Japanese college students• typing speed on mobile devices

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Abstract

In previous work on mobile learning, students used cellphones and pocket computers (PDAs) primarily to view study materials and answer quizzes. But anecdotes suggest that Japanese students type faster on cellphones than on desktop PCs, raising the question as to whether students could use mobile devices to take notes and write reports. This paper is a first quantitative investigation into the ability of Japanese students to enter text on various mobile devices.

In 2-minute transcription tasks, 24 Japanese university students typed Japanese:English at 8:7 wpm on miniature QWERTY thumb keyboards, 10:9 on onscreen QWERTY keyboards, 17:5 on their cellphones, 23:14 on desktop PCs, and 31:30 on pencil and paper. 5-minute composition speeds were slightly less in the student•s native Japanese, and about half in English. Transcription errors were rare in Japanese, but more frequent in English, especially on mobile devices. Students preferred typing on desktops and cellphones.

This data suggests that Japanese students could easily take notes and write reports on their mobile phones, but would require some training before using PDAs and writing in English. Future work includes longitudinal studies of learning various input methods, including handwriting recognition.

Educators around the world are currently investigating the use of handheld computing devices such as mobile phones and pocket-sized •e P DAcomputers for educational purposes. These educational activities sometimes include inputting text using a variety of keyboards on mobile devices. Critics of handheld computing often list the awkwardness of text input as a major drawback in the use of such devices in the classroom. We wanted to find out if, indeed, this was the case among Japanese college students. Because of early and frequent use of mobile phones and handheld game devices, Japanese youth have been labeled by some as a• gthumb culture• h (Emerson, 2001). In ou previous investigations, we found that Japanese university students are much more practiced at using mobile phone keyboards than desktop PC keyboards. With that in mind, this investigation set out to compare students•f i nput speeds in English and Japanese on a variety of mobile keyboards.

Background and Previous Work

Mobile educational media

Previous work has shown that mobile devices allow students to conveniently view educational materials. For example, Ring (2001) found that students appreciated the ability to read course outlines and texts on mobile phones while commuting. Thornton & Houser (2001) found that students receiving frequent emailed lessons on their mobile phones learned more than control groups urged to frequently study identical lessons on web pages or paper handouts. And Thornton & Houser (2003) found that students rated highly web and video teaching materials viewed on mobile phones and PDAs. We see that mobile devices support the flow of information from instructors to students. What about the flow from students back to instructors?

Little research has investigated the use of mobile devices to submit information to instructors. Dufresne, et al. (1996) described the ClassTalk system, in which students use networked PDAs to answer quizzes during short breaks in the middle of lectures allowing lecturers to view students' responses in real-time, and adjust the lecture to correct any misconceptions. This idea was re-implemented using wireless PDAs (Chen, Myers, & Yaron, 2000), custom-built infrared transmitters (Huang, et al. 2001), and students' mobile web phones (Thornton & Houser, 2003). All these systems allow students to answer multiple-choice questions. Could these quizzing systems be extended to accept write-in-choices, fill-in-the-blank quizzes, or detailed rationale explaining why a student chose her response? Can students conveniently use mobile devices to enter text? What about paragraphs and essays? Soloway (2001) describes several programs allowing students to use PDAs to draw concept graphs and write reports. But in spite of these technology-driven research efforts, many educators are still skeptical that students will be able to compose texts on mobile devices.

This paper is a first quantitative investigation into the usability of mobile devices for entering texts. It reports on our experiments measuring the preferences and input speed of Japanese college students entering text on various mobile devices.

Mobile input in general

Research on input using mobile devices is a hot topic, partially because so many new gadgets are being developed every year, and partially because some of them are so heavily used: On their mobile phones, worldwide users write approximately one billion short text messages each day (GSM, 2003).

Researchers acknowledge that the best way to evaluate user's performance on various keyboards is to actually test them in psychometric experiments. But such experiments can be costly and misleading. Experiments are costly because they require measuring the performance of dozens of test subjects. For keyboards unfamiliar to the test subjects, experiments and training must continue for dozens of sessions before the subjects become expert users. Experiments can be misleading because the exact details of the subjects, tasks, phrases typed, length of the test, and many other factors can completely change the results.

Consequently, many researchers are augmenting and sometimes replacing experiments with mathematical predictions. These predictions typically use Fitts' law (Fitts, 1954) to estimate the time taken to move a finger between two keys. Researchers sum all possible motions, weighed by their likelihood as predicted by a table of English letter-pair probabilities (MacKenzie, 1992). This gives the average time needed to type a letter. Researchers traditionally multiply this time by 5 to estimate the average time to type a word. This time is an upper bound on 'expert performance' because it assumes the typist moves her fingers from one key to another as fast as physically possible. To estimate typing speed for novice users, researchers sometimes add a 'reaction time' to each keypress. Some researchers use Hick's law (Hick, 1952; see also Teichener & Krebs, 1974 and Welford, 1968, for reviews) to estimate the time a novice user takes to visually scan an unfamiliar keyboard, looking for the key she intends to type next. Other researchers add additional time, often derived from experiments, to model the time users spend in activities other than simply pressing keys. Such activities might include reading or recalling the text they're typing, checking the display to verify their current typing, wondering about spelling, and simply spacing out as their attention wanders.

