer travel can decrease the user's pressing force without sacrificing typing performance [13]; however, a longer pre travel seems to increase peak muscle activity [8]. When comparing keyboards with different travel characteristics, conventional keyboards performed better in terms of users' self-reported comfort and preference than ultra-low travel keyboards [24]. In terms of micro-travel keyboards, devices with a short travel (0.55 mm) and a dome switch mechanism were associated with more muscle activity, higher typing forces, and a slower typing speed, compared with keyboards with longer travels (1.3 mm and 1.6 mm) and butterfly and scissor switch mechanisms [25]. When simulating the gaming condition, keyswitch travel can also influence the attention allocation and subjective experience of the keyboard user [7].

As for the keyswitch force–travel curve, the curve shape can be used to obtain information. As mentioned above, keyswitches can be classified into linear switches and tactile switches, based on whether the shape presents an approximate linear relationship. Typists demonstrated a lower preference for low-resistance linear keyswitch keyboards [15], and similarly, a high-resistance linear keyswitch was the least preferred in another typing experiment [14]. Linear switches had the worst typing performance and were the least preferred, even though they have a slight advantage in terms of muscle activity [8]. Tactile switches were superior to linear ones in terms of satisfaction, finger fatigue, and pleasure [7]. As a possible influencing factor of this phenomenon, switch interaction feedback has also been discussed in detail. Typists prefer haptic and auditory feedback from keyswitches when typing [1]. This may be interpreted as showing that typing accuracy on switches with more distinct haptic and auditory feedback is significantly higher than on keyswitches with faint feedback. People seem to have a polarized attitude toward clear feedback switches, as they either "very much like or dislike" them [16]. Typing force and muscle activity are less significant on buckle spring keyswitches, which can be explained by the enhanced feedback characteristics of this kind of switch [11]. On laptop keyboards, more haptic feedback may be able to reduce the inordinate key strike force [26]. Moreover, the manufacturing process and keyswitch materials are also discussed [5], and the quality function deployment (QFD) method was adopted to retrieve the main design elements of a keyboard [27].

2.3. Keyboard Backlight Effect

Regarding the backlight effect on keyboards, many studies are based on specific technical issues. Backlight keyboards solutions and relative technical designs have been summarized and a new illuminated design was proposed to fix existing problems [28]. A

thinner LED-based (Light Emitting Diode) backlight has been designed for keyboards to provide brightness and uniformity [29], and a light detection system with machine vision has been proposed as a solution to the lighting problems of backlit keyboards, such as the illumination of the incorrect area [30]. Automatic brightness adjustment of keyboard backlights saves energy and protects the battery [31]. Few researchers have investigated the direct linkage between keyboard backlight design and typing experience; however, a light effect has been proven to impact emotions in the driving cabin scenario [32], and emotions aroused by visual elements has been proven to influence keyboard use [33].

In summary, a host of researchers have investigated how certain keyswitch parameters separately influenced typing performance and experience, while few studies have examined which keyswitch characteristics affect user experience to a significant degree. Further, although several studies are concerned with mechanical keyboard backlight design, they focus on the manufacturing and technology of the onboard light, and how this emerging keyboard element influences human–computer interactions remains unknown. Thus, this study aims to explore which keyswitch parameters are most effective with factor analysis and linear regression, and whether the onboard backlight effect can ensure a better user experience. The contribution of this research is to evaluate the weight of commonly researched keyswitch parameters and the influence of keyboard backlight design in human–computer interactions with keyboards during the typing process.

3. Materials and Methods

A two-way within-subject experiment was designed to measure typing efficiency and user experience. Participants were required to complete a typing task with four different keyboards and typing performance data were collected by typing software.

3.1. Hypotheses

Previous studies have shown that tactile switches have advantages over linear ones in both typing performance and experience [7,8]; thus, it is reasonable to deduce that blue and brown switches perform better than red and black switches. Among switch characteristics, a higher make force was associated with more muscle activity and worse subjective feeling [11,12], a longer pre travel could increase peak muscle activity [31], and switches with longer total travel significantly improved self-reported comfort and were preferred by users [24]. Many parameters have been mentioned but few studies have investigated which of these switch characteristics are most effective and how they combinedly influence user experience. No direct evidence has shown that the keyboard backlight effect can influence typing performance; however, there may be a relationship through emotion, the intermediate variable [32,33]. To investigate the influence of the keyswitch type and keyboard backlight effect on typing experience, and the effectiveness of the switch parameters, this research employed the following hypotheses:

