2022

13th International Conference on Applied Human Factors and Ergonomics (AHFE 2022), New York, USA, Juli 2022.

Chapter XX

How a few custom keycaps make keyboards more ergonomic and reduce eye movement by 35%

Benny Platte[1], Marc Ritter[2], Christian Roschke[2], Rico Thomanek[1], Claudia Hösel[3], Matthias Baumgart[4]

[1]Media Science

[2]Applied Computer and Biological Science

[3]Institute for Competence, Communication and Language

[4]Research Department

[1,2,3,4]Hochschule Mittweida, Germany

ABSTRACT

Ergonomically designed devices for better workplace design get too little at-tention compared to the annual cost of long-term damage. To help workers better achieve their goals in their work environment, we explore small-step changes that any individual can make with many existing keyboards. We studied the keyboards that users have been using as their daily keyboards for at least a year. In an investigation with baseline and treatment phase we pro-vide the users with 800 keycaps of different shapes, colors and surfaces and let them experiment for 3 months during their daily work. The evaluation shows that users were able to reduce the time for daily operations by 12% and halve the number of looks at the keyboard.

Keywords: Ergonomics, ergonomic Devices, ergonomic Keyboard. Eye Movement, A-B-Design

INTRODUCTION

Almost every computer operated by humans uses a keyboard. That makes it, next to a mouse, the most common input device for manual human-computer interaction, with worldwide sales of 5.2 billion USD in 2021 and a shipment volume of 275 million units (*Keyboards - Worldwide*, 2021). This sales potential directly contrasts with the available research in this field. Strasser shows that the "enormous progress in the development of technology ... unfortunately has not brought any significant change in the layout of a keyboard based on a hundred year old standard" (Strasser, 2021, p. 8). Turisova & Sinay derive from this the preference for "simple and cost-effective tactile solutions" (Turisova and Sinay, 2016).

The Covid 19 pandemic period resulted in a sharp increase in people working at home: at one point, the Current Population Survey (CPS) reported that 54 million of nearly 155 million workers, or 35%, were in the home office (*Measuring the Effects of the Coronavirus (Covid-19) Pandemic on the Labor Market*, 2021), where most work with inadequate, non-ergonomic equipment (Lopez Leon, Forero and Ruiz-Díaz, 2020; Xiao *et al.*, 2021). Most office workers don't spend the energy and time to buy a keyboard with angled halves and/or change the configuration of the letters (Turisova and Sinay, 2016). Therefore, we investigate a small-step change, which can be done with many existing keyboards: we first change individual keycaps.

Keycaps are a big topic in keyboard modding communities. They come in all colors, different materials and profiles. Especially gamers always showcase new modifications of their keyboard(s). However, the exchange of the keycaps is always done completely: the profile of the keycaps, i.e. their shape, is only changed completely as a set - if at all. The personalization refers to the colors and materials, so it is always done within a "profile universe". Our approach goes further here: we use the heterogeneity of the usable keycap profiles to give the individual fingers better haptic feedback.

RELATED WORK

Decades of research into ergonomic keyboards seem to have had no impact on the procurement of appropriate devices (Turisova and Sinay, 2016). Research has extensively investigated different designs such as angular positions of the hand halves (Tittiranonda *et al.*, 1999; Emerson, Emerson and Fedorczyk, 2021; Otte, 2021), pitch angles (Marklin and Simoneau, 2004; McLoone *et al.*, 2010) or physical key arrangements (Scott *et al.*, 2010; Tasaka and Akioka, 2018; Zhao *et al.*, 2021).

We could not find any research in the recent 30 years on the extent to which the ergonomics of a keyboard can be achieved by intelligently mixing different keycap profiles (Fig. 1). Meta-analyses consider medical consequences, but do not reveal any studies on the targeted use of different keycap profiles *within* a keyboard.

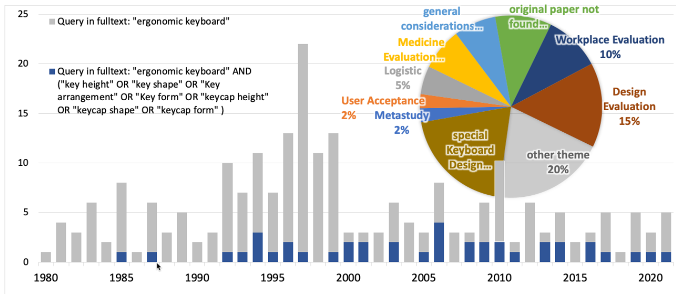

Fig. 1: Overview of studies related to ergonomic keyboards over the last 40 years. The data retrieval was made using dimensions.ai (Adams *et al.*, 2018).

