

# From Keystrokes to Cognition: A Comprehensive Review of Touch Typing's Interplay with Cognitive Processes

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## **Abstract**

In the digital era, despite the proliferation of diverse input methods, touch typing remains a paramount mode of human-computer interaction. This review delves into the intricate relationship between touch typing and cognitive processes. Anchoring its exploration in historical context, the paper underscores the evolution of touch typing from a skill met with skepticism to a complex cognitive endeavor deeply intertwined with implicit memory. Through a novel numerical representation, the paper elucidates the cognitive challenges posed by different keyboard layouts, notably QWERTY and the 9-key Chinese keyboard. Central to the discussion is the paradoxical interplay between implicit motor memory and explicit linguistic articulation, offering a fresh prespective. Drawing from a rich tapestry of empirical studies, theoretical frameworks, and practical implications, the paper calls for a deeper exploration of touch typing, not merely as a mechanical skill but as a testament to human cognition's adaptability and sophistication.

## **Introduction**

The digital age has marked a paradigm shift in human-computer interaction. Despite the emergence of various novel input methods, from gesture recognition to voice-based commands, typing stands as the predominant mode of digital communication. As highlighted by John (1996),

it has retained its primacy even amidst rapidly evolving technological landscapes. This is resonated by Professor John Sutherland of University College London, who asserted, "Typing is an indispensable competency in both personal and professional realms. A deficiency in this skill can significantly constrict opportunities in the professional world." Furthermore, the ubiquity of devices like computers, smartphones, and the groundbreaking Vision Pro by Apple, all integrated with keyboards, underscores the continued centrality of typing in human-computer dialogue.

Touch typing, the art of typing without the visual aid of the keyboard, emerges as a vital proficiency in this context. At first glance, this skill may appear rudimentary, detached from the higher-order competencies of critical thinking or creativity. Yet, touch typing is quintessential for optimal cognitive performance in the 21st century (Partnership for 21st Century Schools, n.d.). Studies have accentuated that the cognitive load imposed by visually guided typing, which necessitates the continual shifting of gaze between the source text and the keyboard, severely impedes efficiency (Yechiam, 2003). In contrast, touch typing, relying on implicit knowledge of key locations and proprioceptive feedback, facilitates concurrent reading and typing. This distinction is starkly evident in the context of educational settings.

Christensen's (2004) pivotal study elucidated a direct correlation between touch typing fluency and the quality of written output. The advantages of touch typing emanate from its ability to free cognitive resources, allowing writers to channel their attention wholly towards the task of composition. This is consistent with the principles of Cognitive Load Theory, which propounds that the human cognitive system can attend to a limited set of tasks concurrently (Paas & Ayres, 2014). As Berninger et al. (2002) postulated, the balance between transcription and executive functions in the writing process is critically contingent on the writer's proficiency in

the former. This balance is imperative for optimal allocation of working memory, a central component of the writing process.

The rising ubiquity of digital devices in educational institutions further amplifies the urgency to inculcate touch typing skills. Notably, word processing has surged as a primary use of computers across academic curricula (Becker, 2000; Goldberg et al., 2003), suggesting an escalating reliance on keyboards for textual input. The potential benefits of touch typing in this context are immense, particularly given the speed and efficiency it offers compared to traditional handwriting. However, the systematic integration of touch typing instruction within educational curricula remains sporadic.

While the importance of developing adept typists is universally acknowledged, a significant gap persists in our understanding of the underlying cognitive mechanisms. While implicit memory elucidates the *how* of touch typing, it doesn't necessarily unravel the *why*—the underlying cognitive mechanisms facilitating this transition remain a rich avenue for exploration. This review seeks to bridge this lacuna, offering an in-depth exploration of the cognitive dimensions of touch typing and its implications for education and beyond.

In essence, as we stand at the forefront of the digital revolution, it is imperative to re-evaluate and understand the nuances of touch typing, not merely as a mechanical skill but as a sophisticated cognitive competency, waiting to be explored.