H1. *Typing with blue and brown switches leads to a higher typing speed and accuracy.*

H2. *Typing with blue and brown switches leads to a better subjective typing experience.*

H3. *Turning on the backlight effect leads to a higher typing speed and accuracy.*

H4. *Turning on the backlight effect leads to a better subjective typing experience.*

H5. *Make force, pre travel, and total travel are the most effective swtich parameters when it comes to improving typing performance and experience.*

3.2. Variables

Two independent variables were set for this research: the keyswitch type (red, black, brown, and blue) and the states of the keyboard backlight effect (on vs. off). The backlight

effect of the keyboard is shown in Figure 3, which is a comparison of the visual effect between the states of turning it on and off.



Figure 3. Backlight effect comparison of keyboard.

The dependent variables included two aspects: the objective typing performance and the subjective typing experience. Speed and accuracy were used to measure the typing performance [23]. Typing speed and accuracy can be automatically recorded by typing software, and the former was measured in correct KPM (Keystrokes Per Minute). Both KPM [14,15] and WPM (Word Per Minute) [24] can be used to measure typing speed; this research took KPM as the same measurement as the typing software output. For subjective typing experience, pleasure and satisfaction were adopted as subjective evaluation indicators in mechanical keyboard usability research [34]; these two factors were also used in the subjective questionnaire when investigating attention allocation while typing [7]. In addition, a refreshing feeling was found to be one of the key factors in the use of physical keyboards [27]. Therefore, "refreshing", "pleasurable", and "satisfying" were adopted as subjective indicators: refreshing referred to a delightful feeling of releasing certain negative emotions, or a feeling of relief from stress or tension; pleasurable referred to a feeling of happiness and enjoyment; and satisfaction referred to a positive feeling of achievement and contentment, which comes from fulfilling a desire, need, or expectation.

3.3. Experimental Design

The experiment was conducted at Tianjin University in a controlled environment. All participants completed the typing task in the same room, as shown in Figure 4. The room temperature was maintained at 26 °C and the illumination was kept at 400 lx in the keyboard center area while the typing software interface was present on the screen. Ambient noise was kept below 35 dB. The worktable measured 126 cm × 63 cm × 75 cm and the keyboard was placed 7 cm from the edge of the table, which followed a previous study [24]. The chairs were adjusted to ensure that the distance between the center of the screen and the participants' eyes was 60 cm [20]. Participants were allowed to adjust themselves until they felt comfortable enough to type on the keyboard, after which they were required to maintain a constant posture and the chair remained unchanged.



Figure 4. Experimental setup.

3.4. Participants

In this research, the G*Power 3.1.9.7 [35] program was used to perform a priori power analysis at a significance level of 0.05 ($\alpha = 0.05$), a statistical power (1-β) of 0.95, and with a medium effect size ($f = 0.25$) [36]. In addition, repeated measures ANOVA (analysis of variance) within factors was used and the number of the measurements was set to eight (four switches by two backlight effects). The correlations value was set to 0.5 and the nonsphericity correction was set to one ($\varepsilon = 1$) by default, then the calculated recommended total sample size was 23.

Considering the possibility that invalid data might be excluded, a total of 33 participants, comprising 11 females (mean = 23, SD = 6.472) and 22 males (mean = 24, SD = 4.346) were invited to the experiment. All participants reported being able to type in English with mechanical keyboards and reported no visual, auditory, or touch disorders. Each participant signed a written informed consent form prior to the formal typing experiment.

3.5. Stimuli and Apparatus

Four mechanical keyboards from the Rapoo brand in Shenzhen, China (model V500 Pro) with red, brown, black, and blue switches were used in the experiment. All keyboards were identical, except for the keyswitch, and were equipped with onboard lights. Their force–travel curves are shown in Figure 5 and their physical parameters are listed in Table 2.