Below we summarize previous research on mobile input, introducing several types of mobile keyboards, and presenting the predicted and experimentally measured typing speeds for novices and experts on these keyboards.

Mobile phone keyboards

The twelve-button keypad on cell phones is perhaps the most commonly used mobile input device: Each day millions use these keypads to write some one billion short email messages. To allow the typing of an entire alphabet with only 12 buttons, each button is mapped to several letters. For example, one button is mapped to A, B, and C. Older phones use multiple taps to differentiate between letters, pressing the button once for A, twice for B, and three times for C. Newer phones use various schemes to somewhat reduce the number of buttons one needs to tap, but however one does it, typing on a 1-inch square keypad seems awkward.

Silfverberg, MacKenzie, and Korhonen (2000) predicted that experts could type 24.5 wpm (using their thumb on a mobile phone keypad employing the •timeout kill• key. We believe this is relevant because few phones in Japan use timeouts). No experiments verified this prediction, but one of the researchers was clocked at 21.0 wpm, which gave the researchers confidence that their prediction was in the right ballpark. But then James and Reischel (2001) conducted an experiment and found that both new and experienced users thumbed 8.0 wpm. They argue that the 'novices vs. expert' distinction doesn't apply to mobile phone input, since all messages are so short, they can't provide enough practice to ever allow a transition to expert. The researchers did note a significant effect of the material to be typed: Newspaper copy was typed at only 5 wpm, but typical mobile phone 'chat' was entered at 10 wpm. (This shows the sensitivity of these results to the experimental conditions.) The experimenters postulate that the gap between prediction and experiment comes from an unrealistic model of a perfect expert with robot-like efficiency.

Thumb QWERTY keyboards

A few new mobile phones, as well as some PDAs, use miniature QWERTY keyboards. These keyboards array dozens of tiny keys in a layout similar to desktop PCs. Touch typing is impossible: The keys are so small that these keyboards must be operated with two thumbs. Still, users can transfer many of their typing skills and their familiarity with the QWERTY layout. And because each letter has its own dedicated button, we expect input will be faster than on the overloaded keypad on a mobile phone.

MacKenzie & Soukoreff (2002) predicted expert performance of 60.74 wpm. At first glance this is astonishing: The authors claim that two thumbs can hunt and peck on a tiny keyboard just as fast as ten fingers can touch-type on a full-sized keyboard. But reflection shows that the claim is intuitively plausible: If users can type 20 wpm on a mobile phone, with one thumb, they could probably type 30 wpm with two. Then pressing each key only once per letter, instead of an average of twice on the mobile phone, would seem to double the speed to 60 wpm. Still, we feel the prediction begs for testing.

Onscreen QWERTY keyboards

A third method of mobile input involves displaying a picture of a keyboard on a PDA•s touch-sensitive screen. Users input text by tapping on the displayed virtual keys. Again, we expect that user•s familiarity with the QWERTY layout would transfer, allowing mobile users to input quickly with little practice.

MacKenzie, Zhang, and Soukoreff (1999) first predicted novice speeds of 9 wpm, and expert speeds of 43 wpm. They postulated that experts would have memorized the QWERTY layout and would be able to tap letters as fast as their hand-eye coordination would allow. They imagined that novices would have to visually search the image of the keyboard in order to find each key, and their calculations suggest that such visual search would slow typing significantly, but they acknowledged the difficulty of finding true novices ? college students unfamiliar with QWERTY keyboards.

Then MacKenzie and Zhang (1999) conducted a longitudinal test of learning onscreen keyboards. QWERTY users went from 28 to 40 wpm in 20 practice sessions of 20 minutes each. Here, prediction closely matched experiment. The authors regressed ($r^2 = 0.98$) their experimental data to a power law of learning, modeling the wpm after s training sessions as 27.6 $s^{0.124}$. From this they extrapolated that their subjects would attain 45 wpm after 17 hours of practice. Finally Zhai, Sue, and Accot (2002) ran another experiment, which confirmed the applicability of Fitts' law to onscreen keyboards (again $r^2 = 0.98$) but resulted in an extrapolated expert prediction of 34.2 wpm ? much lower than the average speed attained in MacKenzie•s experiment. This demonstrates that varying experimental parameters results in quite different results and predictions.

Desktop QWERTY keyboards

Our experiments used a standard QWERTY keyboard connected to a PC as a control. Users of QWERTY keyboards on desktop and laptop computers typically either hunt and peck 20?40 wpm or touch type 40?60 wpm (Card, Moran, & Newell 1983, as quoted in Mackensie & Soukoreff 2002). We expected all mobile input methods would prove slower than this standard keyboard, the most commonly used input method, and included it primarily as a sort of upper bound on input speed.