### **Implicit Memory and the Art of Touch Typing**

The realm of skilled performance is enveloped in a profound paradox. While experts invest years honing their skills, drawing upon a vast reservoir of knowledge to facilitate their adeptness, they often possess limited explicit access to this knowledge. This dichotomy is particularly evident in the domain of typewriting. As highlighted by Logan & Crump (2009),

seasoned typists exhibit a surprising lack of explicit cognizance regarding the intricate movements of their fingers. This enigma has given rise to the conceptual distinction between procedural (implicit) knowledge, which directly underpins skilled performance, and declarative (explicit) knowledge, which remains tangential to the performance process (Anderson, 1982; Beilock & Carr, 2001; Cohen & Squire, 1980).

Diving deeper into this dichotomy, typewriting offers a compelling paradigm. A hierarchical control system, as proposed by Logan and Crump (2009), provides a robust framework to reconcile the paradox. This model comprises two nested feedback loops: an inner loop responsible for the translation of words into individual keystrokes and an outer loop interfacing with linguistic processes, furnishing the inner loop with a sequence of words for transcription. This division intimates an encapsulation wherein the outer loop remains oblivious to the detailed operations of the inner loop. Yet, the efficacy of this model becomes profoundly evident when skilled typists are confronted with tasks that deviate from their routine, such as typing exclusively with one hand. The resulting disruption, as articulated by Logan (2009), underscores the delicate equilibrium between these loops and their specialized functions.

Adding a further layer of complexity to this narrative is the innovative realm of invisible keyboards. The very concept reinforces our understanding of touch typing under implicit memory, positing a scenario wherein typists rely on an absent visual stimulus. Liu's study in 2010 laid the foundation, revealing that despite the rapid and precise keystrokes typists can achieve, their explicit knowledge of the QWERTY layout remains strikingly limited. This phenomenon was further elucidated by Weerdenburg (2019), emphasizing the role of touch typing in bolstering narrative-writing skills. This subtle yet profound connection between implicit memory and typing proficiency becomes even more pronounced when typists

demonstrate proficiency on invisible keyboards, as demonstrated by Zhu (2018). The astounding revelation that typists could approach the speed and accuracy of regular keyboards on invisible counterparts after brief training sessions underscores the sheer depth and resilience of implicit memory in skilled performance.

Thus, this section delves into the prevailing academic consensus: touch typing heavily relies on implicit memory and thus reducing the usage of cognitive resources.

### **Touch Typing: Delving into the Depths of Cognitive Mastery**

The art of touch typing, wherein individuals type seamlessly without the need to visually reference the keyboard, has long been a subject of fascination and inquiry. Historically, such a modality of typing was met with skepticism, particularly considering the QWERTY layout was engineered with a primary aim of mechanical efficiency, rather than intuitive human-machine interaction (Noyes, 1983). The audacity of envisioning individuals typing with all ten fingers, without visual verification, was initially considered an overly ambitious endeavor (Beeching, 1974).

However, as technological epochs shifted, subsequent advancements in word processing software and the evolution of ergonomic keyboard designs further bolstered its widespread adoption.

The conundrum, however, lies in the apparent disconnect between touch typing proficiency and explicit knowledge of the keyboard. Snyder et al. (2014) intriguingly illustrated that skilled typists, capable of executing six to seven keystrokes per second with remarkable accuracy, could explicitly recall the locations of only about half of the keys. This apparent anomaly raises pertinent questions: How do typists attain such proficiency despite an apparent lack of explicit spatial awareness? What cognitive mechanisms underpin this dichotomy?

Several studies propound that touch typing straddles the realms of implicit motor memory and the explicit cognitive nuances inherent in language processing. Neuroimaging research reveals that as typists engage in touch typing, there's a harmonized confluence between the meticulous movements of their fingers and cognitive linguistic processes, all transpiring without imposing a significant cognitive load (Poldrack et al., 2005).

