Training writing skills: A cognitive developmental perspective

Ronald T. Kellogg

Saint Louis University | USA

Abstract: Writing skills typically develop over a course of more than two decades as a child matures and learns the craft of composition through late adolescence and into early adulthood. The novice writer progresses from a stage of knowledge-telling to a stage of knowledge-transforming characteristic of adult writers. Professional writers advance further to an expert stage of knowledge-crafting in which representations of the author's planned content, the text itself, and the prospective reader's interpretation of the text are routinely manipulated in working memory. Knowledge-transforming, and especially knowledge-crafting, arguably occur only when sufficient executive attention is available to provide a high degree of cognitive control over the maintenance of multiple representations of the text as well as planning conceptual content, generating text, and reviewing content and text. Because executive attention is limited in capacity, such control depends on reducing the working memory demands of these writing processes through maturation and learning. It is suggested that students might best learn writing skills through cognitive apprenticeship training programs that emphasize deliberate practice.

Keywords: writing skills, professional writers, cognitive development, working memory,, training

journal of WRITING RESEARCH

Kellogg, R.T. (2008). Training writing skills: A cognitive developmental perspective. *Journal of Writing Research, 1*(1), 1-26. http://dx.doi.org/10.17239/jowr-2008.01.01.1

Learning how to write a coherent, effective text is a difficult and protracted achievement of cognitive development that contrasts sharply with the acquisition of speech. By the age of 5, spoken language is normally highly developed with a working vocabulary of several thousand words and an ability to comprehend and produce grammatical sentences. Although the specific contribution of a genetic predisposition for language learning is unsettled, it is apparent that speech acquisition is a natural part of early human development. Literacy, on the other hand, is a purely cultural achievement that may never be learned at all. Reading and writing are partly mediated by the phonological speech system, but an independent orthographic system must also be learned.

Writing an extended text at an advanced level involves not just the language system. It poses significant challenges to our cognitive systems for memory and thinking as well. Indeed, writers can put to use virtually everything they have learned and stored away in long-term memory. But they can only do so if their knowledge is accessible, either by rapidly retrieving it from long-term memory or by actively maintaining it in short-term working memory. Thinking is so closely linked to writing, at least in mature adults, that the two are practically twins. Individuals who write well are seen as substantive thinkers, for example. The composition of extended texts is widely recognized as a form of problem solving. The problem of content - what to say - and the problem of rhetoric-how to say it - consumes the writer's attention and other resources of working memory. All writers must make decisions about their texts and at least argumentative texts call upon their reasoning skills as well. Finally, the written text serves as external form of memory that others can read and reflect upon, providing a scaffold for thinking and writing in the historical development of a literate culture.

Learning how to compose an effective extended text, therefore, should be conceived as a task similar to acquiring expertise in related culturally acquired domains. It is not merely an extension of our apparent biological predisposition to acquire spoken language. Rather, it is more similar to learning how to type - which is in fact one aspect of composition, as a common means of motor output. Or, it is similar to learning how to play chess - which is another planning intensive task similar to composition in its demands on thinking and memory. Or, it is similar to learning how to play a musical instrument - which demands mastery of both mechanical skills and creative production. Becoming an expert typist, chess player, or, say, violinist, requires a minimum of 10 years of intensive learning and strong motivation to improve. The very best violinists, for example, have accumulated more than 10,000 hours in solitary practice, whereas lesser experts (7,500 hours), least accomplished experts (5,000), and amateurs (1,500) have devoted proportionally less time to self-improvement (Ericsson, Krampe, & Tesch-Römer, 1993).

The theme of this paper is that learning to become an accomplished writer is parallel to becoming an expert in other complex cognitive domains. It appears to require more than two decades of maturation, instruction, and training. The central goal is to gain executive control over cognitive processes so that one can respond adaptively

to the specific needs of the task at hand, just as a concert violinist or grand master in chess must do. Accordingly, we should look to the principles of cognitive apprenticeship, with a focus on deliberate practice, in developing interventions that train as well as instruct writers.

We know that many different types of knowledge related to text content and discourse structure must be available in long-term memory. We know that instruction across disciplines and writing instruction in particular must necessarily impart such knowledge. The focus here is on the equal imperative to train writers so that they can retrieve and use what they know during composition, as dictated by the knowledge-use principle (Kellogg, 1994). Without knowledge being accessible and creatively applied by the writer, it remains inert during composition and unable to yield the desired fluency and quality of writing.

The objectives of the present paper are, first, to sketch the broad outlines of how writing skill develops across three stages, as a child matures and learns the craft of composition through late adolescence and into early adulthood. The first two - knowledge-telling and knowledge-transforming - are well documented. A third stage - knowledge crafting - is more speculative, but important for understanding expert or professional levels of writing skill. Second, it is suggested that the primary constraint on progression through these stages is the limited capacity of the central executive of working memory. Executive attention must not only be given to language generation, but also be available for planning ideas, reviewing ideas, and coordinating all three processes. At the same time, attention must be given to maintaining multiple representations of the text in working memory. Achieving the necessary cognitive control can only occur by reducing the demands on the central executive. Third, the implications of these views for writing education will be discussed. Demand reduction, it will be argued, occurs by learning domain-specific knowledge that can be rapidly retrieved from long-term memory rather than held in short-term working memory and by automating to some degree the basic writing processes. These reductions can perhaps best be achieved using the training methods of cognitive apprenticeship, particularly with an emphasize on deliberate practice. Fourth, there are two facts - literary precocity and working memory decline in older, professional writers - that would seem paradoxical in light of the present arguments. These are considered before concluding the paper.

1. Development of writing skills

The development of written composition skills are conceived here as progressing through three stages, as illustrated in Figure 1. It takes at least two decades of maturation, instruction, and training to advance from (1) the beginner's stage of using writing to tell what one knows, to (2) the intermediate stage of transforming what one knows for the author's benefit, and to (3) the final stage of crafting what one knows for the reader's benefit. The first two stages are well-established by developmental research

and typically mastered by advanced high school and college students (Bereiter & Scardamalia, 1987). The third is seldom discussed, perhaps because it characterizes only mature adults who aim to become skilled professional writers (Kellogg, 2006).

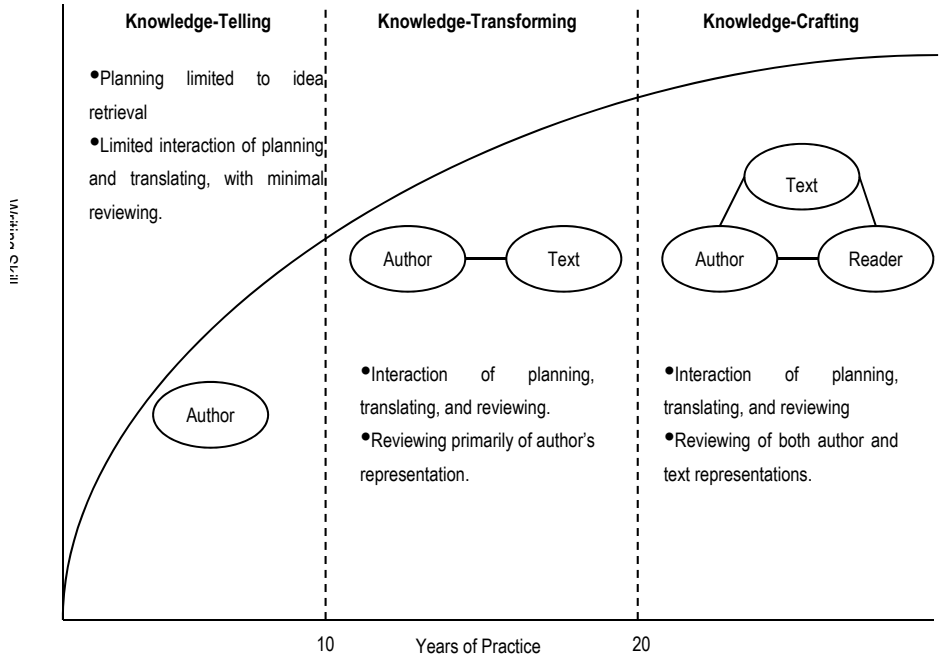

Figure 1. Macro-stages in the cognitive development of writing skill.

