Acta Psychologica 167 (2016) 16–23

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Two thumbs and one index: A comparison of manual coordination in touch-typing and mobile-typing

Tania Cerni [a], Marieke Longcamp [b,*], Remo Job [a]

[a] Department of Psychology and Cognitive Science, University of Trento, Corso Bettini, 31, 38068 Rovereto, Italy
[b] Laboratoire de Neurosciences Cognitives, UMR 7291 CNRS, CNRS – Aix-Marseille Université – Fédération de recherche 3 C, Brain and Language Research Institute, FR 3512 Centre Saint-Charles, Case C, 3 place Victor Hugo, 13331 Marseille Cedex 3, France

ARTICLE INFO

Article history:
Received 14 January 2015
Received in revised form 16 March 2016
Accepted 19 March 2016
Available online 14 April 2016

Keywords:
Touch-typing
Mobile-typing
Bimanual coordination
Peripheral processes

ABSTRACT

It has been extensively demonstrated that in touch-typing, manual alternation is performed faster than manual repetition (see i.e. Rumelhart & Norman, 1982), due to parallel activation of successive keystrokes. In this experiment, we tested whether the manual coordination patterns typical of touch-typing can be observed in mobile-typing. We recruited skilled touch-typists and divided them into two groups depending on their typing habits on the mobile device. The "one-hand" group typed with one index finger on the mobile, and therefore produced words exclusively through manual repetition. The "two-hands" group used two thumbs, and therefore produced words through a combination of mobile-typing repetitions and alternations. The two groups were tested in a typing to dictation task with both a standard keyboard and a mobile keyboard. Results showed that manual alternation and manual repetition patterns are similar in touch-typing and in mobile-typing. For the "two-hands" group, the mean interkeystroke intervals (IKIs) for touch-typing decreased as manual alterations in words increased in both touch- and mobile-typing. The "one-hand" group showed an opposite pattern in mobile-typing. Bigram frequency was correlated with IKIs per bigrams in both tasks and groups, but the correlation for the "one-hand" group in mobile-typing was different. Our results suggest that manual coordination processes are the same in touch-typing and in mobile-typing despite different effectors, provided that both hands are used to type.

1. Introduction

Typewriting is commonly associated with a standard keyboard placed in front of a screen, but nowadays typing is more often performed through mobile devices. The computer keyboard and the mobile keyboard differ in their physical and interactive features. The standard keyboard is devised for "touch-typing", the typing method based on a standard association between each of the ten fingers and a subset of keys. In this way, for trained experts, typing is a bimanual action which requires simultaneous coordination between hands and fingers and in which the right and the left hand never interfere with each other, because they are assigned to different parts of the keyboard (i.e. Shaffer, 1976, 1978; Terzuolo & Viviani, 1980; Rumelhart & Norman, 1982; Larochelle, 1984; Ostry, 1983; Salthouse, 1986). Conversely, handling a mobile keyboard does not rely on formal training and depends on personal strategies. It is possible to write on a mobile device with the index finger or the thumb of the dominant hand, or with the two thumbs of the two hands and, rarely, with the two indexes placing the device on a surface. Therefore, mobile-typing can be unimanual or bimanual.

Despite research on typing which has revealed to us a lot about unimanual and bimanual coordination in touch-typing on a standard keyboard, we know almost nothing about hand coordination in mobile-typing. The purpose of this paper is to demonstrate that manual coordination in mobile-typing reflect the same strategies as typing with ten fingers.

We know that during touch-typing word-level representation causes the activation of letters and keystrokes in parallel (Crump & Logan, 2010a; Yamaguchi, Logan, & Li, 2013). In a series of experiments, Crump and Logan (2010a) had their participants typewrite a probe after visual or oral presentation of the words. When the probe was present in the words, it was typed faster than when it was not present. Therefore, a word is segmented into letters and simultaneously translated into keystrokes before starting to write and the fingers of a skilled typists start moving toward the position of the key in advance (±40 msec), while they are actually producing a previous keypress (McLeod & Hume, 1994). This suggests that response rate is limited by a bottleneck that controls the execution of keystrokes, each of which depends on the

* Corresponding author.
E-mail addresses: tania.cerni@gmail.com (T. Cerni), marieke.longcamp@univ-amu.fr (M. Longcamp), remo.job@unitn.it (R. Job).

http://dx.doi.org/10.1016/j.actpsy.2016.03.007
0001-6918/

preceding keystrokes. Importantly, the anticipation of the following keystroke is earlier for hand alternation than for hand repetition (Larochelle, 1984). Therefore, in the context of whole word typing, this early parallel activation of keypress schemata increases the overlap of successive keystrokes between hands and between different fingers of the same hand in a way that strongly depends on biomechanical constraints.

To sustain the thesis of a parallel activation of keypress schemata, research on the motor mechanisms of typing (Shaffer, 1976, 1978; Terzuolo & Viviani, 1980; Rumelhart & Norman, 1982; Ostry, 1983; Larochelle, 1984; Salthouse, 1986; John, 1996; Wu & Liu, 2008) suggests that in skilled typing the interval between two keypresses (interkeystroke intervals—IKIs) is faster when performed with hand alternation than with hand repetition. This indicates that skilled typists move their hands simultaneously. In this way, when they alternate hands in two successive keystrokes, the movement of the second hand is initiated before the other hand has finished pressing the previous key (Gentner, Grudin, & Conway, 1980; Flanders & Soechting, 1992). In the case of within-hand interkeystrokes, typing rate is a function of the distance between keys: the greater the distance, the greater the IKI (Rumelhart & Norman, 1982). Furthermore, IKIs are produced sequentially by the motor system when the same finger has to be used, since one keystroke begins only after the previous one has been completed (Soechting & Flanders, 1992).