Pen and Paper

As a second control we measured input speed using pen and paper. Most people handwrite with pen on paper at 15?25 wpm (Card, Moran, & Newell 1983, as quoted in Mackensie & Soukoreff 2002).

We included our two controls, desktop keyboards and pen and paper, because we saw them as competing with mobile input devices in the classroom. The desktop keyboard is commonly assumed to be the optimal input device; the conventional wisdom is that mobile input devices trade speed for compactness. Of course pen and paper is not really an electronic input method, but it is still the incumbent, the input method all students use in our current classes. We assumed that paper would be slower, and desktop keyboards faster, than all our mobile input devices.

Summary of previous work on input speeds

Table 1 summarizes the above, showing, for various devices, the input speeds predicted for experts, and measured by experiments:

Wpm	Desktop	Thumb	Onscreen	Cellphone	Paper
Predicted		61	32, 45	25	
Measured	40-60		40	8	15-25

Table 1. Input speeds of various devices

FOA

One way to predict the difficulty of entering text on various devices is to count the number of Foci of Attention (FOA). This is the number of objects competing for visual attention. For example, composing by touch-typing at a keyboard has 1 FOA, since writers look only at the screen. Hunt-and-peck typists require another FOA when they look at the keyboard. Transcribing requires another FOA when the typist looks at the material being copied. So transcribing by hunt-and-peck requires 3 FOA. We assume that tasks with a high FOA tend to cause cognitive overloading, and therefore result in lower performance and more frequent errors.

During our tests, it appeared that most composition tasks had 2 FOA, and most transcription tasks had 3 FOA, regardless of the input device. Our experimental subjects had some training in touch-typing on desktop PCs, but during our tests many subjects still looked at their keyboards, especially when typing punctuation or in L2. Although touch-typing training promises to eliminate the extra FOA when using a large physical keyboard, onscreen keyboards will always require visual attention. Touch-typists can pick up thumb-operated QWERTY keyboards and immediately type quite rapidly, indicating that familiarity with the QWERTY layout transfers to the very different physical task of typing with two thumbs. Yet it is unclear whether thumb typists can touch-type on tiny keyboards, on either PDAs or cellphones. We suspect that all mobile devices will add an extra FOA to the task of typing, over a desktop or laptop PC.

Japanese input

The above descriptions, and all previous research, address the problem of typing English on mobile devices. In contrast, we wish to investigate the problem of mobile typing in the Japanese language, as well as the typing of English as a second language by Japanese college students. Both these problems introduce several issues.

Typing Japanese on a PC

Where European languages use only a few dozen characters, few enough to fit on a standard computer keyboard, Asian languages employ thousands of characters. Japanese is especially complex because the same word can be written up to four different ways: using English letters, using either of two Japanese phonetic alphabets, and using hieroglyphic Chinese ideographs. Asians have experimented with various techniques to input their vast character sets, including handwriting recognition, voice recognition, and even enormous physical keyboards with thousands of keys, but today most Japanese type indirectly using a standard QWERTY keyboard. Input is a two-step process. First Japanese type the phonetic reading of a word, using the standard English QWERTY keys. The computer automatically transliterates the English spelling into Japanese phonetic spelling. (Japanese programmers call this •RKC• abbreviating •Roman letter to phonetic *Kana* Conversion•). In the second step, Japanese choose the written form. The English and Japanese phonetic writings are produced with the press of function keys, but the conversion to ideogram is complex, because Japanese has many homonyms (most words average 10 ideographic writings, but some very common utterances have more than 100 written forms). The typist must call up a menu of the various writings, and choose the intended characters (Japanese call this disambiguation process •KKC• for •phonetic Kana to ideographic Kanji Conversion•). So Japanese touch-typing is impossible: Typists must often look at the screen to choose written forms. Japanese adds a FOA on the homonym menu.

Exacerbating this is the fact that Japanese input is undependable. The items in the homonym menu are initially sorted by frequency, so that the most commonly used written forms are at the top of the list. But as a typist selects written forms, these are moved to the top of the list. This adjusts the menus to the typists, making recently typed homonyms easier to find, but it means that the menus are always changing. Thus typists can never learn where to find writings, and always need to check the screen. The situation is especially chaotic for students, who use several different computers as they move from classroom to classroom and then home during the day. Each computer•s list reflects the typing of the all the students who have used it recently. All this makes it more difficult to type Japanese than English.

The onscreen and thumb keyboards are similar to desktop PCs, sporting similar key layouts, and similar RKC and KKC mechanisms. But mobile phones use a different mechanism.

Typing Japanese on a mobile phone

Where the English alphabet is a simple string of letters, the Japanese phonemes are arranged in a 10x5 two-dimensional grid. This structure makes the mapping of mobile phone keys to Japanese phonemes more logical than to English letters. Each of 10 keys is assigned to a row in the phoneme table. On mobile phones, Japanese type in phonemes directly, skipping the RKC process. Then the phonemes are converted to written forms using KKC, just like on PCs.