However, the rapidity and accuracy with which fingers navigate the keyboard—sans visual affirmation—remain an enigma. How do fingers "remember" key positions absent conscious retrieval? How does this motor prowess intertwine seamlessly with cognitive language articulation? Theories of automaticity suggest that seasoned performance hinges on implicit knowledge, whereas novice endeavors lean more on explicit knowledge (Anderson, 1982; Logan, 1988). Yet, touch typing seems to challenge these assertions, given that precise key localization is paramount. The manifestation of touch typing emphasizes the intricate finesse of our bodily memory and autonomy, suggesting our physiological systems might operate with an elevated degree of independence than previously assumed.

While daily exposure to an object, such as a keyboard, doesn't necessarily culminate in complete explicit memory of the object (Synder et al., 2014), the mechanics of touch typing underscore the complex interplay between motor skills, memory, and cognition. As typists, we might be as unconsciously adept with keyboards as we are with mundane tasks, like using coins or elevator buttons.

In conclusion, touch typing offers a fertile ground for exploration, poised to unravel broader revelations about cognition, memory, and motor capabilities. The journey from skepticism to mastery underscores human adaptability and the intricate dance of cognitive faculties that underpin our interactions with the technological world.

## The Cognitive Landscape of Touch Typing Across Different Keyboard Layouts

In order to further illustrate the sophisticated process of touch typing, the author recasted QWERTY keyboard and Chinese 9-key keyboard in numerical terms. Such representations may fresh our understandings, prompting us to consider the intricate mental processes underpinning our familiarity with keyboard layouts (Logan & Crump, 2011).

### *1. QWERTY: Beyond Alphabetic Mapping*

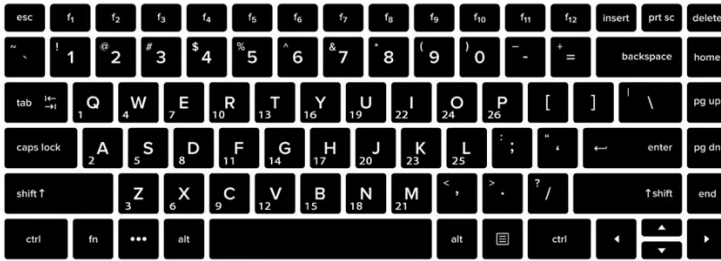
The QWERTY keyboard, a ubiquitous presence in our daily computing endeavors, transcends its apparent alphabetic arrangement. Historically, its inception wasn't tailored for the touch typing system that dominates today but rather for "hunt and peck" typing, a method where typists search for each key individually. Sholes and Glidden, the original inventors, envisioned a device capable of producing text at rates comparable to handwriting (Noyes, 1983).

This QWERTY layout, as reframed numerically in this paper, emerges as: Q=1, A=2, Z=3, ... L=25, P=26.

Table 1

KEY	NUMBER	KEY	NUMBER	KEY	NUMBER
Q	1	I	22	A	2
Z	3	J	20	W	4
X	6	E	7	S	5
C	9	R	10	D	8
F	11	T	13	V	12
B	15	Y	16	G	14
H	17	U	19	N	18
K	23	O	24	M	21
L	25	P	26		

Figure 1



Consider the straightforward English sentence, "The supper is ready." In touch-typing notation, this translates to:

13,17,7,5,19,26,26,7,10,22,5,10,7,2,8,16 13,17,7,5,19,26,26,7,10,22,5,10,7,2,8,16.

Additional illustrations include:

- "I felt really tired recently." →

22,11,7,25,13,10,7,2,25,25,16,13,22,10,7,8,10,7,9,7,18,13,25,16 22,11,7,25,13,10,7,2,25,2,5,16,13,22,10,7,8,10,7,9,7,18,13,25,16.

- "I will send you the document in ten days." →

22,4,22,25,25,5,7,18,8,16,24,19,13,17,7,8,24,9,19,21,7,18,13,22,18,13,7,18,8,2,16,5 22,4,22,25,25,5,7,18,8,16,24,19,13,17,7,8,24,9,19,21,7,18,13,22,18,13,7,18,8,2,16,5.