The three stages shown in Figure 1 are intended to demarcate three macro-stages of writing development. Writing skill is shown as continuously improving as a function of practice, as is typical for perceptual-motor and cognitive skills in general. The micro-changes underlying the gradual improvement that drive the transition to the next macro-stage fall beyond the scope of the present article. But, in general, it is assumed that both the basic writing processes of planning, language generation, and reviewing, plus the mental representations that must be generated and held in working memory, undergo continuous developmental changes through maturation and learning within specific writing tasks. As a consequence of the task specificity, a child might be operating at a more advanced stage in writing, say, narrative texts, assuming these are most practiced, compared with persuasive texts.

2. Author, text, and reader representations

In the most advanced stage of knowledge-crafting, the writer is able to hold in mind the author's ideas, the words of the text itself, and the imagined reader's interpretation of the text. The representations of the author, the text, and the reader must be held in the storage components of working memory and kept active by allocating attention to them (Traxler & Gernsbacher, 1993). Thus, for expert writers, not only are the basic processes of planning, sentence generation, and reviewing juggled successfully, but so are three alternative representations of content. The author's ideas, comprehension of what the text currently says, and the interpretations of an imagined reader may be quite different mental representations.

By contrast, during earlier stages of a writer's development, the text and reader representations may be either relatively impoverished or sufficiently detailed but not adequately maintained in working memory during text composition. A young child of, say, 6 years of age might have a only partial representation of how the text actually reads in comparison to a much richer representation of his or her own ideas. Gradual gains in writing skill within the stage of knowledge-telling across several years of writing experience would stem from growth in the child's ability to represent the text's literal meaning. Similarly, a 12 year old might be aware of the prospective reader, but this reader representation may be too unstable to hold in working memory. Although such a developing writer's audience awareness might well guide, say, word choices in language generation at the moment of transcription, the reader representation would not be available for reviewing the text, if it cannot be maintained adequately in working memory.

As shown in Figure 1, then, the stage of knowledge-telling is dominated by the author's representation. By the stage of knowledge-transforming, the text representation is both sufficiently detailed and stable enough to maintain in working memory to permit an interaction between the author and text representations. Yet, the reader representation is not yet routinely entered into the interaction in working memory until the stage of knowledge-crafting. It must first become sufficiently elaborate and stable to maintain *and* working memory resources must be available to coordinate all three representations. The key point made here is the heavy demands made on working memory by planning, sentence generation, and reviewing processes limit not only the coordination of these basic cognitive processes, but also the maintenance and use of the three distinct representations underlying the composition of expert writers.

2.1 Knowledge-telling

The initial stage of knowledge-telling consists of creating or retrieving what the author wants to say and then generating a text to say it. The author is not entirely egocentric in knowledge-telling and can begin to take into account the reader's needs. Specifically, by the time children are beginning to write they realize that another person's thoughts about the world may differ from their own. By about the age of 4, children have acquired a theory of mind that allows them to take another's perspective (Wellman, 1990; Wellman, Cross, & Watson, 2001). This helps them to plan what they need to say or write to communicate their ideas.

However, it would appear that the writer's representation of what the text actually says to him or her and, to an even greater degree, how the prospective reader would interpret the text as written are impoverished early on in writing acquisition. As the child develops during middle childhood and adolescence, first the text representation, and then the reader representation, gradually become richer and more useful to the composer. The assumption made here is that the author must first be able to comprehend what the text actually says at a given point in the composition (i.e., possesses a stable text representation) before he or she can imagine how the text would read to another person (i.e., acquire a reader representation). It is further assumed that these representations must be constructed by the writer in a stable form before he or she can hold these representations in working memory and make use of them in planning and reviewing. Extending McCutchen's (1996) analysis of how working memory limitations constrain planning, language generation, and reviewing, it is proposed here that the three representations of the author, text, and reader are not fully accessible in working memory until the most advanced stage of knowledge-crafting is achieved.

What is known empirically is that writers operating at the initial knowledge-telling stage of development clearly struggle with understanding what the text actually says. As Beal (1996) observed, young writers who compose by telling their knowledge have trouble seeing the literal meaning of their texts, as those texts would appear to prospective readers. The young author focuses on his or her thoughts not on how the text itself reads. The verbal protocols collected by Bereiter and Scardamalia (1987) of children clearly document the essential focus on the author’s representation rather than the text and reader representations. The text produced is essentially a restatement of their thoughts.

2.2 Knowledge-transforming

The second stage of knowledge-transforming involves changing what the author wants to say as a result of generating the text. It implies an interaction between the author's representation of ideas and the text representation itself. What the author says feeds back on what the author knows in a way not observed in knowledge-telling. Reviewing the text or even ideas still in the writer's mind can trigger additional planning and

additional language generation. In reading the text, the author builds a representation of what it actually says. At times such reviewing may lead to a state of dissonance between what the text says and what the author actually meant, but it can also become an occasion for re-thinking afresh the author's ideas (Hayes, 2004). During knowledge-transforming, the act of writing becomes a way of actively constituting knowledge representations in long-term memory (Galbraith, 1999) rather than simply retrieving them as in knowledge-telling. Verbal protocols of writers at the stage of knowledge-transforming reveal extensive interactions among planning, language generation, and reviewing in this stage of development (Bereiter & Scardamalia, 1987). The text actually produced is a greatly condensed version of the author's thought processes. When the transition to knowledge-transforming is completed, it is clear that the writer can maintain and use both the both the author and text representations.

2.3 Knowledge-crafting

The third stage characterizes the progression to professional expertise in writing. The writer must maintain and manipulate in working memory a representation of the text that might be constructed by an imagined reader as well as the author and text representations. Notice that this stage now involves modeling not just the reader's view of the writer's message but also the reader's interpretation of the text itself. In knowledge-crafting, the writer shapes what to say and how to say it with the potential reader fully in mind. The writer tries to anticipate different ways that the reader might interpret the text and takes these into account in revising it. As Sommers (1980; p. 385) observed in journalists, editors, and academics, "experienced adult writers imagine a reader (reading their product) whose existence and whose expectations influence their revision process."

Holliway and McCutchen (2004) stressed that the coordination of the author, text, and reader representations "builds on multiple sources of interpersonal, cognitive, and textual competencies" and may well account for most of the difficulties that children experience with revision. In an early study of expert versus novice differences in writers, Sommers (1980) documented that professional writers routinely and spontaneously revise their texts extensively and globally, making deep structural changes. They express concern for the "form or shape of their argument" as well as "a concern for their readership" (p. 384). By contrast, college freshmen made changes primarily in the vocabulary used to express their thoughts. Lexical substitutions predominated rather than semantic changes. The students seemed to view their assignment primarily as an exercise in knowledge telling and did not "see revision as an activity in which they modify and develop perspectives and ideas…" (p. 382). There seemed to be little interaction between the text and author representation in her sample of college freshmen, let alone a focus on a reader representation.

