On the Effect of Human-Computer Interfaces on Language Expression

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ABSTRACT
Language expression is known to be dependent on attributes intrinsic to the author. To date, however, little attention has been devoted to the effect of interfaces used to articulate language on its expression. Here we study a large corpus of text written using different input devices and show that writers unconsciously prefer different letters depending on the interplay between their individual traits (e.g., hand laterality and injuries) and the layout of keyboards. Our results show, for the first time, how the interplay between technology and its users modifies language expression.

1. INTRODUCTION
Language expression is known to be dependent on attributes intrinsic to the author, such as education, gender, and age [3]. However, after ideas are initially formed, they are often verbalized via interaction with mechanical input devices. In this paper we show that the technology — and, in particular, keyboard — has a measurable influence on language expression. Specifically, we show that writers' unconsciously prefer different letters depending on the interplay between their individual traits and the layout of the keyboard. We also show that the same writer may have different "personas" (as evidenced by different letter preferences) when interacting with different kinds of keyboards.

Arguably, the most common text input mechanism today is the QWERTY keyboard. It was designed to distribute frequently-used letter pairs between the two hands in order to increase typing speed. The keyboard is asymmetrical, with more letters located to the left of the midline [2]. Recently, it has been shown that letter location on the keyboard is associated with sentiment, and words containing letters from the right side of the keyboard are estimated as having more positive meaning [2]. However, to the best of our knowledge, it has not been previously known whether writers actually modify their language expression when interacting with different keyboards.

We examined publicly accessible free-form text passages written voluntarily at Yahoo! Answers, a social question-answering web site. The passages were typed using various input devices: desktop keyboards\(^1\), smartphones, and tablet computers. Observe that when users interact with a full-size keyboard on desktop computers, they usually type with both hands. However, this practice changes when users interact with tablet computers or smartphones. In these cases, users often hold the device with one hand and type with the other hand (often using a single finger), or hold the device with both hands and type with the thumbs. Our findings indicate that when the same users operate different devices, they exhibit statistically significant preferences for different letters on each device. Importantly, this observation remains valid even when we focus on sub-populations of users, namely, those who have voluntarily self-identified to be left- or right-handed, or those who have self-declared to be suffering from Carpal Tunnel Syndrome (CTS). These special populations are interesting because they have notably different patterns of keyboard use compared to the general population. Nonetheless, we clearly see that users in these groups also exhibit statistically significant preferences for different letters on different devices.

Our findings indicate that human-computer interfaces, and specifically keyboards, are not language-neutral, and instead have measurable effect on language expression by their users. To the best of our knowledge, this effect has not been discovered in prior studies. Further research is required to quantify the differences in the perception of language produced on different input devices. We believe future research should also focus on developing language-neutral input interfaces, which do not noticeably affect language expression.

2. METHODOLOGY
We report the results of three experiments comparing different populations active on Yahoo! Answers. Previous research [4] showed that users who state their preferences and physical attributes on Yahoo! Answers are overwhelmingly accurate in the data they provide. Therefore, in this work we assumed that users' statements about their personal traits, such as hand laterality or being affected by Carpal Tunnel Syndrome, are accurate.

In the first experiment, we analyzed English-language posts entered by Yahoo! Answers users in 2012. There were about 1.8 million such posts, and Table 1 describes their properties, broken by input device. In general, the numbers observed for tablet devices in Table 1 are between those for desktop and mobile phones, therefore, in the discussion below we mainly compare desktops and mobile phones. Posts from desktop computers are typically longer by 67 characters or 11 words, when compared to posts from mobile phones. This is not surprising when one compares the convenience of the full-size keyboard of desktop computers with the limitations of small keyboards available on handheld devices (either on-screen or mechanical). The latter usually require more keystrokes to type

\(^{1}\)We use the term "writer" in the broad sense to refer to people who write texts, not solely to authors of manuscripts of substantial size or scope.