Many Americans feel that the desktop QWERTY keyboard is the undefeated champion of input devices, but many Japanese feel differently. Some have postulated that the logical assignment of letters to cellphone keys makes it easier to learn to type on cellphones rather than on desktop PCs. In both English and Japanese, cellphones arrange their keys in alphabetical order, making a sought letter easy to find. In contrast, the desktop QWERTY arrangement seems random and slows visual search. Kuroda (2000) says •America • is the anomaly. Most of the people in the world never have and never will use a QWERTY keyboard • The billions of • wireless email messages thumbed every day are mostly written by • Japanese: their first and only messaging device is a cellphone • [K]ids have been clocked by trendy wireless cellphone teen culture magazines at messaging upwards of 60 words per minute.• Kuroda argues that such speed comes from extensive practice using keypads, as most Japanese spend many hours each week commuting on crowded public transportation, and those hours are increasingly being used to write email on mobile phones.

In any event, because the processes used to enter Japanese are so different on mobile phones and PCs, and also so different from those used to enter English, we doubted the input-speed predictions of earlier work would apply. Further, we expected that Japanese would be slower typing English than native speakers, not only because of their unfamiliarity with English, but also because the processes they use to input the two languages are so different. For example, we observed that most Japanese are fairly familiar with the QWERTY layout, since they are given touch-typing training on it, but many of our subjects had little experience typing English, and seemed to use less efficient techniques, such as typing first in Japanese and then changing to an English writing.

Experiment

Experimental Design

We asked subjects to type on various input devices. We used a within-subjects design and counterbalanced the order of entry methods to avoid learning effects. The independent variables are the type of mobile device (e.g., mobile phone or PDA with thumb keyboard), the language (L1=Japanese or L2=English), and the task (transcription or composition). The dependent variables are the input speed in wpm, error rate, and the subjective opinions of students about the use of mobile devices for educational input tasks.

Subjects

The experimental subjects were 24 Japanese university students. All were paid volunteers, female, with ages ranging from 18-22 and a mean age of 20. Twelve were studying foreign languages in the Department of Language and Culture, and 12 were studying computers in the Department of Information and Culture. There were 10 freshmen, 5 sophomores, 7 juniors, and 2 seniors. On a pre-experiment questionnaire, the subjects reported using PC email for an average of 41 months and mobile phone email for an average of 40 months. Although the time was approximately the same, the average number of compositions (including reports and emails they composed) created on each media was quite different, with PC email at an average of 2.1 per week (range 0-5) and mobile phone email an average of 66 per week (range 10-280). (See Figure 1.) None of the students reported owning or using a PDA.

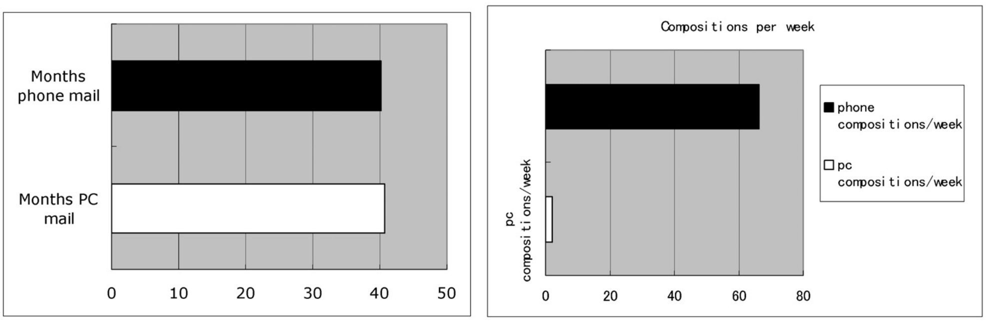


Figure 1, Left: Months of experience using email on PCs and cellphones.

Right: Email and document compositions per week on PCs and cellphones.

Because this study is particularly interested in the use of mobile devices for foreign language learning, students were asked to rate their interest in learning English and state the number of university-level English courses they had taken. Nine students reported liking English, nine reported liking it somewhat, and six reported not liking to study English. One student did not respond. The average number of English classes taken was 8.2 (range 0-18). (The required number of semester courses in English for the Department of Language and Culture is 12 [6 for freshmen and 6 for sophomores] and for the Department of Information Culture is 8 [4 for freshmen and 4 for sophomores]. Six students had chosen elective courses in English, and therefore had taken more than the required number in their respective departments.)