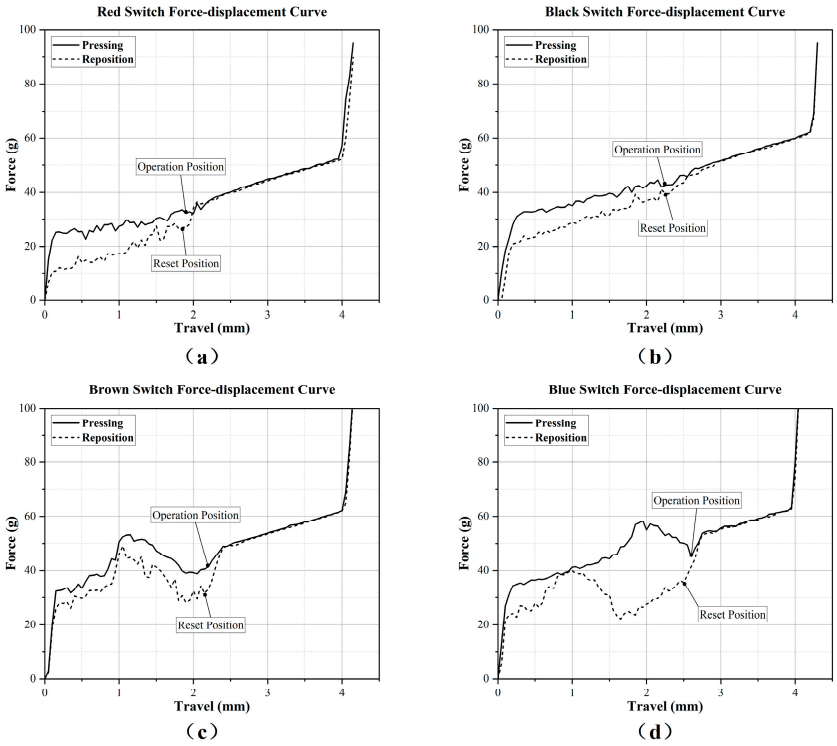


Figure 5. Force–travel curves of four keyswitches used in this research. (**a**) Red switch; (**b**) black switch; (**c**) brown switch; (**d**) blue switch.

Table 2. Physical characteristics of the four switches used in this research.

Keyswitch	Red	Black	Brown	Blue
Make Force	32.16 g	42.72 g	41.33 g	45.21 g
Reset Force	26.83 g	39.64 g	31.5 g	35.56 g
Bottom Force	52.18 g	62.31 g	62.18 g	63.38 g
Pre Travel	1.9 mm	2.25 mm	2.2 mm	2.6 mm
Reset Travel	1.85 mm	2.25 mm	2.15 mm	2.5 mm
Total Travel	3.95 mm	4.2 mm	4.0 mm	3.95 mm

A specially designed device was used to measure the switches of the four selected keyboards, as shown in Figure 6. This device was based on the design theory of previous research, which combined force and travel sensors, moving vertically together to measure the force and switch travel [37]. Unusually, this device was manually operated instead of using a step motor; thus, the parameters were measured in quasi-static mode. The main component of the device was the screw slide fixed on the table, with a displacement of 50 mm, a lead of 5 mm, and a resolution of 0.03 mm. A handwheel was used to control the upward and downward movement of the sliding table, and a laser distance scanner (HL-G112-A-C5 from Panasonic in Beijing, China) was used to measure the key travel, with a measuring range of 120 mm and a resolution of 8 μm. A strain gauge cell was fixed onto a sliding table by a 3D-printed connector to measure the pressing force, which could be viewed from the dashboard. The connector, strain gauge cell, and dashboard were customized by a local manufacturer (Anhui JingCe Intelligent Technology in Bengbu, Anhui, China), with a measuring range of 200 g and a resolution of 0.06 g. All measuring device ranges could cover the selected switch total travels to ensure the accuracy of measurement. First, the cell probe was aligned with the switch and then the sliding table was manually moved downwards by 0.05 mm each time to measure the force curve of the pressing process, until the switch reached the bottom. Subsequently, the sliding table was moved upwards to retrieve a force curve of the resetting process. During the test, keyboards were connected to the computer to observe the activation and reset points. Notably, force has been measured by both N [12] and g [8] in previous research. Because the force was represented on the dashboard through g in this research, as shown in Figure 6, we take g as the unit of force measurement in this research, to avoid any conversion deviation between units.

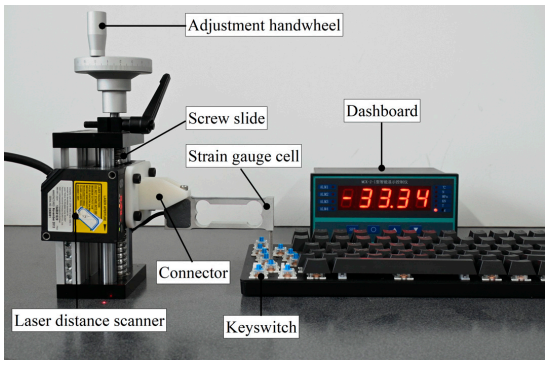


Figure 6. Keyswitch parameters measuring device.