\(^{2}\)When referring to desktop computers, we also include laptops since both have full-size mechanical keyboards, and also we have no way to distinguish between them in the server logs.

\(^{3}\)This work has been done while the author was with Yahoo! Research. The author’s current affiliation is Google, Mountain View, CA, USA.
punctuation and other special characters, and only allows typing using one or at most two fingers at once. We also see that the number of URLs posted from mobile phones is much lower, which might be due to the difficulty of switching to a different application, such as a web browser or mail client, in order to retrieve the URL. Similarly, the frequency of commas is reduced by 50% on mobile devices, and we note that these require one to switch away from the standard keyboard layout, at least on the popular iPhone devices. The frequency of periods is also reduced, but only by 33% - perhaps due to the autocomplete feature (replacing a double space with a period). Surprisingly, emoticons are more frequent on mobile phones compared to desktop computers. We believe that in this case the need for expressing emotion in casual conversations is stronger than the added difficulty of typing less accessible characters.

However, such analysis ignores several confounding variables. For example, the ownership rates for web-capable phones and corresponding data plans might vary by age and level of education. On top of that, the propensity of a user to actually browse the web from their mobile device, given that they have a suitable device, might depend on age or gender. These kinds of biases could easily lead to differences in the texts typed on various devices, which cannot be solely attributed to the nature of interaction with the particular device.

To overcome this difficulty, we identified 479 U.S.-based users who contributed text from a desktop computer and, at distinct occasions, also from a mobile phone or a tablet computer. We can now perform paired tests of contributions from these users, eliminating the confounding variables such as age, gender, or level of income. We extracted posts from these users, and removed the URLs from them. Then, we computed the probability of using each letter for each device. We used a paired sign test at the significance level of 0.05 with Dunn-Sidak correction [1] to evaluate which letters were used at significantly different levels on each mobile device (smartphone or tablet), compared to the desktop.

In our second experiment, we looked at Yahoo! Answers posts from users who self-identified as suffering from Carpal Tunnel Syndrome. CTS is a medical condition causing wrist and hand pain and difficulty in typing. A typical user would disclose this fact when posting a relevant question in the “injuries” or “pain & pain management” categories. Using text matching on either the disease acronym or its full name, we identified 2636 such users. For these users we extracted all the questions and answers they contributed to Yahoo! Answers over a span of 6 years (2007—2012). As a baseline, we used the text from a random sample comprised of the same number of users.

In the third experiment, we extracted text contributed by users who voluntarily identified their handedness (1081 left-handed and 1555 right-handed users). As an example, users often disclose their handedness when posting a question about a particular sport technique, e.g., serving a ball in tennis. To this end, we extracted the text from all questions and answers posted by the users who explicitly stated that they were right- or left-handed, over a span of 6 years (2007—2012).

We associated each letter with its Euclidian distance from the center of a standard English-language QWERTY keyboard. We hypothesized that the dominant hand may be placed at different locations on the keyboard depending on hand laterality, making different areas of the keyboard more accessible. Therefore, we tested each possible location on the keyboard as a potential center. For each such location we measured the average distance (from the keyboard center) of the keys used by left-handed users, divided by that of right-handed users. We assessed the statistical significance of the difference using the Kruskal-Wallis test.

## 3. RESULTS

Our first experiment was designed to measure the effect of different input devices on the same person. Here we analyzed, for each writer, the text she entered using a desktop computer and either a mobile phone or a tablet computer. We found statistically significant differences in the usage of letters, as follows. On mobile phones, the letters KYUJ were more frequently used, compared to their use by the same writers on a desktop computer. Conversely, the letters (statistically significantly) more often used on desktop computers as compared to mobile were QIBSVXLWENOQTHPRADCFMZ. Comparing tablet computers to desktops, we found that the letters XBGKZ were more frequently used on tablets and the letters QP were more frequently on desktop computers. See Figure 1 for an illustration.