Hsiao et al. investigated the influence of different keycap sets for four keyboards (Hsiao, Wu and Chen, 2014). They found that "keyboards with square keycaps had better input accuracy than those with rectangular keycaps" (Hsiao, Wu and Chen, 2014, p. 7). Monty et al. studied 6 individual keyboards on 18 participants (Monty, Snyder and Birdwell, 1983). Regardless of the position of the carriage return key, which has become unimportant in today's world and no longer has to be pressed after each line, the acoustic feedback was queried. Here, " participants [...] had strong preferences for the style and shape of the keycaps." Monty et al. further designate the influence of "keycap size and shape, keycap spacing, reflectance of keycaps and housing" and determine a strong influence of different keycaps per se, but leave the "one keyboard - one type of keycaps" system untouched. On the subject of keycaps, Ilg at al. names at least "light beige keycaps in matt finish" as a requirement for good legibility. (Ilg, 1987). More in the medical sector is the work of Utz et al. who use strain gauges integrated into the keycaps to measure finger strength (UTZ, SERINA and REMPEL, 1994). Shi et al. make individual keycaps touch-sensitive to trigger special functions.

METHODS

Though the aforementioned studies address the influence of keycaps, they consistently treat them as a keyboard-inherent, non-resolvable block. Our approach is to assume the keycaps not as a "set" but as individual components and to search for the best keycap for the user for each single key. We investigate 2 standard mechanical keyboards and additionally a keyboard with ergonomic split angle, shown in Fig. 2 on top. The brands in question are Durgod Taurus K320 TKL (87 keys), Anne Pro (60% keyboard, 61 keys), Redox v2. In everyday life, the keyboard resides in front of the user, and the mouse on the left or right side, depending on the user's handedness. During everyday situations, the same keys have to be found again many times. Regardless of whether the user is proficient in 10-finger touch typing or not, he or she needs to retrieve needed shortcuts all the time. When researching web pages, creating presentations and similar tasks, the most frequently needed commands are "copy" and "paste". These are located on the left side in the standard keyboard layout. Since most people operate the pointing device with the right hand, the left hand can execute these most common commands. Objects or words are selected with one hand and the other performs the corresponding copy and paste operations. The observations of the users of the above-mentioned keyboards showed that almost all of them change their gaze and look at the keyboard again and again during *each single* copy and paste operation.

Preliminary considerations

The keyboards listed above had been used regularly at the workplace for at least 1 year in their respective standard condition. It could therefore be assumed that the test subjects knew their keyboards. For the copy-paste block under study, we created a set of 5 operations to be performed by the user. For this, the operations were announced by a second person. This person also performed the time measurement. The subject could prepare her work environment in each case. The condition was that the test person used this environment during each examination in this form, e.g. the arrangement of the windows on the screen next to each other or one above the other. Some operations specified this explicitly. Operation 3, for example, specified that the browser window and the text file should be on top of each other for copying back and forth, and that switching between the windows should be done using shortcuts to force a repositioning of the hand.

To rule out any improvement due to the "learning effect" component, the operations to be performed were made known in advance so that all participants knew the tasks. We created a set of 5 operations that were very common in the participants' daily environment:

1. copy the first and third sentence from the file "Text 1" to the end of the file "Text 2"
2. create 8 copies of the red rectangle in the presentation
3. open the web page "x" in the browser and copy every second paragraph into a text file
4. copy the URL of the first 5 tabs in the browser one after the other into a text file. Use the key combination Alt-Tab to switch between browser and text file.
5. presentation: mark all blue circles on slide 1 and copy them to slide 2

Some operations can be accelerated by "parking" the finger on a key. For example, this can be used in operation 2. Operations like in example 3 force the re-finding of keys, because between copy and paste there is a completely different action and the keys have to be re-found either by looking or by sensing. On each (measurement) day, each keyboard with its user was measured four times per operation. This corresponds to 60 measurements per day. To minimize side effects, 5 consecutive measurement days, always starting on Monday, were constructed as an equally distributed layered sample. The dependent variables are thereby "time required" and "look count". The sample size of n=3 is too small for an investigation of the population of individuals. We therefore conduct a single within-subject investigation using repeated measures A-B-Design.