Forty randomly selected chapters from Grimm's Fairy Tales were used as the typing text [9]. Each chapter had an average of 442 words, and none of the participants were able to finish any of the 40 chapters during a single text entry task, indicating that the number of words was sufficient. The Jinshandazi 2003 version was used as the typing software for its automatic speed and accuracy recording function. A desktop computer with an Intel (R) Core (TM) i3-4170 CPU @3.70Ghz, 4 GB RAM, and Windows 10 Home 20H2 version operating system was used. The typing text was displayed on a 24-inch monitor with a resolution of 1920 × 1080, which was a DELL model E2414H.

3.6. Experimental Procedure

Before the formal experiment, an online questionnaire was prepared to collect participants' subjective feedback using a 7-point Likert scale ranging from −3 to 3 [9]. Here, −3 represented the worst experience and 3 the best experience. Thereafter, the experiment table was prepared in a manner that ensured that there would be no disturbances and that the computer and keyboard worked properly.

Afterwards, the experimenter introduced the tasks, and the participants clicked on four keyboards to feel the characteristics of the four keyswitches. First, all participants

were informed about the meaning of the three subjective feelings. Second, the keyboard light was turned off and participants kept typing for two minutes with a randomly chosen keyboard and typing text. According to previous research, the typing duration should be short to avoid participants feeling tired of typing [38], and it is appropriate to finish a typing experiment in 30 min for every participant [8,26,27]. Considering that every participant needed to finish eight typing missions besides preparation and rest, a two-minute typing duration was adopted in this research. They were asked to type as usual, which meant that they could follow their own daily typing habits and did not need to ensure that the text was typed accurately or in full [23]. An example of the typing software interface is shown in Figure 7. The target English texts were only presented visually on the first line in the software while the participants' typing results were shown on the second line. The black block cursor indicated the character to input and the typing process. This software automatically recorded the typing data. There was a one-minute break after every typing session, during which the participants filled in the 7-point emotion Likert scale to evaluate their subjective typing experience. They were invited to score their three kinds of feelings (refreshing feeling, pleasure, and satisfaction) individually from −3 to 3 on an online questionnaire system. Next, the participants finished typing with the other three randomly chosen keyswitches and texts, filling in the scale another three times to complete the whole typing assignment with four keyswitches that had the onboard backlight effect turned off. Third, the onboard light was turned on. The light effect was kept in constant-on mode and was not influenced by typing behavior. Each participant completed four more typing tasks with randomly chosen keyboards and texts, as in the previous step. Finally, a short interview was conducted with each participant to record their overall thoughts about the typing process on the four keyboards. The whole experiment lasted for about 30 min.

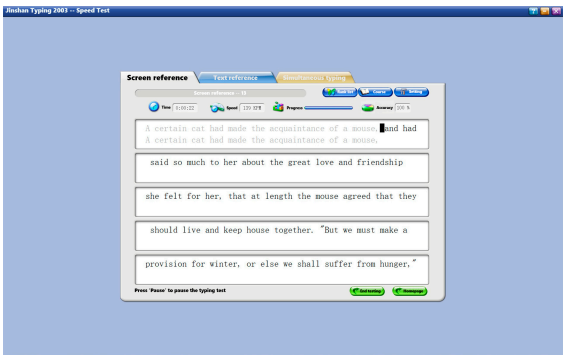


Figure 7. Typing software interface.

4. Results

The typing test data of two participants were removed because they reported themselves to be touch typists in the interview, who might not be influenced by the backlight effect. According to our observations in the experiment, the rest of the participants all needed to look at keyboards occasionally to finish the typing mission. Then, SPSS 24.0 was used for data analysis. First, a reliability and validity analysis of dependent data was conducted. Second, an in-group two-way repeated-measures analysis of variance (RM-ANOVA) was used to investigate the influence of keyswitches and backlight effect on typing performance (typing speed and accuracy) and user experience (refreshing feeling, pleasure, and satisfaction). Lastly, factor analysis and linear regression were conducted to analyze the most influential parameters of keyswitches.