Thus, within-subject preference for letters on mobile phones is for letters on the right-hand side of the keyboard (KYUJ), which we attribute to the common practice of typing with the thumb of the same hand (usually right) that is holding the mobile phone, or alternatively, holding the device with the left hand and typing with the right index finger. In tablets, 3 out of 5 preferred letters were in the bottom row of the keyboard, while the least preferred letters were all in the top row. We believe this is explained by the common typing position where one hand performs most of the typing while hovering above the screen surface, which makes extending the arm towards the top row more difficult.

In the second experiment, we examined inter-subject variability in text contributed by writers who voluntarily stated that they were affected by the Carpal Tunnel Syndrome. When compared to the control population, these writers preferred keys farther from the center of the keyboard, when the latter is defined at seven letters from the left hand side of the keyboard ($p = 0.0013$, Kruskal-Wallis test). This preference is greater by 0.7% in the CTS-affected population, compared to the control. These findings indicate that the layout of the keyboard influences letter selection for people afflicted by CTS, and may be due to CTS sufferers’ using only one hand to type.

In the final experiment, we examined inter-subject variability in text expression by people of different hand laterality. Using the same methodology as above, we discovered that left-handed writers tend to prefer keys farther from the center of the keyboard, when the latter is defined at six letters from the left-hand side of the keyboard, compared to right handed writers ($p = 0.03$, Kruskal-Wallis test). This preference is greater by 0.3% in left-handed writers, compared to right-handed writers.

We also tallied the occurrences of consecutive pairs of letters, where each could be on the left (L) or right (R) side of the keyboard. For each post, we normalized the counts by the total number of pairs ($N - 1$ pairs for a post of length $N$). Our findings are summarized in Table 2. We found that for RR pairs (two consecutive letters on the right side of the keyboard), the left-handed group types them more often than the right-handed group. For LL pairs, the right-handed group types them more often than the left-handed group. For both LR and RL pairs, the right-handed group types more often than the left-handed group.

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1. On Android devices, both comma and period are on the main keyboard layout screen.
2. We excluded URLs because users effectively have no choice of letters when typing them.
3. See the last paragraph of the previous section for an explanation why multiple alternative positions of the center of the keyboard had to be considered.
4. The space bar was considered to be on neither side.
Table 1: Statistics on Yahoo! Answers posts for U.S. users, broken down by device. In each row, the difference is statistically significant at the level \( p < 0.001 \) for all three pairs.

| Metric                      | Desktop | Mobile | Tablet |
|-----------------------------|---------|--------|--------|
| length in characters        | 215     | 148    | 165    |
| length in words             | 39      | 28     | 30     |
| characters per word         | 5.7     | 5.3    | 5.3    |
| URL count                   | 0.07    | 0.013  | 0.05   |
| emoticons per word          | 0.079   | 0.084  | 0.075  |
| period count                | 3.3     | 2.2    | 2.5    |
| comma count                 | 1.6     | 0.8    | 1.0    |

Table 2: Frequencies for typing consecutive pairs of keys from the left (L) and right (R) sides of the keyboard. Differences are statistically significant at the level \( p < 10^{-10} \), with the exception of the LR difference between the control and right-handed populations.

| Population       | LL    | LR    | RL    | RR    |
|------------------|-------|-------|-------|-------|
| Control          | 16.65%| 16.34%| 16.07%| 15.44%|
| Left-handed      | 16.44%| 16.32%| 15.86%| 15.70%|
| Right-handed     | 16.51%| 16.34%| 15.90%| 15.53%|

We envision two promising avenues for future research on the topic. First, it is interesting to understand whether the differences in language expression that we have identified actually lead to different perception by the readers of the texts written on different input devices. Second, it remains an open question whether it is possible to design unbiased devices for mechanical text entry, which will not affect language expression for various user populations.

5. REFERENCES

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Figure 1: Letter preferences on different pairs of devices. Letters shown on the blue background are preferred by desktop users, while letters shown on the black background are preferred by mobile phone/tablet users. In diagram (b), letters shown in light gray background are not preferred by either population.