Table 2

SENTENCE	QWERTY REPRESENTATION
<b>THE SUPPER IS READY.</b>	13, 17, 7, 5, 19, 26, 26, 7, 10, 22, 5, 10, 7, 2, 8, 16
<b>I FELT REALLY TIRED RECENTLY.</b>	22, 11, 7, 25, 13, 10, 7, 2, 25, 25, 16, 13, 22, 10, 7, 8, 10, 7, 9, 7, 18, 13, 25, 16
<b>I WILL SEND YOU THE DOCUMENT IN TEN DAYS.</b>	22, 4, 22, 25, 25, 5, 7, 18, 8, 16, 24, 19, 13, 17, 7, 8, 24, 9, 19, 21, 7, 18, 13, 22, 18, 13, 7, 18, 8, 2, 16, 5



The ostensibly random sequence challenges conventional cognitive mapping paradigms. How do our fingers instinctively traverse the keyboard, pinpointing precise locations without an overt consciousness of key placement? This deftness underscores an intricate interplay of implicit memory. The historical rationale behind QWERTY's design, as posited by Noyes (1983), was to circumvent mechanical constraints by separating frequently used letter pairs, a strategy conceived by Densmore, a colleague of the inventors. This revelation debunks the popular myth that QWERTY was intentionally designed to retard typing speed (Cocking, 1970).

Once the QWERTY layout became a standard, typists invested time and effort in learning it, leading to a form of lock-in. Even if a more efficient keyboard layout were introduced later (like the Dvorak layout), the switching costs for individuals and society as a whole would be high, so the QWERTY layout persisted. (David, 1985)

Therefore, the QWERTY layout serves as a testament to human adaptability and cognitive dexterity, illuminating the harmonious marriage of historical necessity with modern proficiency. As we further unravel this complex tapestry, we stand to gain profound insights into the realms of cognitive psychology and human-machine interactions.

## ***2. The 9-Key Chinese Keyboard: A Multifaceted Cognitive Challenge***

The 9-key Chinese keyboard, a staple in modern mobile communication in China, condenses character input into a limited keyset. Gong & Liu (2018) emphasize that while the 9-key keyboard offers the advantage of large key areas (optimizing it for users with visual impairments or larger fingers), its design doesn't always reflect the nuanced spelling rules of Pinyin. For instance, frequent letters in Pinyin, like 'N', are placed in less accessible positions, while infrequent ones, such as 'V', occupy prime real estate. Therefore, adapting to this compact layout and its associated cognitive demands is supposed to be higher than the QWERTY system.

Furthermore, the inherent complexity of mapping multiple characters to single keys requires a dynamic blend of phonetic, visual, and spatial strategies, as evidenced in research that delves into the cognitive aspects of typing in various languages (Rumelhart & Norman, 1982).

Here, similarly, keys are systematically enumerated:  $A,B,C=1, \dots W,X,Y,Z=8$ .

Table 3

KEYS	NUMBER
A, B, C	1
D, E, F	2
G, H, J	3
J, K, L	4
M, N, O	5
P, Q, R, S	6
T, U, V	7
W, X, Y, Z	8

Figure 2



For instance, the Chinese expression "晚饭好了" (The supper is ready) in Pinyin, "wan fan hao le", translates to: 8,1,5,2,1,5,3,1,5,4,28,1,5,2,1,5,3,1,5,4,2. Other examples include:

- "我最近真的很累" (I felt really tired recently) in Pinyin "wo zui jin zhen de hen lei" → 8,5,8,7,4,3,4,5,8,3,2,5,2,2,3,2,5,4,2,48,5,8,7,4,3,4,5,8,3,2,5,2,2,3,2,5,4,2,4.
- "我将会在十天内把文件发送给你" (I will send you the document in ten days) in Pinyin "wo jiang hui zai shi tian nei ba wen jian fa song gei ni" → 8,5,3,4,1,5,3,3,7,4,8,1,4,6,3,4,7,4,1,5,5,2,4,1,1,8,2,5,3,4,1,5,2,1,6,5,5,3,3,2,4,5,48,5,3,4,1,5,3,3,7,4,8,1,4,6,3,4,7,4,1,5,5,2,4,1,1,8,2,5,3,4,1,5,2,1,6,5,5,3,3,2,4,5,4.