It is too strong a statement to suggest that adolescents and young adults always fail to make changes in meaning or take into account the needs of the reader as they review. For example, Myhill and Jones (2007) reported that students aged 14 to 16 can

verbalize such concerns when prompted to comment on their writing processes after a writing session. As many as half of their sample of 34 students commented on revisions made to improve coherence and add text in addition to avoiding repetition and making it sound better in general. It is suggested, though, that working memory limitations in holding and manipulating representations of how the reader interprets the text, while simultaneously managing the author and text representations, is a fundamental brake on the writing skill of developing writers throughout childhood, adolescence, and young adulthood. It helps to explain, for example, why adolescent writers do not routinely and spontaneously make the kinds of deep structural revisions found in experienced adult writers.

Tellingly, college students benefit by simply providing them with 8 minutes of instruction to revise globally before they are asked to start a second and final draft of a text (Wallace, Hayes, Hatch, Miller, Moser, & Silk, 1996). Although this could be interpreted to mean that the students lack the knowledge that revision entails more than local changes, the results of Myhill and Jones (2007) with 13-14 year olds render such an interpretation unlikely. An alternative interpretation is that, when left to their own devices, college students invest their available working memory resources as best they can, but still fail to maintain the reader representation needed in making deep structural changes to the text. Because students can, with minimal instruction, change their focus of attention to the reader's perspective, they apparently know how to revise globally as well as locally. But they typically do not do so in their college writing assignments to avoid shortchanging the time and effort devoted to other necessary processes and representations during composition and subsequent revision. For example, the degree of planning they do, the fluency of their language generation, the effectiveness of their local-level reviewing, and the interaction of author and text representations activated in transforming their knowledge about the topic would likely suffer from making global changes in the text a priority.

Finally, interventions that prompt the writer to "read-as-the-reader" explicitly focus working memory resources on the reader representation. These are effective in improving the revising activities of 5th and 9th graders (Holliway & McCutchen, 2004) as well as of college students (Traxler & Gernsbacher, 1993). However, it is unclear from these studies what costs are incurred when limited attention and storage capabilities are focused on the reader representation rather than on the author and text representations. In all of these studies, the task involved writing a text that described a geometric figure to the reader and thus possibly limited the importance of interactions between author and text representations and knowledge-transforming. That is to say, the act of composing a draft and revising it did not demand an intensive discovery of what the author thinks about the topic, as would be necessary in an open-ended persuasive task as opposed to a descriptive task using a limited set of perceptually available stimuli.

To summarize the studies reviewed here and the argument made, even young children understand that they must take into account the reader's thoughts as they compose a message in oral and written communication during the first stage of

knowledge-telling. Yet, being aware of a fictional reader in generating text is different from being able to read the text as it is currently written from another person's perspective. Audience awareness should be regarded as a necessary, but not sufficient, condition for eventually developing the capacity to read and interpret the author's own text from the standpoint of an imagined or fictional reader. An additional necessary condition is having a sufficiently developed working memory system to coordinate the author, text, and reader representations concurrently with relative ease. Executive attention, in particular, must be fully mature and effectively deployed to maintain and manipulate all three of these representations as the writer recursively plans, generates, and reviews the emerging text. In knowledge-crafting, the reader's interpretation of the text must feed back to the way the text reads to the author and to the message the author wishes to convey in the first place. Knowledge-crafting, then, is characterized by a three-way interaction among representations held in working memory. The author can spontaneously engage in deep conceptual revisions as well as surface revisions to a text to try to make certain that readers see matters the way the author does. By anticipating in detail the responses of readers to an existing text, the writer operating at the level of knowledge-crafting engages in extensive revisions at all levels of the text.

The concept of knowledge-crafting proposed here draws from the work of Walter Ong. About 30 years ago, Ong (1978) argued that a skilled author creates a fictional audience for the text to understand its meaning from the prospective readers' point of view. In contrast to oral communication, the audience for written communication is not actual, but fictional, a product of the writer's imagination that can play an active role in composition. As Ong explained, "the writer must anticipate all the different senses in which any statement can be interpreted and correspondingly clarify meaning and to cover it suitably." To effectively interpret the text from the reader's point of view, the author is forced to think about and decide what knowledge the reader already knows that need not be made explicit in the text. As Ong (1975) noted, "This knowledge is one of the things that separates the beginning graduate student or even the brilliant undergraduate from the mature scholar." Tomlinson (1990) underscored the point that mature scholars absolutely must by necessity represent their audience fully because "those who accept or reject or manuscripts, or, worse, those who hire and fire us" are decidedly real rather than fictional readers.

Writing development, then, is not complete at the end of university or even post-graduate work. An individual who writes on the job as a professional, even if it is but a part of his or her work, is preoccupied with what the text says in relation to what the writer already knows. Scientific writers, for example, must know "what problems the discipline has addressed, what the discipline has learned, where it is going, who the major actors are, and how all these things contribute" to the writer's own project (Bazerman, 1988). Such domain-specific knowledge may have several beneficial effects for the writer, but one would be the ability to interpret the text as written thus far from the vantage point of another member of the scientific community.

Advanced level, academic writers know their disciplines deeply enough to be able to anticipate their readers' responses to the text they are composing and revising (Hyland, 2001). From examining 240 published research articles from a variety of disciplines and conducting interviews with authors, Hyland identified the ways that readers are drawn into the text. The use of the inclusive we or second person pronouns are one way of binding the reader together with the writer. Another is the use of personal asides that "appeal more to the readers willingness to following their reasoning" (p. 561). A third is to employ directives to readers to see matters as the author desires or, more subtly, "to *note, concede,* or *consider* something in the text, thereby leading them to a particular interpretation" (p. 564). Hyland's central point is that writers operating at a professional level of expertise are adept at actively crafting reader agreement with their positions.

Even so, it should be noted that even experienced authors vary in the degree to which they explicitly represent their readers in working memory. Kirsch (1990) asked faculty member to inform readers about the writing program that they teach and to persuade the readers as to the value of freshmen composition. They wrote two such texts, with one addressed to incoming freshmen and another to an interdisciplinary faculty committee. The differences in how the audiences were framed were most strikingly illustrated by three of the five writers studied. Whereas one interpreted both audiences as "skeptical, if not hostile; another expected both audiences to be 'friendly but uninformed' and yet another writer rarely analyzed either of the audiences, concentrating instead on exploring her topic in depth" (p. 220).

It is important to remember that the process of reviewing ideas and text is not limited to the revision phase of composition. It is usually embedded in the composition of a first draft, along with planning and language generation. The reviewing of ideas alone--perhaps held solely as mental representations or perhaps recorded as visual-spatial symbols or brief, cryptic verbal notations--an even occur during prewriting before a first draft is undertaken. Highly extensive reviewing during pre-writing and drafting characterize the strategy of attempting to produce a perfect rather than a rough first draft (Kellogg, 1994). Thus, the capacity to see the text from the perspective of the reviewer can be put to use during the composition of a first draft rather than delayed until revising an initial effort, depending on the strategy adopted by the author. For example, experienced scientists show a wide range of individual composing strategies (Rymer, 1988). Whereas some use a linear strategy of extensive planning during prewriting before starting a draft, others jump right in with a very rough draft and revise endlessly. Both the specific task and the medium or tool used for writing influence the choice of composing strategies (Van Waes & Schellens, 2003). Regardless of the particular composition strategy employed, what characterizes the knowledge-crafting of expert writers is the capacity to keep in mind how a reader would interpret the text as well as representing the author's ideas and what the text says, in its present form, communicates to the author and to the reader.