4.1. Reliability and Validity Analysis

Cronbach's alpha value was used to measure data reliability, wherein a value between 0.7 and 0.8 was regarded as satisfactory, and a value greater than 0.9 indicated high reliability [39]. Factor analysis was used to analyze the validity, which could be evaluated using the Kaiser–Meyer–Olkin (KMO) test; the result is shown in Table 3. Regarding

reliability, all dependent variables were greater than 0.7, which meant the data were reliable. In terms of validity, even though subjective variables had lower KMO values than objective ones, both were acceptable.

Table 3. Cronbach's alpha for reliability analysis and KMO for validity analysis.

	Cronbach's Alpha	KMO	*p*
Typing speed	0.985	0.941	<0.001
Accuracy	0.910	0.815	<0.001
Refreshing feeling	0.791	0.694	<0.001
Pleasure	0.734	0.613	<0.001
Satisfaction	0.822	0.693	<0.001

4.2. Two-Way Repeated-Measures ANOVA

The RM-ANOVA results are listed in Table 4 and Figure 8. Notably, the significance (p) of the two-way RM-ANOVA was calculated according to the result of Mauchly's test of sphericity. The Greenhouse–Geisse and Huynh–Feldt methods could have been used to modify the result [40] had the data not supported the sphericity hypothesis. The Huynh–Feldt method was recommended; however, it would have been better to adopt the Greenhouse–Geisse method [41] had the epsilon value been greater than 0.75.

Table 4. The RM-ANOVA result of five dependent variables.

	Statistics	Keyswitch	Light	Keyswitchc × Light
Typing Speed	*F*	4.208	69.406	0.601
	df	3	1	2.840
	p	0.008	<0.001	0.607
	Partial η^2	0.123	0.698	0.020
Accuracy	*F*	8.894	0.412	0.889
	df	3	1	2.783
	p	<0.001	0.526	0.444
	Partial η^2	0.229	0.014	0.029
Refreshing Feeling	*F*	6.709	12.444	2.189
	df	3	1	3
	p	<0.001	0.001	0.095
	Partial η^2	0.183	0.293	0.068
Pleasure	*F*	3.330	8.999	1.219
	df	3	1	3
	p	0.029	0.005	0.308
	Partial η^2	0.101	0.231	0.039
Satisfaction	*F*	1.614	3.9360	1.143
	df	3	1	2.956
	p	0.192	0.056	0.336
	Partial η^2	0.051	0.116	0.037

No significant interactive effect of keyswitches and backlight states was observed. Turning on the backlight effect could significantly improve typing speed [F(1,30) = 69.406, $p < 0.001$, partial η^2 =0.698], refreshing feeling [F(1,30) = 12.444, $p = 0.001$, partial η^2 =0.293], and typing pleasure [F(1,30) = 8.999, $p = 0.005$, partial η^2 =0.231], but it had no significant influence on typing accuracy and satisfaction. Keyswitches could significantly influence typing speed [F(3,28) = 4.208, $p = 0.008$, partial η^2 =0.123], accuracy [F(3,28) = 8.894, $p < 0.001$, partial η^2 =0.229], refreshing feeling [F(3,28) = 6.709, $p < 0.001$, partial η^2 =0.183], and pleasure [F(3,28) = 3.330, $p = 0.029$, partial η^2 =0.101].