Treatment: Keycaps Changing

At the beginning of the treatment, we provide the users with an extensive set of different keycaps (800) and instruct them: "change the keycaps so that you can perform your frequently performed tasks with less distraction. Use different heights or profiles to re-find the keys faster. Leave only those configuration on the keyboard that you find useful and feel comfortable with." We then have the participants perform their daily tasks for 3 months and then repeat the measurements.

RESULTS

A total of 600 measurements were taken, 300 for baseline acquisition and 300 after the end of the three-month treatment period. Two of the keyboards found after the treatment are shown in the lower section of Fig. 2. The measurements of the time resulted in a reduction of the required time between 2.2 and 2.8 s, shown in Fig. 3. The total look count decreased between 161 and 92. The relative subject-related decrease averages 55%. For all keyboards, a consistent decrease can be noted in all individual operations, both in the times and in the look count.

Fig. 2: Two of the keyboards with changes during intervention

To determine statistical confidence, a repeated measures ANOVA was performed with the within-subject variables "Phase" and "Operation" for the dependent variables "Time" and "Look Count", respectively. The within-subject factor "Phase" is significant for both Time ($p<0.006$) and Look Count ($p<0.02$) and shows strong effect sizes (Time: $\eta^2=0.98$, Look Count: $\eta^2=0.95$). Thereupon, paired one-sided t-tests were performed for all operations for each examined keyboard (subject). The results are shown in Fig. 4.

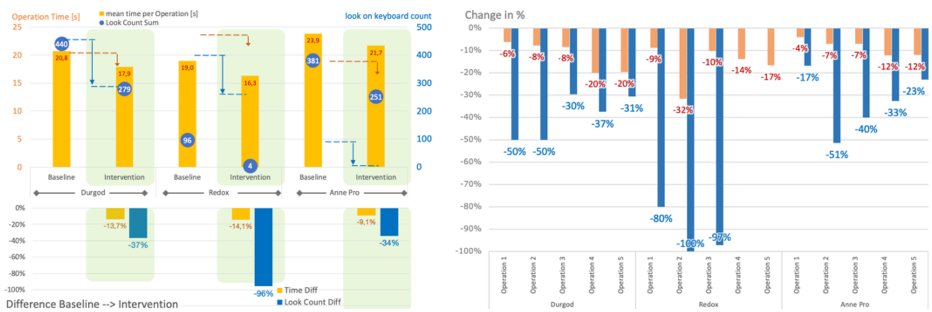

Fig. 3: Left: Average times and look count of all operations. - Right: Mean changes from baseline to intervention. All values show a decrease in both time and look count.

Thereupon, paired one-sided t-tests were performed for all operations for each examined keyboard (subject). The results are shown in Fig. 3. All 3 subjects show significant decreases in time required ($0 < p < 0.029$) and look count ($0 < p < 0.025$). All operations except for operation 1 show p-values below 0.001. The alpha error accumulations of the variable Time are at most 0.038 and those of the variable Look Count are 0.024 (both for subject "Anne Pro"). All individual effect sizes according to Cohen (for all subjects and operations) show values $r > 0.62$ for the variable "Time" and $r > 0.65$ for "Look Count". The average effect size is $r = 1.78$ standard deviations, which can be rated as high.

Extreme values

The confidence interval for the "redox" keyboard and operation 5 and 6 is not calculable (Fig. 1 right): for these operations, the participant never looked at the keyboard in the baseline, as well as after the treatment. Consequently, no p-value can be calculated here, since both the difference and the variance of all measurement time points were 0. The infinite effect sizes for operation 1 and 2 of the participant "Anne Pro" have their cause in the always same look count at each measurement time. The variance is therefore 0 and results in an infinite effect size. All these extreme values were not included in the mean value calculations.