3. The 10 year rule of developing expertise

Studies of outstanding performers in music, chess, typewriting, and other domains indicate that deliberate practice must continue for a minimum of a decade for an individual to acquire expert standing (Ericsson et al., 1983). In the case of composition, the clock starts early, since spoken language and scribbling are developed in preliterate children (Lee & Karmiloff-Smith, 1996). By the age of 14-16 years, children have spent 10 years mastering the mechanics of handwriting and spelling, achieving fluency in written as well as spoken production, and mastering the telling of knowledge. Approximately a second decade of practice is needed to advance from knowledge-telling to knowledge-transforming. Note that Bereiter and Scardamalia (1987) turned to graduate student writing to provide clear illustrations of knowledge-transforming, although less developed forms of it are certainly evident in the writings of teenagers.

It is unknown precisely how long it takes to advance further to knowledge crafting whereby professionals can mentally represent and adeptly process the author's ideas, the text's meaning, and the reader's interpretations of both the author's ideas and the text itself. But several years are probably needed to acquire the domain-specific rhetorical skills and practice at crafting knowledge for a specific audience (Rymer, 1988). For example, biographies of poets have revealed that, for the vast majority, their earliest work in the Norton Anthology of Poetry came at least 10 years after the approximate date that they began reading and writing poetry (Wishbow, 1988). Childhood practice at story writing was so commonly mentioned in Henry's (2000; p. 37) ethnographies that "people who were attracted to writing after childhood may even refer to themselves as 'late bloomers'."

Thus, the progression from knowledge telling to knowledge crafting depends on training that must continue from childhood well into adulthood. Even college-educated writers are unlikely to continue the training required to compose like a professional at the level of knowledge crafting.

4. Working memory constrains writing development

To summarize, expert writers who have advanced to the stage of knowledge crafting are capable of representing and manipulating three different representations in working memory. They do so by means of complex interactions among planning, generation, and reviewing that must be coordinated through executive attentional control in working memory. Both of these attributes implies a high degree of self-regulation of cognition, emotion, and behavior that sees the writer through the lonely and challenging job of serious composition. In terms of the seminal model of text composition proposed by Flower and Hayes (1980), limited executive attention must be allocated to the monitor component instead of to the basic processes of planning, translating, and reviewing.

It is important to understand the heavy demands that are placed on working memory, particularly on the central executive, to see the need for training to free the availability of executive attention for the monitor component of the writing model. One must first reduce the attentional and storage demands of planning ideas, generating text, and reviewing ideas and text for self-regulation to occur. In Baddeley's (2001) model of working memory, the central executive serves as a supervisory attentional system that controls storage components, such as the phonological loop for verbal representations and the visual-spatial sketchpad for object representations. Verbal working memory maintains representations during the mandatory sub-processes of sentence generation, namely, grammatical, phonological, and orthographic encoding (Bonin, Fayol, & Gombert, 1994; Levy & Marek, 1999; Chenoweth & Hayes, 2001). When concrete nouns are used in a sentence, images of their referents may be stored in the visual-spatial sketchpad (Kellogg, Olive, & Piolat, 2006; Sadoski, Kealy, Paivio, & Goetz, 1997). Similarly, spatial working memory appears to have a specific role in generating ideas during planning (Galbraith, Ford, Walker, & Ford, 2005). Although the phonological loop and visual-spatial sketchpad have a role in writing, it has been argued on theoretical grounds that these storage components are involved in fewer aspects of planning, sentence generating, and reviewing in comparison with the central executive.

In the neuropsychological literature, overall executive functioning is witnessed in planning, reasoning, and emotional regulation tasks that require the coordination of a large number of cognitive processes. Writing researchers have frequently hypothesized and documented the critical role of executive attention in managing the composing process. Interference or slowing in response times to a secondary task measures the degree to which the primary task of writing consumes executive attention (Olive, Kellogg, & Piolat, 2002; Piolat, Olive, & Kellogg, 2004). As a person is writing, they respond to an auditory beep that occurs at random intervals. Interference is calculated by subtracting the time needed to respond to the beep when presented in isolation. Writing processes show markedly more slowing in response time compared with other kinds of cognitive tasks.

Rapid concurrent decisions also require executive attention and disrupt writing. Kalsbeek and Sykes (1967) found that the need to make decisions about whether to depress a pedal with the right foot or left foot degraded concurrent writing ability. The participant was told to write something interesting, which was possible only when the primary distracting task was slow and easy to perform. As the primary task gradually increased to a maximum speed of rapid decisions and responses, the length of the sentences generated was shortened and then the grammatical structure was lost. Then, only a single word could be written repeatedly and, finally, only a single letter.

Another way to study the issue is to distract executive attention with a demanding primary task, such as holding six digits in mind. Experiments with this and similar kinds of concurrent primary tasks show that when executive attention is drawn away from sentence generation, there is a reduction in sentence length (Ransdell, Levy, & Kellogg,

2002; Kellogg, 2004), a disruption in grammatical encoding (Fayol, Largy, Lamaire, 1994; Moretti et al., 2003), and a slowing in word production (Ferreira & Pashler, 2002).

Given these findings with adult writers, it should not be surprising that the availability of executive attention ought to be a major constraint on the development of writing skill. In fact, Vandenberg and Swanson (2007) reported that individual differences in writing ability among high school students are reliably related to central executive capacity. Such a relationship was not observed for the phonological loop nor was it found for the visual-spatial sketchpad.

Writing development, then, seems to echo other important cognitive skills in its dependence on executive functioning. Neo-Piagetian theorists proposed that the limited capacity of a central, domain-independent pool of cognitive resources acts as a brake on progression from one stage of development to the next (Pascual-Leone, 1987). The transition from pre-operational to formal operational thought, for example, requires growth in this central resource, called M-Space activation by Pascual-Leone. The rapid emergence of executive strategies in memory and problem solving tasks similarly depends on the growth of centralized attentional resources (Case, 1985). Increased executive control appears to be fundamental to the brain changes that occur during the second decade of life (Kuhn, 2006), when concrete thought gives way to the abstract thought of formal operations. Having sufficient executive control over planning, generation and reviewing is plausibly necessary for the production of coherent text. In fact, Scinto (1986) found that the later transition between concrete and formal operations was associated with the emergence of the ability to generate cohesive links in written texts.

It is also well-established that the basic mechanical skills of handwriting and spelling deplete the limited resources of working memory in children, constraining their ability to generate language fluently. The primary grades of school is the normal period of time for learning the mechanics of writing to a point of automaticity, thus freeing working memory resources for higher order processes (Graham, Berninger, Abbot, & Whitaker, 1997). Unless children develop sufficient fluency in handwriting (or typing) before the age of 12 or so, then their subsequent development of writing skill is weakened substantially.

McCutchen (1996) reviewed a wide range of evidence demonstrating that planning, generating, and reviewing are each constrained by the limits of working memory in younger compared with older children. Individual differences in writing ability at a given age are also predicted by differences in working memory capacity (Ransdell & Levy, 1996). Finally, the self-regulation of planning, translating, and reviewing requires mastery of handwriting and spelling (Graham & Harris, 2000) and age-related growth in working memory capacity (McCutchen, 1996).

To summarize, interactions among planning, generating, and reviewing observed in advanced writers requires available capacity in working memory in several ways. The writer must hold in mind a representation of what he or she wants to say and a

representation of what the text actually says. This requires not only well-developed short-term storage capacity, but also executive attention to keep the representations active and to inhibit irrelevant information. As a writer progresses further from author-centered reviewing to reader-centered reviewing, it is also necessary to maintain a representation of how the imagined reader perceives the text. Moreover, executive attention must be allocated to coordinating and monitoring the transitions from one basic writing process to the next (Hayes and Flower, 1980).