Apparatus
Hardware (See Table 2.)
The following devices were used in the study:

?? Paper and pencil for handwritten text
?? Sharp Zaurus for onscreen keyboard input (QWERTY)
?? Palm V for onscreen keyboard input (QWERTY)
?? Compaq iPaq for onscreen keyboard input (QWERTY)
?? Palm 505 with attached Snap N Type thumb keyboard by Targus (QWERTY)
?? A standard desktop PC with QWERTY keyboard
?? Students• own mobile phones that included a variety of Japanese brands and models with Multi-tap keypads:
9 Docomo: N211i, N503i, N210, N503i, N251i, SH251is
8 J-Phone: J-N05, J-SH7, J- T-51, J-T05, J-SH04, J-P51, J-N03, J-SH08
5 AU: A301SA (au), 3012CA (au), A3013T, A1013K
2 Tsuka: D503

Apparatus Type	Brand				Input method
PDA	Sharp Zaurus 	PalmV 	Compaq iPaq 		Onscreen QWERTY keyboard
PDA	Palm 505				Attached QWERTY Thumb keyboard 
Desktop PC					Full-sized QWERTY keyboard
Cellphones	9 Docomo  N211i, N503i, N210, N503i, N251i, SH251is	8 J-Phone  J-N05, J-SH7, J-T51, J-T05, J-SH04, J-P51, J-N03, J-SH08	5 AU  A301SA, 3012CA, A3013T, A1013K	2 Tsuka D503	Multitap Phone pad

Table 2: Mobile input devices used in the experiment.

Texts for transcription task

We wrote an English (L2) paragraph that represented common topics and an appropriate language level for high beginner English language learners. We didn•t want students to be distracted by trying to decode unfamiliar words. The Japanese paragraph (L1) was a typical explanatory paragraph about the customs of Valentine•s Day. Both were standard academic paragraphs for foreign language (L2) and culture (L1).

L2

Hello. How are you?

My name is Kinjo Kyoko. I am a student at Kinjo Gakuin University. I am studying about computers. I like to listen to music. My favorite food is ice cream. I have one brother and two sisters. My father works in a bank. My mother is a housewife. I go to school by train. It takes 25 minutes. I have a dog. His name is Taro. Everyday I take him for a walk.

L1

1 バレン 日 で か プレ となっ
す アメ で 生 関 な き カ プレ 告 を
ま 小 で カ 交 パー われ ク で 交 ク 全
カ き 中 個 カ し キ をする な ん
して 高 とも 指 な プレ えて 大 にと
は バ 主 で 花 さん バレン ロ セ わ デパ
ハ っ アクセ ハ ネク 靴 トレ さ
レス で バレン ディ 提 され

Topics for composition task

We chose topics that are commonly used in beginning-level foreign language learning materials. The topics were

- Self-introduction
- Family
- High school
- Hobbies or clubs

Procedure

Small groups of participants (2-5 subjects per group) were assigned a 90-minute time slot. The subjects were assigned the type of device to use randomly and then rotated at intervals.

Before the test, subjects completed a Pre-Experiment Poll about their experience using mobile devices and desktop computers and giving their opinions about the use of those devices for educational tasks. Subjects were then given brief instructions about the task and instructions on the use of the PDAs. All subjects had no prior experience using PDAs. They were encouraged to enter a few phrases in English and Japanese on each of the PDAs. Examiners answered questions about keys and input for Japanese or English and about how to select the desired language. Subjects were told that their speed and accuracy would be measured, and that they should type as rapidly as possible, and correct any errors they find.

The experiment included 2-minute transcription tasks and 5-minute composition tasks. Students were rotated at random through the devices and completed a series of 2-minute transcription tasks (alternating L1 and L2 on the same device) followed by one composition task in each language. The data to be transcribed were provided to the subjects on paper. Subjects were instructed not to look at the data until the proctor indicated that the task was beginning. The proctor used a stopwatch to keep track of the time. When time was called, subjects were instructed to stop typing and to save their work on the PDAs and desktop PC and to email their work to the examiner from their mobile phone. When all subjects were ready, the next language transcription task was begun on the same device, following the same protocol described above. After subjects completed transcription tasks in both languages on one device, they were randomly rotated to another device and the transcription protocol was repeated. Subjects used a minimum of 3 and a maximum of 5 devices for transcription depending on the small group size.

Next, subjects were given a topic for composition. Once the topic was explained the proctor began counting the 5-minute time interval. Subjects input a composition on different topics in the L1 and L2 on the same device.

At the end of the experiment, all subjects answered a Post-Experiment Questionnaire indicating their opinions of the mobile devices and their appropriateness for educational input tasks.

Errors

The participants were told to correct any errors they made. Their goal was an error-free text. Later, we counted any remaining uncorrected mistakes.

Measurements

We measured input speeds for transcription (in L1 and L2) and analyzed errors. We measured input only speeds for composition (in L1 and L2), since there could be many possible reasons for errors, especially in a foreign language.

Typing speed is traditionally measured in •words per minute.• This WPM is defined as c*12, where c is typing speed in characters per second. (WPM = c*60/5. This formula is based on the definition of a •word• as five •characters•, where characters are letters, punctuation symbols, and blanks; it corresponds only approximately to actual words. So the traditional WPM actually measures *characters* typed, not words.) The formula is simple to apply to typing English on a QWERTY keyboard, since each *keystroke* (button pressed on the keyboard) results in a single onscreen *character*.