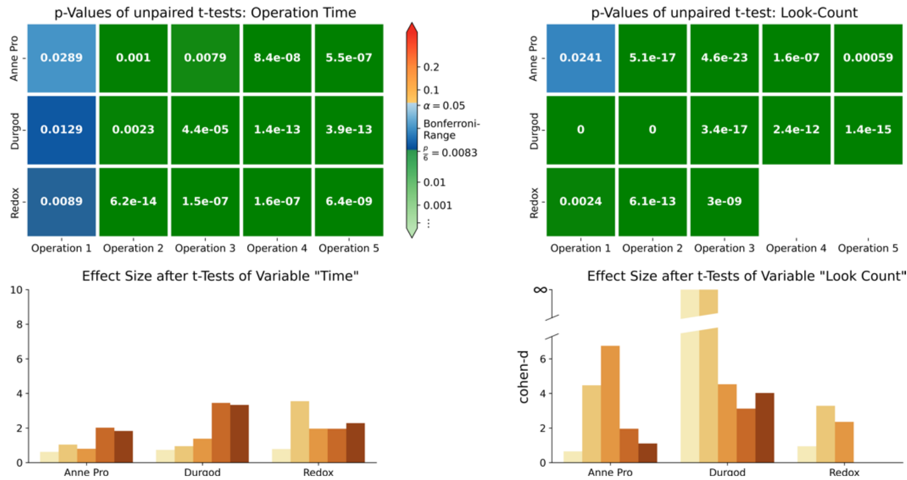

Fig. 4: Confidence Intervals (top) and Effect Sizes by Cohen (bottom) for the two dependent vars “Time” (left side of Figure) and “Look Count” (right side of Figure).

DISCUSSION

The results clearly show that changing the keycaps leads to a significant reduction in everyday operations. The time required decreases by an average of 2.6 s for the selected sample. The analysis of the mean values of all single operations shows that the decrease occurs in all single operations. This reduction in the time required of 12.1% is statistically significant ($p_{mean} = 0.02$). Although the mean effect size is high by statistical standards, it is not so large that it would justify the possibly time-consuming adjustment process in everyday life.

What indeed surprised us, however, was the extent of the reduction in the need to look at the keyboard while performing the operations. At baseline, participants consistently reported that they themselves felt they were looking at the keyboard too often. We found this statement represented in the baseline: especially the users of the standard keyboards looked at the keyboard again and again almost every time they copied and pasted. After the 3-month treatment period, they reported a very large improvement in their daily life, as they looked much less at the keyboard. The keyboards were not used for testing, but as daily devices to accomplish everyday work throughout the study. In order not to slow down the work, adjustments were made entirely by the participants whenever they felt it was appropriate, without any involvement from us. As a result, users reduced their look count by 34% and 37% for the two non-angled keyboards. The user of the redox keyboard reduced his look count during copy and paste processes by 96%: he hardly looked at the keyboard during the operations. In total, he had looked at the keyboard 96 times during the whole baseline. He performed the same operations after the treatment with only 4 times looking at the keyboard. The Redox is an angled keyboard with standard layout. These extreme improvements are due to the fact that the user of such a keyboard is familiar with touch typing and also has an affinity for ergonomics. This already previously rare looking had increased once again.

The average look count reduction of all users is 55%. However, for stating the reduction in the title, we decided to exclude the extreme improvement of the user of the redox keyboard. The remaining conservative 35% rather reflects the improvement to be achieved by standard users. The users of the keycaps felt much more efficient in their daily work after the intervention. By dealing with the diverse possibilities of the keycaps, they had recognized the potential for themselves and actually changed the keycaps several times. After many attempts, they had found a combination for themselves that made the keys haptically distinguishable.

CONCLUSION

On average, users were able to reduce their necessity to look at the keyboard by more than a half. This was expressed not only in the pure count, but above all in the *self-perception of the users*. They reported being much less distracted with the gain in comfort. A gain in time does not play a role for them, since the limiting factors are usually work-determining thoughts. However, with only half as many eye changes to the keyboard, they were able to focus better and concentrate on a task longer.

This strong improvement was only achieved by the "smart" exchange of keycaps. In further investigations, we dedicate ourselves to the adaptation of the letter keycaps on touch writers and evaluate the improvement possibilities available there. Thus, we open a wide field of *improvement of workplaces with minimally invasive changes*, which everyone can perform at his place without much effort.

The work shows that in all-day workplaces, even small changes have a big impact.

REFERENCES

Adams, J. *et al.* (2018) ‘Dimensions - A Collaborative Approach to Enhancing Research Discovery’, in. doi:10/gngm29.