5. Implications for writing education

The implications of these ideas for writing education will be briefly considered next. Educational research has carefully documented the extensive range of knowledge that must be available in long-term memory for effective text composition. A large mental lexicon, heightened grammatical competence, a variety of discourse structures, and domain-specific knowledge of the topic are among these (Nystrand, 1982). Equally important, but perhaps less appreciated, is that writers must be able to retrieve their knowledge during composition and creatively apply it to decide what to say in the text and how to say it. Accessibility in working memory or through rapid, well-timed retrieval from long-term memory is necessary or else the writer's knowledge is inert during composition (Kellogg, 1994).

An expert, professional writer - operating at the stage of knowledge-crafting - is able to maintain and manipulate in working memory representations of the author's ideas, the text itself, and the prospective reader's interpretation of the text. Both knowledge-crafting and the intermediate stage of knowledge-transforming require the ability to coordinate complex interactions of planning ideas, text generation, and reviewing ideas and text. The most important constraint on developing from knowledge-telling to knowledge-transforming, and possibly then on to knowledge-crafting is the limitations of the central executive component of working memory. Writers may know a great deal, but they cannot use what they know unless multiple representations are maintained in working memory and writing processes are artfully orchestrated. It is not enough to know how to plan or how to write clear sentences, for example, if the developing writer is unable to interweave planning and generation in a manner characteristic of mature writers. These basic composing processes must be controlled effectively as well.

In what ways can the educational process aid the functioning of working memory in the service of writing skills? There are undoubtedly numerous ways, but here three points are emphasized. The required degree of cognitive control in working memory of processes and representations most likely depends on (1) maturation of the executive component of working memory, (2) reducing the load on working memory by providing rapid, effortless access to domain-specific knowledge in long-term memory, and (3) reducing the working memory cost of planning, sentence generation, and

reviewing processes so that executive attention can be devoted to managing their deployment.

The frontal lobe regions of the brain that support executive functioning mature slowly throughout the decades involved in writing acquisition. High-resolution structural magnetic resonance images reveal a higher degree of frontal development in young adults, 23-30 years of age, compared with 12-16 -year olds (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999). These regions quite possibly are needed (1) to maintain simultaneous representations of the author's ideas, the text as written, and the perspective of an imagined reader and (2) to coordinate interactions among planning, generating, and reviewing. The slow maturation of the central executive component of working memory stresses the absolute necessity of reducing the burden placed on it by writing processes.

5.1 Long-Term Working Memory

Gaining domain-specific expertise allows the writer to retrieve relevant knowledge from long-term memory at just the right moment. Ericsson and Kintsch (1995) called this form of knowledge accessibility long-term working memory and distinguished it from laboriously maintaining information in an active state in short-term working memory. This indirectly helps with the overload on the central executive component of working memory by reducing the occasions on which it is needed. The ability to rely on long-term working memory ought to significantly help writers to manage the composition process (McCutchen, 2000). Indeed, a high degree of domain-specific knowledge about the topic significantly reduces the momentary demands made on executive attention (Kellogg, 2001).

Writing about topics that students know well provides a scaffold to support the writers and to allow them to devote a higher degree of executive attention to the juggling of planning, generating, and reviewing. For example, seniors in college should know the most about their major field and so should be provided with extensive opportunities to write within the discipline. The writing across the curriculum movement has stressed the value of situating writing assignments within the discourse community of a discipline on the grounds that writing is inherently a social act. While this is certainly true, writing within the discipline of one’s major field has the added benefit of allowing the writer to free short-term working memory for the task by relying to some extent on long-term working memory.

5.2 Relative Automaticity

Another approach is to directly reduce the demands on the central executive by training the writer in planning, sentence generating, and reviewing skills. There are likely to be multiple ways in which this objective can be achieved and what follows are but a few illustrations.

For example, one can train writers to use strategies that focus effort on a single process at a given moment in time. Preparing an outline during prewriting helps writers to focus on text generation in producing a first draft (Kellogg, 1988). There is still an interaction among planning, generation, and reviewing after outlining first, but relatively more time is devoted to the generating sentences and cohesive links among them when the macrostructure of the text has been sketched out in the form of a hierarchical structure. A later study showed that the benefits of outlining were substantially reduced when writers had already developed their thinking about the specific topic, knowledge that could be retrieved from long-term working memory rather than computed and stored in working memory during composition (Kellogg, 1990).

Galbraith and Torrance (2004) replicated and extended these earlier findings by showing that organized notes aid writing regardless of whether or not these notes are available in preparing a final draft of the text. Just generating text without any planning in advance can also benefit a writer, as long as these initial unorganized notes or sentences are not available to the writer in preparing a final draft. In this case writers use language generation as a planning device - as a way of constituting knowledge through the act of writing in Galbraith's terms. When the unorganized notes or sentences are in front of them during final draft composition, writers perhaps divide their attention among planning, text generation, and reviewing. By withdrawing these materials, they perhaps focus more on planning and text generation with less effort given to reviewing what had been produced earlier.

Similarly, it is possible to prompt revisions even in young students operating at the first stage of knowledge-telling. Chanquoy (2001) reported that 3rd, 4th, and 5th grade students (ages 8-10) increase the amount and depth of their revisions when reviewing is delayed rather than immediate. The time delay could facilitate the construction of a reader representation that accurately captures what the text literally says as the students re-read what they had written earlier. These young writers appear to be capable of correcting ambiguities in texts written by others, but nevertheless fail to do so when writing their own texts and left to their own devices (Bartlett, 1982).

In L2 writers 13-14 years of age, Lindgren and Sullivan, (2003; 2006) also found that multiple writing opportunities and post-composition recall of their own writing processes, prompted by a computer-based replay of their keystrokes, enhanced conceptual as well as surface level revisions. Success with such scaffolds for revision in L2 writers certainly indicates their potential value in developing L1 writers as well. The essential point is that we should teach developing writers the specific strategies that can effectively reduce the momentary demands of composition. Establishing exactly what they strategies are, for whom, and under what circumstances is an important goal for composition research.

One can also train writers so that planning, generation, and reviewing each become relatively automatic. McCutchen (1988) made the important point that these processes are too complex to become automatic in the strict sense of becoming effortless, unintentional, and unavailable to conscious awareness. Still, it is certainly possible to

reduce the *relative effort* required to plan ideas and their organizational structure, fluently generate sentences and cohesive links among them, and review the plans and text from the perspective of both the author and the imagined reader (Kellogg, 1994). In fact, the development of effective writing skill is impossible without reducing these relative demands, according to the argument advanced here. Increased automaticity has been conceived in terms of converting declarative knowledge into procedural knowledge (Anderson, 1983) or into retrieval from long-term memory as opposed to computation in working memory (Logan, 1988). Practice is the means for doing so under either of these models. The best documented cases with respect to writing skill are the relative automatization of transcription as writers master handwriting and spelling (McCutchen, 1996; Bourdin & Fayol, 1994) and the revision of subject-verb agreement errors that progresses from a slow, effortful algorithm to a rapid automatic check (Fayol, Hupet, & Largy, 1999; Largy, Dédévan, & Hupet, 2004).

5.3 Training Methods

If we think training a writer, much like a musician or an athlete is trained, then what interventions are likely to be successful? One is the tried and true method of learning by doing. That practice makes perfect is so well known as to be a cliché, but the concept of deliberate practice is far more interesting and not well understood in the context of writing. The second method would appear to be the opposite of learning by doing, namely, learning by observing. The tradition of apprenticeship has stressed the importance of social learning from a mentor. A cognitive apprenticeship in writing, then, underscores the value of observing rather than doing. Yet, both observing and doing are essential to the learning of complex skills and the two traditions, in good measure, blend well in effective training.