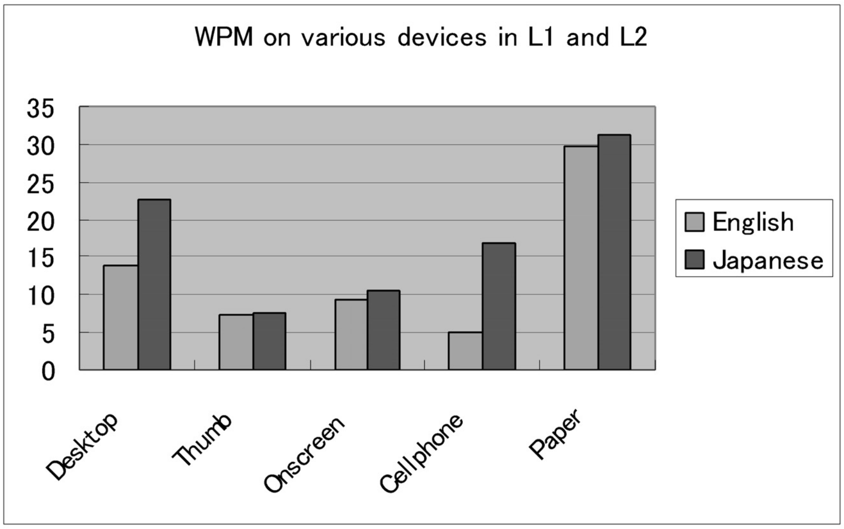
We found as we began our data analysis that we had to make some decisions about how to extend the WPM measurement to various languages and devices. When typing other languages, or using keyboards other than QWERTY, we often need multiple keypresses to produce a single onscreen character. For example, typing English on a cellphone requires more keypresses because most cellphones use the •multitap• input method. To produce •HELLO• on most cellphones requires 14 keypresses (2 for the H, 2 for the E, 3 each for the Ls with a right-arrow keypress between them, and 3 for the O). In the case of English on cellphones, we decided to ignore the extra keypresses and just count the number of characters entered. This allows us to compare English typing speeds on various devices. We measure the result, ignoring the effort various devices demand to produce it. Therefore when students type on cellphones, the actual speed of input (in terms of keypresses per second) is higher than reflected in our comparison. But, as educators we are interested in the amount of text (characters) that can be produced rather than the literal physical input speed.

We also sought to extend the WPM definition to Japanese. Japanese language does not use spaces between words, and the boundaries between words can be ambiguous. So we decided to follow the convention of counting characters, as in the English WPM, and use the same c*12 formula. The problem then is defining a character, since Japanese employs a medley of characters, each requiring some number of keystrokes to enter. The number depends on the character and the input device. For example, Japanese type the two characters for •Tokyo• using 8 English letters on a qwerty keyboard (Toukyou_), or 19 taps on a Japanese cellphone (using the typical •kana multitap• system). In order to compare English and Japanese input on QWERTY keyboards, we decided to count Japanese keystrokes (not characters). When our test subjects type •Tokyo• we count that as 8 letters. The most controversial aspect of our counting is that we use the same keypress count (8) on all devices, even non-qwerty devices like cellphones and paper (where the keystroke count is different, or the very concept of keys meaningless). Our rationale is that this commonality allows us to compare Japanese output across devices. In summary, we analyze Japanese typing speed by deconstructing written text back into the keystrokes required to produce it on a QWERTY keyboard, and then using the WPM formula (c*12). We posit this will give us comparable numbers, even across different input devices and radically different languages.

(We also calculated, using our transcription texts, the ratio of multitap keypresses to QWERTY characters, and found that for Japanese there was a 1.7 ratio and for English 4.1. However we decided not to incorporate that data into our text comparisons.)

Results

Our experiments showed that Japanese university students have the fastest production in both languages using paper and pencil rather than any electronic tool. Among the electronic input tools, we found some differences between the two languages. The desktop PC was fastest for both languages. However, remarkably, for Japanese language, students were able to produce only a little less on their cellphones. In spite of the awkwardness of typing on mobile phones, our subjects were so well practiced that they approached desktop speeds. In English, none of the mobile devices had a high output and cellphones were the lowest. (See Figure 2.) In both languages, the attachable thumb keyboard had low results and had unfavorable ratings on the post-experiment questionnaire. During the experiment, we observed that students had the most difficulty with the thumb keyboard. They forgot how to produce punctuation and accidentally pressed function keys, occasionally switching to another application, and sometimes erasing their text. We believe these problems were caused by inadequate training and the cryptic keycap symbols on our thumb keyboard. We feel that with a few more minutes of training and practice, subjects would learn to make far fewer errors using thumb keyboards.