Emerson, S., Emerson, K. and Fedorczyk, J. (2021) ‘Computer workstation ergonomics: Current evidence for evaluation, corrections, and recommendations for remote evaluation’, *Journal of Hand Therapy*, 34(2), pp. 166–178. doi:10/gncngq.

Hsiao, H.-C., Wu, F.-G. and Chen, C.-H. (2014) ‘Design and evaluation of small, linear QWERTY keyboards’, *Applied Ergonomics*, 45(3), pp. 655–662. doi:10/gncvr7.

Ilg, R. (1987) ‘Ergonomic keyboard design’, *Behaviour and Information Technology*, 6(3), pp. 303–309. doi:10/c8qp77.

Keyboards - Worldwide (2021). Available at: https://www.statista.com/outlook/cmo/consumer-electronics/computing/keyboards/worldwide (Accessed: 8 November 2021).

Lopez Leon, S., Forero, D. and Ruiz-Díaz, P. (2020) 'Recommendations for working from home during the pandemic (and Beyond)', *Work*, 66, pp. 1–5. doi:10/gnfpnz.

Marklin, R.W. and Simoneau, G.G. (2004) 'Design features of alternative computer keyboards: a review of experimental data.', *Journal of Orthopaedic and Sports Physical Therapy*, 34(10), pp. 638–49. doi:10/gncngc.

McLoone, H.E. *et al.* (2010) 'User-centered design and evaluation of a next generation fixed-split ergonomic keyboard.', *Work*, 37(4), pp. 445–56. doi:10/gncm3x.

Measuring the Effects of the Coronavirus (Covid-19) Pandemic on the Labor Market (2021). Current Population Survey (CPS). U.S. Bureau of Labor Statistics. Available at: https://www.bls.gov/cps/effects-of-the-coronavirus-covid-19-pandemic.htm (Accessed: 12 November 2021).

Monty, R.W., Snyder, H.L. and Birdwell, G.G. (1983) 'Keyboard Design: An Investigation of User Preference and Performance', *Proceedings of the Human Factors Society Annual Meeting*, 27(3), pp. 201–205. doi:10/fx55d4.

Otte, C. (2021) 'Ergonomische PC-Tastaturen – das sollten Sie wissen!', *Ergonomieblog*. Available at: https://ergonomie.blog/ergonomische-pc-tastaturen-das-sollten-sie-wissen/ (Accessed: 8 November 2021).

Scott, J. *et al.* (2010) 'RearType: text entry using keys on the back of a device', in *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services - MobileHCI '10*, pp. 171–180. doi:10/bhc389.

Strasser, H. (2021) 'Compatibility as guiding principle for ergonomics work design and preventive occupational health and safety', *Zeitschrift für Arbeitswissenschaft* [Preprint]. doi:10/gncnhw.

Tasaka, T. and Akioka, S. (2018) 'Flexible Keyboard for Everyone', in Stephanidis, C. (ed.) *HCI International 2018 – Posters' Extended Abstracts*. Cham: Springer International Publishing (Communications in Computer and Information Science), pp. 100–107. doi:10/gncvt6.

Tittiranonda, P. *et al.* (1999) 'Workplace Use of an Adjustable Keyboard: Adjustment Preferences and Effect on Wrist Posture', *AIHA Journal*, 60(3), pp. 340–348. doi:10/b24pn8.

Turisova, R. and Sinay, J. (2016) 'Ergonomics versus product attractiveness', *Theoretical Issues in Ergonomics Science*, pp. 1–13. doi:10/gndpq7.

UTZ, P., SERINA, E. and REMPEL, D. (1994) 'A system for evaluating the effect of keyboard design on force, posture, comfort, and productivity', *Ergonomics*, 37(10), pp. 1649–1660. doi:10/bmx9jf.

Xiao, Y. *et al.* (2021) 'Impacts of Working From Home During COVID-19 Pandemic on Physical and Mental Well-Being of Office Workstation Users', *Journal of Occupational and Environmental Medicine*, 63(3), pp. 181–190. doi:10/gk6vfk.

Zhao, Y. *et al.* (2021) 'High-Precision and Customized Ring-Type Virtual Keyboard Based on Layout Redesign', *IEEE Sensors Journal*, pp. 1–1. doi:10/gnckwc.