5.4 Deliberate Practice

A central factor in the development of expert performance across a wide range of both physical and cognitive task domains is the use of deliberate practice (Ericsson, et al., 1993). This method of skill development involves (1) effortful exertion to improve performance, (2) intrinsic motivation to engage in the task, (3) practice tasks that are within reach of the individual's current level of ability, (4) feedback that provides knowledge of results, and (5) high levels of repetition.

Distinguished novelists, for example, credit their success to the use of deliberate practice. In the words of Joyce Carol Oates: "I consciously trained myself by writing novel after novel and always throwing them out when completed" (Plimpton, 1989; p. 378). Norman Mailer (2003; p. 14) said: " I learned to write by writing. As I once calculated, I must have written more than a half a million words before I came to the *Naked and the Dead."*

The effects of deliberate practice can be seen in the cumulative productive of authors. As decades of practice take effect, the writer's productivity gains in a nonlinear fashion. For example, Isaac Asimov's wrote far more books per year in his later years as

an author, as decades of practice, compared with his early years. His production of books follows the power function that one would expect from the effects of pure practice (Ohlsson, 1992).

Practice can markedly improve college student writing when it is done in the context of a professionally relevant task domain that motivates efforts to learn. Johnstone, Ashbaugh, and Warfield (2002) found that superior writing skills correlated reliably with the degree of repeated practice and, controlling for practice, with writing in the professionally relevant domain of greatest interest to the student. Accounting students who took business writing intensive two courses in their junior year (1 year of practice) and two more in their senior year (2 years of practice) gained significantly in their writing skills in comparison with an assessment taken at the end of their second year as sophomores. By sharp contrast, the control group of students in other majors who did not take the writing intensive courses in their field slightly declined in performance from their second year to their senior year. The writing assignments in the treatment group were designed to challenge the students by requiring that they write as accounting professionals for a professional audience. The feedback that students received was consistent and thorough, including grading of grammatical conventions, organization, professionalism of presentation, technical accuracy of the accounting, and the quality of the analysis.

Learning by doing sounds simple enough, but writing educators need to be aware of the pitfalls in deliberate practice. For example, spaced rather than massed practice is important for two reasons. A common mistake of developing writers is to compose in marathon sessions or binges of massed practice that can exhaust and frustrate the writer. Writing apprehension and even writer's block can result from this misconceived kind of practice at the task (Boice, 1985). Professional writers learn to compose for just a few hours per day at most, but on a highly consistent daily schedule and students should be trained in the same fashion (Kellogg & Raulerson, 2007).

Another advantage of spaced practice is that it maximizes long-term learning at the expense of immediate training performance (Schmidt & Bjork, 1992). Although high levels of training performance can be obtained with mass practice, the learning does not transfer as effectively to a different task in the future in comparison with spaced practice. Consider the familiar practice regimen used to teach young children handwriting skills. Typically, the child writes the same letter multiple times in blocked or massed practice for that letter. If instead the child practices a randomly chosen letter on each trial, then training performance suffers some, but transfer tests given 20 minutes or 24 hours after training reveal a clear advantage for the random, spaced practice (Ste-Marie, Clark, Findlay, & Latimer, 2004).

Providing individually tailored feedback is a timely manner is another serious problem in designing effective writing practice. Even holistic grading in the absence of corrections and commentary can be highly labor intensive and subject to poor reliability in large classroom settings (Freedman & Calfee, 1983). Feedback from an instructor to a student is often measured in days and even weeks rather than minutes

and hours. Recent advances in cognitive science and computational linguistics offer the intriguing possibility of automated essay scoring to provide reliable, immediate, and individualized feedback (Shermis & Bernstein, 2003). The commercially available systems called *e-rater* and *Intelligent Essay Assessor* are two examples. Thus far, however, writing educators have not embraced these systems as even aids to instructors trying to provide effective feedback to developing writers. The essays in a book edited by Ericsson and Haswell (2006) question the validity of automated essay scoring and argue against its acceptance in the field. Peer feedback and delayed feedback by instructors remain the most commonly used methods.

5.5 Cognitive apprenticeship

As noted at the outset, there is nothing natural about learning to read and write in the way that learning to speak is part and parcel of normal cognitive development. The acquisition of cultural practices, such as writing, benefits from a cognitive apprenticeship approach in which a mentor provides a model for social learning (Rogoff, 1990). Cognitive apprenticeship entails the following features. It involves the learner in guided participation whereby a mentor or coach helps the novice to work through the task at hand. For example, a mentor might focus the attention of the learner on a manageable subgoal, such as preparing a preliminary outline first. A second core feature is Vygotsky's (1978) concept of the zone of proximal development, which focuses learners on tasks that stretch their current capacities so as to reach for growth. By working under a mentor's guidance, the learner is able to perform at a higher level than would be possible when working alone. The best learning tasks, then, then are those that lie within the zone of proximal development. In Vygotsky's terms, learning precedes development in the sense that the environment induces and supports students to learn beyond their current level of development. Finally, cognitive apprenticeship features learning by observing instead of learning by doing. Apprenticeship underscores the centrality of social learning by observation of the mentor.

Learning by observation has a unique advantage from the point of view that writing overloads executive attention. In observing a mentor, the student can focus attention on the model's behavior instead of attending to the cognitive processes and motor execution needed to do the task (Rijlaarsdam et al., 2005). For example, in a study on learning to revise texts, much larger effect sizes were obtained when the writers learned by observing readers instead of doing revision themselves. The best intervention came from observing readers who responded to one's own written text plus receiving additional written feedback (Couzijn & Rijlaarsdam, 1996).

One final illustration makes clear that deliberate practice and cognitive apprenticeship can be readily integrated in writer training. Schunk & Zimmerman (1997) formulated a four step training regimen with the explicit goal of fostering self-regulation. It begins with observation of a model's actions. Next, the learner tries to emulate the behavior of the model. Third, the learner deliberately practices in order to reduce the momentary demands of the cognitive processes underlying performance.

Through this reduction, executive attention becomes free to control cognitive processes. Finally, with additional practice at adapting performance to changes in internal and external conditions the self-regulation characteristic of expert performance is achieved.

The point to be made here is that learning by observing can be combined effectively with learning by doing at a different step of the training regimen. The writing intervention data from Zimmerman & Kitsantas (2002) show that observational learning from a model can produce large effect sizes. However, when feedback is provided then the effect of practice can combine with the effect of the model to yield truly impressive gains in writing skill.

A recent meta-analysis of writing instruction for adolescents supports the tenets of cognitive apprenticeship (Graham & Perin, 2007). Two forms of scaffolding resulted in large effect sizes: peer assistance (.75) and mentor assigned goals for the writing project (.70). Different ways of explicitly and systematically teaching students strategies for planning, revising, and editing text so that students can eventually use them on their own also produced large effect sizes (.82 overall). Mastering these techniques through explicit instruction and practice contrasts with simply engaging students in, say, prewriting activities, which had only a modest beneficial effect (.32). Practice at sentence combining (.50) following explicit instruction also reliably improves writing skill, presumably because it renders more automatic sentence generation and reviewing.

Some results of an earlier meta-analysis also can be interpreted as supportive of a cognitive apprenticeship approach. Hillocks (1986;1995) found that the most effective interventions assigned well-structured writing tasks with clear objectives, actively guided students in how to solve content and rhetorical problems, and provided peer feedback. These practice-oriented approaches to learning (the Environmental Mode in Hillock's terms) were four times as effective as the Presentational Mode of listening to lectures about how to write.