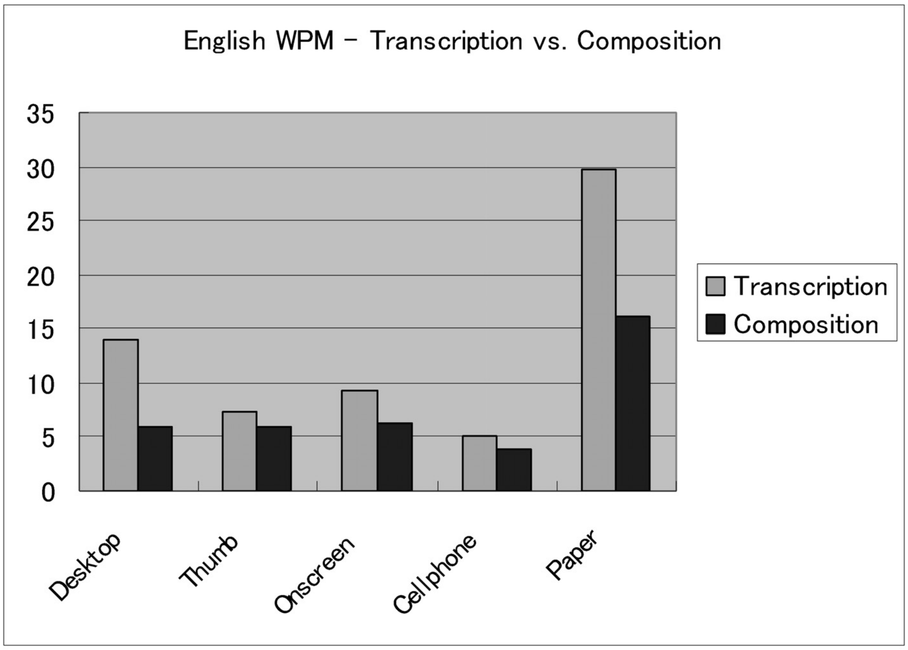


WPM

	Desktop	Thumb	Onscreen	Cellphone	Paper
English	13.94	7.362	9.195	5.016	29.71
Japanese	22.54	7.638	10.55	16.83	31.1

Figure 2: Transcription speed on various devices in L1 and L2.

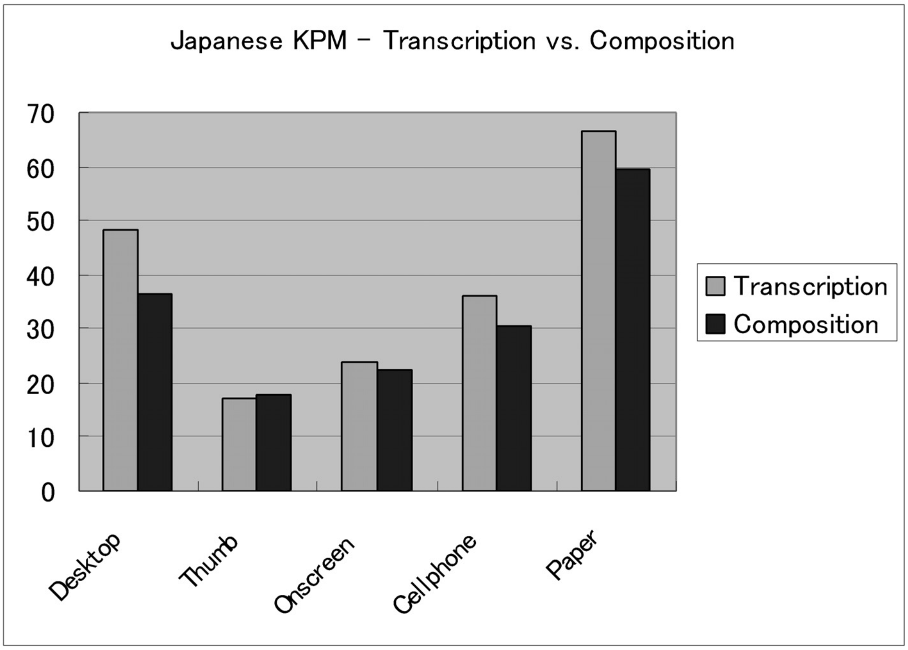
When comparing transcription and composition, we see similar trends among the devices, with composition almost always resulting in lower output. In English, the w ords per minute were similar for all electronic input devices, except for cellphones which were lower. Again, paper and pencil gave the best result. In Japanese, the transcription and composition tasks gave similar results. (See Figures 3 and 4.)



English WPM - Transcription vs. Composition

	Desktop	Thumb	Onscreen	Cellphone	Paper
Transcription	13.94	7.362	9.195	5.016	29.71
Composition	5.952	5.88	6.253	3.795	16.17

Figure 3: Transcription vs. compo sition speed in L2 English.