Here, we hypothesized that the bimanual advantage, typical of touch-typing performance, could be observed in mobile-typing when transition between hands is possible, that is, when the two thumbs of both hands are used. Conversely, for single-hand users of mobile devices, the constraints typical of typing with the same finger of the same hand should drive the mobile-typing performance.

To test this hypothesis, we recruited two groups of skilled touch-typists, with different typing styles on the mobile keyboard: the "one-hand" group used only the index of the right hand to type; the "two-hands" group typed with two thumbs. Subjects were tested in a typing to dictation task with both a standard keyboard and a mobile keyboard. Word stimuli were selected according to the percentage of bimanual transitions necessary to type them, from 0% (unimanual words) to 100% (bimanual words). We hypothesized that if the typing execution constraints are the same on both devices, the "two-hands" group would display a similar effect of bimanual transition in both the computer-typing and the mobile-typing tasks. For the "one-hand" group, we expected the opposite effects of bimanual transitions in the two tasks, since for the one hand group bimanual transitions on the mobile become unimanual.

As further evidence of a similar behavior on the two keyboards we hypothesized that if touch-typing and mobile-typing skills are similar, then the same lexical and sub-lexical factors should impact the performance in the two modalities.

At the whole word level we tested for lexical frequency and its interaction with transition ratio. In typing research the effect of lexical frequency on the peripheral-motor processes of typing is being debated (see for review e.g. Baus, Strijkers, & Costa, 2013), but several studies have demonstrated that high frequency words are named and written faster than low frequency words (Gentner, Larochelle, & Grudin, 1988; Inhoff, 1991; Bonin & Fayol, 2000, 2002; Caramazza & Costa, 2001; Caramazza, Costa, Miozzo, & Bi, 2001; Roelofs, 2001; Bonin & Fayol, 2002; Jescheniak, Meyer, & Levelt, 2003; Navarrete, Basagni, Alario, & Costa, 2006; Kittredge, Dell, Verkuilen, & Schwartz, 2008; Strijkers, Costa, & Thierry, 2010).

At the bigrams level we tested the effect of bigram frequency, a factor known to affect typing at the motor/peripheral level (Gentner et al., 1988). Frequent letter pairs are typed faster than less frequent pairs probably because the execution of frequently practiced bigrams is easier. This effect remains evident even when the type of transition is controlled (Terzuolo & Viviani, 1980; Grudin & Larochelle, 1982; Salthouse, 1984a, 1984b, 1986).

2. Method

2.1. Participants

Twenty-four participants, Italian native speakers, volunteered. Before the experimental session they filled in a questionnaire in order to collect: a) age and b) manual preferences by means of Edinburgh Handedness Inventory (Oldfield, 1971). We selected only participants with a minimum laterality index of 45 indicating dominant use of the right hand. Then, we collected their writing habits c) with the standard keyboard, d) with the mobile keyboard and e) with pen on paper in order to select participants who used the keyboard for a suitable amount of hours per day and to ensure that they have mobile-typing experience. Finally, we asked them to estimate their experience with the standard keyboard by asking f) for how many years they have used a computer and g) if they had attended a typing course in the past.

In order to collect a quantitative measure of typing experience and to ensure that all the participants are skilled touch-typists, we used a typing pretest, designed by means of Typing Test TQ 6.3 software (© Giletech e.K.) where participants had to copy two short texts displayed on the screen on a computer keyboard. Order of the presentation of the two texts was counterbalanced between participants. We collected typing accuracy - calculated as the total amount of words in the text minus the number of errors divided by the total amount of words - and typing rate - calculated as words (5 characters) typed per minute minus the number of mistyped words (MacKenzie, 2013). Finally, we recorded videos of the participants during the pretest to ensure that they used ten fingers and respected the division between the right and left keys of the keyboard. Thanks to these measures we were able to establish that our sample was composed of good touch-typists with a minimum typing rate of 40 wpm. In order to test our two experimental hypotheses, we considered two groups: the "one-hand" group and the "two-hands" group. The first group included 8 participants who were expert typists with the keyboard but used only one hand – in particular the index finger of the right hand – on the mobile device. This group had only moderate-to-low daily mobile-typing activity.

The remaining 16 participants constituted the second group, characterized by a greater experience with the mobile phone and the use of two thumbs to type on the mobile. This group was more heterogeneous than the first group with respect to typing experience. Table 1 displays the complete data collected by the questionnaire and the typing test.

2.2. Stimuli

As experimental stimuli we presented 136 Italian nouns from 6 to 8 letters, selected from *PhonItalia* 1.1 lexical database (http://www.phonitalia.org/). Words were controlled by calculating the amount of bimanual transitions in typing on the QWERTY keyboard. Bimanual

Table 1
Features of the sample.

Features	"One-hand" group	"Two-hands" group	*t*-Test
N	8	16	–
Mean age	47	31.5	6.2^{***}
Right-handed (%)	95.9	82.5	2.0
Daily typing time (minutes)	275	441.95	-2.7^{*}
Daily mobile-typing (minutes)	12.5	157.9	-2.9^{**}
Daily handwriting time (minutes)	50	63.75	−0.7
Typing experience (years)	26.9	15.3	3.5^{**}
Typing course in the past (%)	100%	31.25%	6.2^{**}
Typing accuracy (%)	95.9	96.5	−0.3
Typing rate (wpm)	61.7 (SD 9.2)	53.9 (SD 14.1)	1.4

Note. Statistical significance: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.