5.6 Two paradoxes

In light of the arguments raised here, there are two facts about writing development across the lifespan that would appear to be paradoxical. To see this point, it is helpful to begin by summarizing the central theme of the paper. The development of writing skills arguably requires decades of learning and moves through increasingly sophisticated stages of knowledge-telling, knowledge-transforming, and knowledge-crafting. Serious written composition simultaneously challenges the human capacities for language, memory, and thinking. The most advanced stage - achieved only at professional levels of expertise - involves routinely and adeptly juggling multiple representations in working memory and coordinating numerous interactions among multiple writing processes.

Both knowledge-transforming and, especially, knowledge-crafting place a heavy demand on working memory resources. In particular, executive attention must be available for self-regulation and this presumably cannot happen without adequate maturation, domain-specific learning, and training. To expect a 5 year old to write like a college-student is to expect the impossible, if for no other reason than the frontal lobes supporting executive function have not yet matured. Moreover, as working memory begins to decline with advanced age in older adults, one might equally expect a deterioration of writing ability.

The first paradox, then, is literary precocity in the form of advanced writing skill in very young children, who would appear to lack not only sufficient maturation but also a high degree of domain-specific learning and decades of practicing writing to lessen the burden on working memory. Yet, Edmunds and Noel (2003) documented a case of literary precocity in Geoffrey, a five year old prolific writer. In their view, Geoffrey had achieved the stage of knowledge-transforming in that he could take source information and work with it so as to yield novel connections and a novel story. Geoffrey's writings most certainly reflected a higher level of thinking and planning than would normally be found in the rudimentary knowledge-telling of a five year old. Of interest, Geoffrey learned to type at a very young age and showed early mastery of the mechanics of writing, freeing executive attention for higher level processes and a precocious rate of development as a writer. But did Geoffrey really show knowledge-transforming at age five?

A possible resolution of this case with the theoretical argument raised here is that Geoffrey's text revealed no editing at all. Unlike knowledge-transforming, there was no evidence of a preoccupation with trying to modify the text to express the author's ideas more accurately. A second point of resolution is to take note that precocity in writing is extremely rare (Feldman, 1993). Of course, precocious mathematicians, musicians, and chess players are also atypical, but they are far more prevalent than precocious writers, possibly because cultures support very early cognitive apprenticeships in these other domains more commonly than in writing.

The second paradox is that older professional writers are fully capable of composing at high levels of skill despite that their short-term working memory system is likely in decline. It is well established that working memory and executive functioning, in particular, reach their maximum by the third decade of life and noticeably fall off by the fifth or sixth decade. The working memory index of the WAIS-III, for example, drops substantially after the age of 45-54, along with an even steeper decline in the index of processing speed (Kaufman & Lichtenberger, 1999). How is it possible, then, for professional writers to continue as highly effective composers of text well into their 60s, 70s, and even 80s? One answer may be that they continue deliberate practice and the effort of planning, generation, and reviewing continues to decline as a result throughout the lifespan. A second answer may be that older writers come to rely more on retrieval from long-term working memory, lessening the demands placed on the declining functioning of short-term working memory in the first place. Consistent with this view,

crystallized intelligence, including verbal comprehension, would appear to depend on retrieval from long-term memory and it remains stable across the life span.

6. Conclusions

In summarize the case presented here, writing involves multiple representations and processes, with limitations in working memory constraining skill development. Advanced writing skills require systematic training as well as instruction so that executive attention can successfully coordinate multiple writing processes and representations. Finally, the principles of deliberate practice and cognitive apprenticeship offer writing educators the means to train writers to use their knowledge effectively during composition.

References

Anderson, J. R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.

Baddeley, A. D. (2001). Is working memory still working? *American Psychologist, 56*, 851-864. doi: 10.1037/0003-066X.56.11.851

Bartlett, E. (1982). Learning to revise: Some component processes. In M. Nystrand (Ed.), *What writers know: The language, process, and structure of written discourse* (pp. 345-363). New York: Academic Press.

Bazerman, C. (1988). *Shaping written knowledge*. Madison: University of Wisconsin Press.

Beal, C. R. (1996). The role of comprehension monitoring in children's revision. *Educational Psychology Review, 8*, 219-238. doi: 10.1007/BF01464074

Bereiter, C., & Scardamalia, M. (1987). *The psychology of written composition*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Boice, R. (1985). Cognitive components of blocking. *Written Communication, 2*, 91-104. doi: 10.1177/0741088385002001006

Bonin, P., Fayol, M., & Gombert, J. E. (1994). The role of phonological and orthographic codes in picture naming and writing. *Current Psychology of Cognition, 16*, 299-324.

Bourdin, B., & Fayol, M. (1994). Is written language production more difficult than oral language production? A working memory approach. *International Journal of Psychoogy, 29*, 591-620. doi: 10.1080/00207599408248175

Case, R. (1985). *Intellectual development: Birth to adulthood.* New York: Academic Press.

Chanquoy, L. (2001). How to make it easier for children to revise their writing: A study of text revision from 3rd to 5th grades. *British Journal of Educational Psychology, 71*, 15-41.doi: 10.1348/000709901158370

Chenoweth, N. A., & Hayes, J. R. (2001). The inner voice in writing. *Written Communication, 20*, 99-118. doi: 10.1177/0741088303253572

Couzijn, M., & Rijlaarsdam, G. (1996). Learning to read and write argumentative text by observation. In G. Rijlaarsdam, H. van den Bergh, & M. Couzijn (Eds.), *Effective teaching and learning of writing. Current trends in research* (pp. 253-273*).*

Edmunds, A., & Noel, K. A. (2003). Literary precocity: An exceptional case among exceptional cases. *Roeper Review, 25(4),* 185-195

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102*, 211-245.

Ericsson, K. A., Krampe, R. Th., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363-406.

Ericcson, P. F. & Haswell, R. H. (2006). *Machine scoring of student essays*. Logan, UT: Utah State University Press.

Fayol, M. (1999). From on-line management problems to strategies in written composition. In M. Torrance & G. Jeffery (Eds.), *The cognitive demands of writing: Processing capacity and working memory effects in text production* (pp. 13-23). Amsterdam: Amsterdam University Press.

Fayol, M., Largy, P., & Lemaire, P. (1994). When cognitive overload enhances subject-verb agreement errors. *Quarterly Journal of Experimental Psychology, 47A*, 437-464. doi: 10.1080/14640749408401119

Fayol, Hupet, & Largy (1999). The acquisition of subject-verb agreement in written French. *Reading and Writing: An Interdisciplinary Journal, 11*, 153-174.doi: 10.1023/A:1008038127807

Feldman, D. H. (1986). *Nature's gambit: Child prodigies and the development of human potential*. New York: Basic Books. doi: 10.1038/322120b0/ doi: 10.1038/324433a0

Ferreira, V. S., & Pashler, H. (2002). Central bottleneck influences on the processing stages of word production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 1187-1199.doi: 10.1037/0278-7393.28.6.1187

Flower, L., & Hayes, J. (1980). The dynamics of composing: Making plans and juggling constraints. In L. Gregg & F. Steinberg (Eds.), *Cognitive processes in writing* (pp. 31-50). Hillsdale, NJ: Lawrence Erlbaum Associates.

Freedman, S. W., & Calfee, R. C. (1983). Holistic assessment of writing: Experimental design and cognitive theory. In P. Mosenthal, L. Tamor, & S. A. Walmsley (Eds.), *Research in writing: Principles and methods* (pp.75-98). New York: Longman.

Galbraith, D. (1999). Writing as a knowledge-constituting process. In M. Torrance, & D. Galbraith (Eds.), *Studies in writing: Vol. 4. Knowing what to write: Conceptual processes in text production* (pp. 139-160). Amsterdam: Amsterdam University Press.