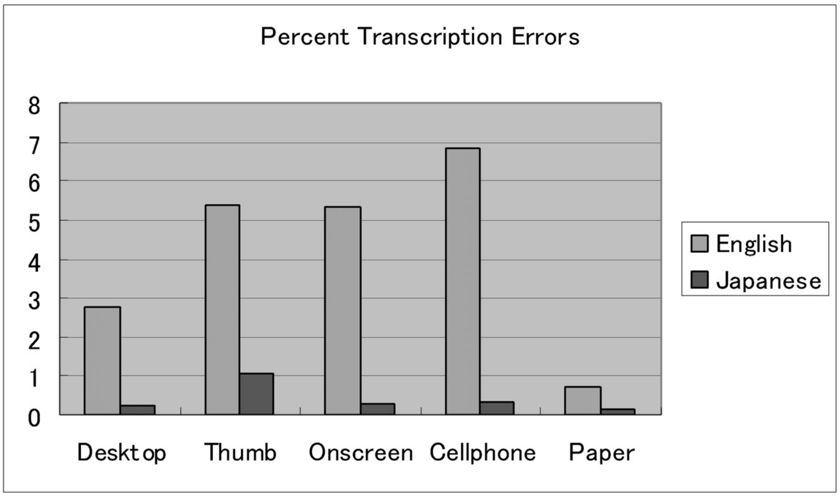


Japanese KPM - Transcription vs. Composition

	Desktop	Thumb	Onscreen	Cellphone	Paper
Transcription	48.44	17.32	23.68	36.19	66.56
Composition	36.23	17.71	22.28	30.42	59.47

Figure 4: Transcription vs. composition speed in L1 Japanese (in Japanese characters per minute).

Concerning errors made in the transcription task, for all input methods, there were more errors in English L2 than in Japanes e L1. In English the highest percentage of errors (6.8%) was found with the cellphone, and the lowest percentage (0.7%) occurred with paper and pen. In Japanese, the highest percentage of errors was with the thumb keyboard (1%), and the lowest with paper and pen (0.1%). (See Figure 5.)



Per cent Transcription Errors

	Desktop	Thumb	Onscreen	Cellphone	Paper
English	2.745	5.369	5.329	6.821	0.748
Japanese	0.231	1.071	0.284	0.363	0.143

Figure 5: Transcription errors on v arious devices.

Subjective results

As shown in Figure 6, subjects preferred typing on cellphones and desktops. Cellphones and desktops were equally well liked for typing short texts, but desktops were slightly preferred for long texts. The novel input met hods were less preferred: Onscreen keyboards and thumb keyboards were the least well liked.

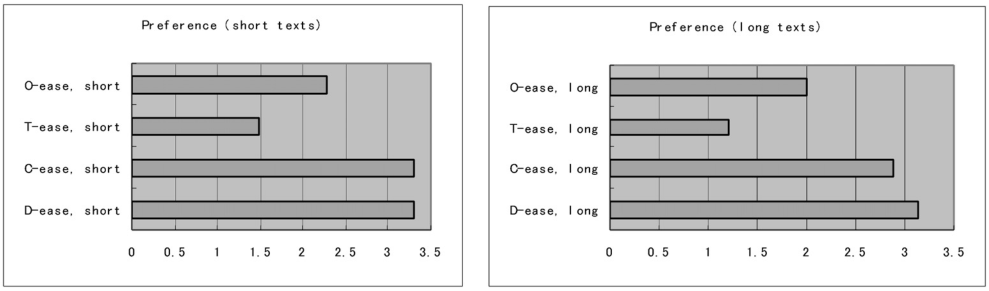


Figure 6: Preferences for mobile input devices for short (left) and long (right) texts.

Discussion and Conclusion

We measured the speed, accuracy, and preferences of Japanese students typing both English and Japanese on several mobile input devices. Our results showed that with practice, small mobile keyboards, like those found on cellphones, produce good text output results. We believe this is due to the fact that our Japanese students can be considered expert users of cellphone keyboards in the Japanese language (see Thornton & Houser, submitted). Since our subjects were novice users of PDA keyboards and English cellphone keyboards, those devices gave poorer results. What does this mean for education?

In university classrooms, one can find both transcription and composition tasks. Transcription tasks might include copying notes from PowerPoint slides or the blackboard and copying notes from textbooks and other print sources. Composition tasks would include summarizing lectures and texts, writing short or long essay questions, writing reports and presentations, or creative writing such as L2 fiction and journals. Based on our data, we believe that Japanese students could easily do both transcription and composition tasks in their native Japanese language with their readily available cellphones, without any training or additional practice. However, if universities wish to adopt other mobile technologies such as PDAs, some training and practice time will be needed before the tools can become useful and adequate as an input device in both English and Japanese. The same is true for the use of cellphones for English input among Japanese students.

We were a little surprised to see the obvious dominance of paper and pen over electronic input devices. Certainly it would be hard to find many American college students who could handwrite faster than they could type. We posit that Japanese students have years of experience transcribing English and Japanese texts on to paper throughout high school and college, and only infrequently use computers. (Japanese schools are of course infamous for emphasizing rote learning, and rarely assign essay writing, or indeed homework of any kind.) Pen and paper are approachable, but the medium deprives students of the advantages of electronic media (easy storing, searching, editing, printing, and exchanging). Mobile devices are especially advantageous for students, because they make notes and assignments available whenever students have a few moments to study. As a future project, we plan a longitudinal study, giving students more time to become accustomed to novel input methods such as onscreen and thumb keyboards. We also hope to train and test students on the use of a handwriting recognition system on PDAs, such as Palm•s *Graffiti*, as a possible way to capitalize on Japanese students• handwriting abilities, and to combine the benefits of pen with the benefits of electronic text for Japanese students.

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