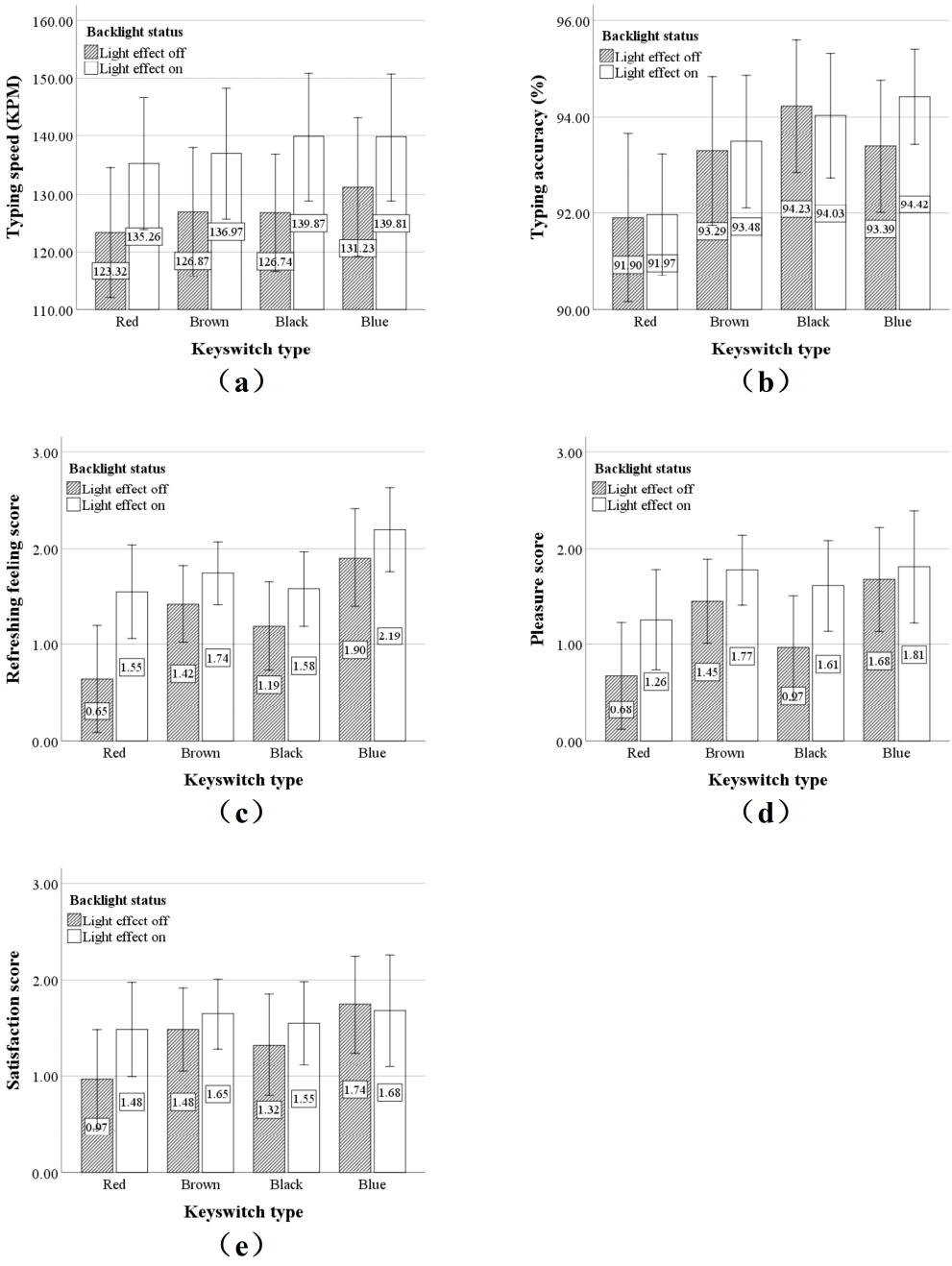


Figure 8. Dependent variables mean value charts with error bars based on 95% CI. (**a**) Typing speed; (**b**) typing accuracy; (**c**) refreshing feeling score; (**d**) pleasure score; (**e**) satisfaction score.

According to the pair comparison result (with Bonferroni main effect) for the backlight effect, typing speed with the backlight effect on (mean = 137.976, SD = 5.265) was significantly [$p < 0.001$, CI = (8.255, 13.616)] higher than that with the backlight effect off (mean = 127.040, SD = 5.191). The refreshing feeling score with the backlight on (mean = 1.766, SD = 0.139) was significantly [$p = 0.001$, CI = (0.200, 0.751)] higher than with the backlight turned off (mean = 1.290, SD = 0.168). The pleasure score with the backlight on (mean = 1.613, SD = 0.163) was significantly [$p = 0.005$, CI = (0.134, 0.705)] higher than with the backlight off (mean = 1.194, SD = 0.157). No significant influence was discovered on accuracy and satisfaction in the backlight effect pair comparison. As for the switches, typing speed on blue switches (mean = 135.516, SD = 5.519) was significantly [$p = 0.003$, CI = (1.728, 10.724)] higher than that on red switches (mean = 129.290, SD = 5.457). Typing accuracy on red switches (mean = 91.935, SD = 0.643) was significantly [$p = 0.003$, CI = (0.626, 3.761)]

lower than that on black switches (mean = 94.129, SD = 0.602) and [p = 0.006, CI = (0.432, 3.504)] blue switches (mean = 93.903, SD = 0.516). Regarding the refreshing feeling, the score for red switches (mean = 1.097, SD = 0.214) was significantly [p = 0.017, CI = (0.122, 1.781)] lower than blue switches (mean = 2.048, SD = 0.210). No significant influence was observed regarding pleasure and satisfaction in the switch pair comparison.