Table 4

SENTENCE (PINYIN)	9-KEY REPRESENTATION	SENTENCE (CHINESE)	TRANSLATION (ENGLISH)
WAN FAN HAO LE	8, 1, 5, 2, 1, 5, 3, 1, 5, 4, 2	晚饭好了。	The supper is ready.
WO ZUI JIN ZHEN DE HEN LEI	8, 5, 8, 7, 4, 3, 4, 5, 8, 3, 2, 5, 2, 2, 3, 2, 5, 4, 2, 4	我最近真的很累。	I felt really tired recently.
WO JIANG HUI ZAI SHI TIAN NEI BA WEN JIAN FA SONG GEI NI	8, 5, 3, 4, 1, 5, 3, 3, 7, 4, 8, 1, 4, 6, 3, 4, 7, 4, 1, 5, 5, 2, 4, 1, 1, 8, 2, 5, 3, 4, 1, 5, 2, 1, 6, 5, 5, 3, 3, 2, 4, 5, 4	我将会在十天内把文件发送给你。	I will send you the document in ten days.

Navigating different keyboard layouts underscores the adaptability and plasticity of the human brain. As we transition between layouts, rapid cognitive recalibrations occur, highlighting the intricate interplay between memory, motor skills, and linguistic processing. Such adaptability also speaks to the broader cognitive implications of our interactions with technology, suggesting avenues for future research in the realm of human-computer interaction.

The interplay of touch typing, cognitive processing, and diverse keyboard layouts presents a rich tapestry for exploration. Both the QWERTY and 9-key layouts underscore the depth of human cognition and adaptability. As we continue to probe this domain, insights regarding the relationship between cognition, memory, and motor skills are poised to deepen our understanding of human-technology interfaces.

## **Discussion**

The realm of touch typing presents a captivating paradox in the landscape of cognitive science. A seemingly mechanical task, touch typing requires the rapid and precise location of keys on a keyboard, all accomplished without the direct aid of visual cues. At its core, this skill exemplifies a harmonious ballet between our fingers and cognitive faculties, wherein the latter orchestrates the dance without actively participating in each step. This paper delves into the intricacies of touch typing, a phenomenon that stands at the crossroads of implicit and explicit memory systems, challenging our understanding of cognitive processes and offering a fresh perspective on human-machine interactions.

Touch typing's reliance on implicit memory is, undeniably, a manifestation of profound cognitive complexity. One might surmise that the precise localization of keys, especially given the seemingly random distribution of alphabets on a standard QWERTY layout, would necessitate the involvement of explicit knowledge. Astonishingly, this is seldom the case. Current literature acknowledges the non-trivial nature of typing (Rumelhart, 1982). However, the depth of complexity intrinsic to touch typing remains a much under-explored frontier.

The act of touch typing, while mechanically dependent on implicit memory, is in essence an expressive endeavor. It is an act of linguistic articulation, seamlessly interfacing with our conscious linguistic processes. This paradoxical juxtaposition—of a task deeply rooted in

implicit memory yet integral to explicit linguistic expression—invites critical introspection. While touch typing as a testament to the prowess of implicit memory is well-accepted in contemporary scholarship, this paper contends that such an understanding, though accurate, remains superficial. Recognizing how touch typing occurs is a stride forward, but comprehending why it can manifest with such finesse is the true enigma.

It is the objective of this review to probe deeper, to unravel the layers beneath the surface of touch typing. Beyond merely recognizing it as a poster child for implicit memory, we seek to understand the potential autonomy or intricate memory mechanisms inherent within our implicit cognitive systems. This exploration, we believe, holds the key to unlocking broader revelations about the human cognitive apparatus and its interactions with the digital realm.

In the review, we embark on a journey through the cognitive dimensions of touch typing, hoping to illuminate the potential mechanisms that enable its realization. This is not merely an academic exercise, it is a quest to fathom the depths of our cognitive abilities, challenging established norms, and setting the stage for future research that transcends boundaries.

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