Inner loop sequence representations are typing-specific for finger movement control, but are developed for the more general purpose of fluent language production. Our theory assumes that language comprehension and production processes are cannibalized or co-opted in the service of controlling typing (Tubau, Hommel, & López-Moliner, 2007). The outer loop for language production that is normally connected to inner loops for motor control in speech and writing becomes integrated with an inner loop for typing. Novice typists use verbal codes for letters and control serial ordering of keystrokes with outer loop monitoring of actions. But, with practice, experts use verbal codes for words, retrieving integrated keystroke sequence representations executed and monitored by the motor system. Thus, acquisition of typing skill should be promoted by increased reliance on verbal codes, but also constrained by individual differences in verbal fluency and lexical retrieval abilities (Alves, Castro, & Olive, 2008). The outer loop connects established verbal codes as hierarchical control units for keystroke execution.

Speaking out loud and silently using an inner voice reflect deeply powerful language comprehension and production processes that are often used in the service of cognition and performance more generally. In memory, the phonological loop transitions to-be-remembered information into long-term memory through short-term rehearsal (Baddeley & Hitch, 1974), and the act of speaking out loud itself improves future retrieval (MacLeod et al., 2010). Verbal recoding can facilitate sequence learning by casting elements into chunks with recallable names (Miller, 1956). Botvinick and Plaut (2004) argue that verbally coded instructions together with recurrent associative learning of real-world action sequences provide the control needed to model routine tasks like making coffee. A similar proposal has been adopted to account for action sequencing in laboratory tasks (Tubau et al., 2007). The control capacities inherent to overt and covert speech are also co-opted during skilled typewriting. Skilled typists think in words and sentences, not in letters typed by their fingers (see preliminary data for E2.1). The inner loop, developed through practice to execute keystrokes, co-opts existing verbal control processes to extend the use of verbal codes for speech to control finger movements. The outer loop’s use of words as inputs to the motor system for typing is a common assumption in all major theories of typing (John, 1996; Logan & Crump, 2011; Rumelhart & Norman, 1982; Wu & Liu, 2008). My prior work supports this idea because words, but not random letter strings, activate constituent letters in parallel for typing (Crump & Logan, 2010c). Lexical representations are a fundamental intermediary between the outer and inner loops that prepare the inner loop with parallel activation of to-be-sequenced actions. This suggests that typing skill is critically mediated by learning to connect developing motor routines with established verbal control processes.

     

12

This project tests how connections between verbal codes and motor plans speed acquisition of typing skill. **Experiment 2.1: Making typists speak in words vs. letters.** This experiment will manipulate whether typists rely on verbal codes at the word or letter level during copy typing. 40 skilled typists will copy type four ~115 word paragraphs of English text. Each paragraph will be typed with instructions to simultaneously speak each word out loud, speak each letter out loud, silently articulate each word or letter, or type normally with no specific verbalizing instruction.

We assume that skilled typists use verbal codes at the word level, and expect that keystroke timing and accuracy will be superior when typists use word rather than letter verbal codes. Word level verbal codes afford parallel activation of to-be-typed letters, but letter level codes will serialize response-selection and have a rate-limiting effect on typing speed. People can recite individual letters in 100-125 ms (Landauer, 1962; Logan & Klapp, 1991) so the rate-limiting effect should not be driven by slower letter-voicing times, but by the match between the verbal codes and representations controlling typing strokes. Speaking out loud and typing require the outer loop to simultaneously control two motor control loops for speech and typing. The greater tax on outer loop resources will generally slow typing performance compared to silent speech.

This experiment will be conducted in the lab to ensure compliance with the speaking instructions. Nevertheless, preliminary data for this experiment were collected from 45 typists recruited from AMT who completed only the inner voice conditions. They copied two sentences under different inner voice speaking instructions: silently voice letters or words while typing. The same typists typed at 58 WPM while silently voicing letters, and 76 WPM while silently voicing words, and the difference was significant. As part of the online demographics collected, typists were asked if their inner voice speaks in words vs. letters while they type; 93% claimed silently voicing words while typing. The figure shows that silently voicing letters interfered more strongly with faster than slower typists, consistent with the idea that experts rely more on verbal codes for words, and novices rely on verbal codes for letters because they have not learned to use the outer loop for word-level control.

What does this work relate to?

Verbal code and plan based ideas

Pfeuffer, C. U., Moutsopoulou, K., Waszak, F., & Kiesel, A. (2017). Multiple priming instances increase the impact of practice-based but not verbal code-based stimulus-response associations. *Acta Psychologica*.

Dual-tasking