4.3. Factor Analysis and Linear Regression

Factor analysis and linear regression were conducted to investigate the efficacy of physical characteristics and the relationship between the factors and their outcomes.

Six parameters were measured in this research, which might be redundant for linear regression; thus, factor analysis was adopted to reduce the dimensions. Firstly, all the raw parameter raw were standardized to eliminate the influence of their physical dimension. Secondly, the covariance matrix was calculated, then the eigenvalue and eigenvector were derived. Lastly, the main factors were deduced according to the cumulative contribution of the eigenvalue. The six physical parameters measured in Table 2 (three kinds of forces and three kinds of travels) were taken as factors and a dimensionality reduction process was created in SPSS. Results are shown in Table 5 after calculating the rotated matrix. The KMO could not be used to evaluate the suitability of the factor extracting process because the samples (four switches) were less than the factors (six parameters).

Table 5. Main factors (eigenvalue greater than one) extracted from six chosen factors.

		Factor 1	**Factor 2**
Statistics	Eigenvalue	4.598	1.250
	Variance percentage	76.625%	20.832%
Factor composition	Make force	0.950	0.291
	Reset force	0.661	0.734
	Bottom force	0.896	0.342
	Pre travel	0.991	−0.013
	Reset travel	0.985	0.118
	Total travel	0.025	1.000

According to the factor composition results, if the Factor 1 coefficient of a parameter is bigger than that of Factor 2, we would assume this parameter contributed more to Factor 1, and vice versa. As a result, Factor 1 represented approximately three-quarters of the keyswitch characteristics, focusing on make force, bottom force, pre travel, and reset travel, while Factor 2 focused on reset force and total travel. Next, a linear regression of these two factors and the five dependent variables was conducted to examine their relationships, as shown in Table 6.

Table 6. Linear regression result of Factors 1 and 2 with dependent variables.

	Statistics	**Regression p**	**Constant**	**Factor 1**	**Factor 2**
Typing Speed	Coefficient	0.521	132.508	2.198	0.358
	p		<0.001	0.260	0.854
Typing Accuracy	Coefficient	0.002	93.339	0.713	0.468
	p		<0.001	0.003	0.051
Refreshing Feeling	Coefficient	<0.001	1.528	0.336	−0.088
	p		<0.001	<0.001	0.268
Pleasure	Coefficient	0.007	1.403	0.279	−0.050
	p		<0.001	0.002	0.571
Satisfaction	Coefficient	0.115	1.484	0.173	−0.024
	p		<0.001	0.040	0.775

According to the regression result, if Factor 1 and 2 are expressed by x and y, respectively, three significant relationships could be described by the formulas below. All three coefficients of x (factor 1) had significance, while none of the coefficients of y (factor 2) had statistical significance:

$$\text{Typing accuracy} = 93.339 + 0.713x + 0.468y \ (p = 0.002), \quad (1)$$

$$\text{Refreshing feeling score} = 1.528 + 0.336x - 0.088y \ (p < 0.001), \quad (2)$$

$$\text{Pleasure score} = 1.403 + 0.279x - 0.05y \ (p = 0.007) \quad (3)$$

where typing accuracy was measured with a percentage, and refreshing feeling and pleasure were measured in a score from −3 to 3. Additionally, x and y (Factor 1 and 2) were both standardized variables; thus, they were not applicable as physical dimensions.

5. Discussion

When the backlight effect was turned on, it improved typing speed and provided a refreshing feeling and pleasure, which supports hypotheses 1 and 2. The influence of the backlight effect on typing speed might be attributed to the participants' hunt-and-peck typing style, which meant they needed to look at the keyboard. In this case, the lights on the keyboard made it easier to find certain keys, thereby helping users achieve a higher typing speed. The refreshing feeling and pleasure observed aligned with the results of a previous study, which found that in-car light effects could significantly influence emotions [32]. The backlight effect being turned on had no impact on typing accuracy, a result that contradicts a previous study, which suggested that the emotions aroused by visual stimuli could significantly influence accuracy [33]. One possible explanation is that emotion might not be the intermediate variable between light and accuracy, or that a switch auditory feedback effect [38] could have covered the influence of the backlight effect. No significant influence of the backlight effect being turned on was observed on satisfaction, which could be explained by the fact that satisfaction might be a composite feeling induced by an assortment of other feelings [27]. Satisfaction has also been used to evaluate the influence of switches on attention allocation, but no significant effect was observed [7], which might be potential evidence that satisfaction is complex.

Second, keyswitches had a significant impact on typing speed, accuracy, refreshing feeling, and pleasure. Compared with red switches, blue switches performed better in typing speed, accuracy, and the refreshing feeling score, which accords with previous research indicating that tactile switches perform better than linear ones [7,8]. This supports the red switch and blue switch comparison part in hypotheses 3 and 4. In addition, blue switches had clearer auditory and haptic feedback than red switches, echoing the result that interaction feedback was helpful for typing [1]. The factor analysis revealed that Factors 1 and 2 could represent approximately 97% of the physical characteristics. Pre travel, reset travel, make force, and bottom force in Factor 1 seemed to be more effective in terms of the switch characteristics. This result is highly consistent with the results of a previous study, which demonstrated that these four factors were the key design factors for a keyswitch [27] and revealed the effectiveness of keyswitch characteristics [8]. It should be noted that in the results of the factor analysis, the Factor 1 and 2 coefficients of the reset force did not show much difference compared with the other five parameters, which made them difficult to classify, requiring further research. According to the regression results, these four factors had a significantly positive influence on typing accuracy and provided a refreshing feeling and pleasure, as shown in the fact that the three mentioned independent variables were positively correlated with Factor 1. This supports the make force and pre travel part of hypothesis 5; however, it does not support the total travel part. According to the switch pair comparison results, blue switches with a higher make force, bottom force, pre travel, and reset travel performed better than red switches in terms of typing speed, accuracy, and refreshing feeling, which supported the regression results. Regarding make force, this result was consistent with the assumption that a make force of 0.47N or less

should be employed [12]. However, it contradicted the assumption that a larger make force was associated with more muscle activity and higher subjective discomfort [11], which could be explained by tactile and linear differences. Moreover, typing time was limited to two minutes so that the muscle activity burden would not be a primary influencing factor. Regarding pre travel, this result conflicted with the previous finding that a longer pre travel was related to higher peak muscle activity [8], which might also be caused by a short typing time and tactile switch characteristics. No significant influence of total travel was observed. This may be because there were interactive effects among these switch characteristics, which are worth investigating further.

6. Conclusions

This study evaluated the influence of keyswitches and the keyboard backlight effect on typing performance and subjective experience based on an English-language typing experiment. Here are some conclusions obtained from this research:

Mechanical keyboard switch types can significantly influence typing performance and subjective experience. Typing speed, accuracy, and refreshing feeling score were significantly higher on tactile switches than on linear switches, according to the pair comparison between blue and red switches.

Turning on the keyboard backlight effect can improve typing speed, refreshing feelings, and pleasure, but no influence was observed on typing accuracy and satisfaction.

Among the six studied switch parameters (make force, reset force, bottom force, pre travel, reset travel, and total travel), pre travel, reset travel, make force, and bottom force were the four most effective physical characteristics of keyswitches, and according to linear regression, these four parameters are positively correlated with typing accuracy, refreshing feelings, and pleasure.

Our findings could serve as a reference for mechanical keyboard manufacturers and keyboard interaction research. Tactile switches similar to blue switches (with longer pre travel, reset travel, bigger make force, and bottom force) and which have an onboard backlight effect can be used to improve user experience.

7. Limitations

Four commonly used keyswitches were studied in this experiment; however, there are more than twenty types of switches and the other switches need to be studied as well. All four researched keyboards were from one manufacturer; thus, the results could be more representative if products from different manufacturers were used. Additionally, with two backlight states (constant-on and -off), our study could only conclude that the backlight effect significantly influences typing performance and experience; however, more specific backlight factors such as contrast, brightness, and light mode still need to be further investigated. Apart from switches and the backlight effect, it would also be of interest to investigate other design elements, for example, the materials of keycaps. And the conclusion would be more persuasive and generalized if more participants from different demographics were involved. Moreover, the influence of switches and backlight design could have been studied on a deeper level if the muscle activity and EEGs (electroencephalograms) of participants had been measured in this research.

Furthermore, we set two minutes as every single typing mission time considering the fatigue factor and the total experiment duration for every single participant, but this seems to be not enough for simulating daily typing scenarios. Separating the experiment into several parts might be a better choice to solve this problem, which could ensure a long enough single typing duration and prevent participants from feeling tired, or a between-subject experimental design with more participants could be adopted to reduce the number of typing missions for every participant, thus ensuring longer single typing durations.

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