Galbraith, D., & Torrance, M. (2004). Revision in the context of different drafting strategies. In L. Allal, L. Chanquoy, and P. Largy (Eds.), *Revision: Cognitive and Instructional Processes* (pp. 63-85). Amsterdam: Kluwer Academic Publishers.

Galbraith, D., Ford, S., Walker, G., & Ford, J. (2005). The contribution of different components of working memory to knowledge transformation during writing. *L1-Educational Studies in Language and Literature, 5*, 113-145.doi: 10.1007/s10674-005-0119-2

Graham, S., Berninger, V. W., Abbott, S. P., & Whitaker, D. (1997). The role of mechanics in composing of elementary school students: A new methodological approach. *Journal of Educational Psychology, 89*, 170-182. doi: 10.1037/0022-0663.89.1.170

Graham, S., & Harris, K. R. (2000). The role of self-regulation and transcription skills in writing and writing development. *Educational Psychologist, 35*, 3-12.doi: 10.1207/S15326985EP3501_2

Graham, S., & Perin, D. (2007). A meta-analysis of writing instruction for adolescent students. *Journal of Educational Psychology, 99*, 445-476. doi: 10.1037/0022-0663.99.3.445

Hayes, J. R. (2004). What triggers revision? In L. Allal, L. Chanquoy, & P. Largy (Eds.), *Revision of written language: Cognitive and instructional processes* (pp. 9-20). Boston/Dordrecht, Netherlands/New York: Kluwer. doi: 10.1007/978-94-007-1048-1_2

Henry, J. (2000). *Writing workplace cultures: An archeology of professional writing*. Carbondale, IL: Southen Illinois University Press.

Hillocks, G., Jr. (1986). *Research on written composition: New directions for teaching*. Urbana, IL: National Conference on Research in English/ERIC Clearinghouse on Reading and Communication Skills.

Hillocks, G., Jr. (1995). *Teaching writing as reflective practice*. New York: Teacher College Press.

Holliway, D. R., & McCutchen, D. (2004). Audience perspective in young writers' composing and revising. In L. Allal, L. Chanquoy, & P. Largy (Eds.), *Revision of written language: Cognitive and instructional processes* (pp. 87-101). Boston/Dordrecht, Netherlands/New York: Kluwer. doi: 10.1007/978-94-007-1048-1_6

Hyland, K. (2001). Bringing in the reader: Addressee features in academic articles. *Written Communication, 18*, 549-574.doi: 10.1177/0741088301018004005

Johnstone, K. M., Ashbaugh, H., & Warfield, T. D. (2002). Effects of repeated practice and contextual-writing experiences on college students' writing skills. *Journal of Educational Psychology, 94*, 305-315.doi: 10.1037/0022-0663.94.2.305

Kaufman, A. S., & Lichtenberger, E. O. (1999). *Essentials of WAIS-III Assessment*. New York: John Wiley & Sons.

Kellogg, R. T. (1988). Attentional overload and writing performance: Effects of rough draft and outline strategies. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 355-365. doi: 10.1037/0278-7393.14.2.355

Kellogg, R. T. (1990). Effectiveness of prewriting strategies as a function of task demands. *American Journal of Psychology, 103,* 327-342. doi: 10.2307/1423213

Kellogg, R. T. (1994). *The psychology of writing.* New York: Oxford University Press.

Kellogg, R. T. (2001). Long-term working memory in text production. *Memory & Cognition, 29*, 43-52.doi: 10.3758/BF03195739

Kellogg, R. T. (2004). Working memory components in written sentence generation. *American Journal of Psychology, 117*, 341-361.doi: 10.2307/4149005

Kellogg, R. T. (2006). Professional writing expertise. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge Handbook of Expertise and Expert Performance* (pp. 389-402). New York: Cambridge University Press. doi: 10.1017/CBO9780511816796.022

Kellogg, R. T., Olive, T., & Piolat, A. (2006). Verbal, visual, and spatial working memory in written language production. *Acta Psychologica, 124,* 382-397.doi: 10.1016/j.actpsy.2006.02.005

Kellogg, R. T., & Raulerson, B. A. III. (2007). Improving the writing skills of college students. *Psychonomic Bulletin & Review, 14*, 237-242.doi: 10.3758/BF03194058

Kalsbeek, J. W. H., & Sykes, R. N. (1967). Objective measurement of mental workload. *Acta Psychologica, 27*, 253-261.doi: 10.1016/0001-6918(67)90066-2

Kirsch, G. (1990). Experienced writers' sense of audience and authority. In G. Kirsch and D. H. Roen (Eds.), *A sense of audience in written communication* (pp. 216-230). Newbury Park, CA: Sage Publications.

Kuhn, D. (2006). Do cognitive changes accompany developments in the adolescent brain? *Perspectives on Psychological Science, 1*, 59-67. doi: 10.1111/j.1745-6924.2006.t01-2-.x

Largy, P., Dédévan, A., & Hupet, M. (2004). Orthographic revision: A developmental study of how revisers check verbal agreements in written texts. *British Journal of Educational Psychology, 74*, 533-550.doi: 10.1348/0007099042376382

Lee, K. & Karmiloff-Smith, A. (1996). The development of external symbol systems: The child as a notator. In R. Gelman, T. Kit-Fong (Eds.), *Perceptual and cognitive development* (pp. 185-211). San Diego: Academic Press.doi: 10.1016/B978-012279660-9/50024-5

Levy, C. M., & Marek, P. (1999). Testing components of Kellogg's multicomponent model of working memory in writing: the role of the phonological loop. In G. Rijlaarsdam & E. Espéret (Series Eds.), & M. Torrance & G. Jerrery (Vol. Eds.), *Studies in Writing: Vo 3. The cognitive demands of writing: Processing capacity and working memory effects in text production (pp. 25-41)*. Amsterdam: Amsterdam University Press.

Lindgren, E. & Sullivan K. P. H. (2003). Stimulated recall as a trigger for increasing noticing and language awareness in the L2 writing classroom: A case study of two young female writers. *Language Awareness, 12,* 172–186.doi: 10.1080/09658410308667075

Lindgren, E. & Sullivan K. P. H. (2006). Analyzing on-line revision. In G. Rijlaarsdam (Series Ed.) and K. P. H. Sullivan, & E. Lindgren. (Vol. Eds.), Studies in Writing, Vol.18, *Computer Keystroke Logging: Methods and Applications*, (157–188). Oxford: Elsevier.

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review, 95*, 492-527. doi: 10.1037/0033-295X.95.4.492

Mailer, N. (2003). *The spooky art: Some thoughts on writing.* New York: Random House.

McCutchen, D. (1988). Functional automaticity in childre's writing. *Written Communication, 5*, 306-324.doi: 10.1177/0741088388005003003

McCutchen, D. (1996). A capacity theory of writing: Working memory in composition. *Educational Psychology Review, 8*, 299-325. doi: 10.1007/BF01464076

McCutchen, D. (2000). Knowledge, processing, and working memory: Implications for a theory of writing. *Educational Psychologist, 35*, 13-23.doi: 10.1207/S15326985EP3501_3

Moretti, R., Torre, P., Antonello, R. M., Fabbro, F., Cazzato, G., & Bava, A. (2003). Writing errors by normal subjects. *Perceptual and Motor Skills, 97*, 215-229.doi: 10.2466/PMS.97.5.215-229/ doi: 10.2466/pms.2003.97.1.215

Myhill, D. & Jones, S. (2007) More than just error correction. *Written Communication, 24*, 323-343.doi: 10.1177/0741088307305976

Ohlsson, S. (1992). The learning curve for writing books: Evidence from Professor Asimov. *Psychological Science, 3*, 380-382.doi: 10.1111/j.1467-9280.1992.tb00051.x

Nystrand, M. (Ed.). (1982). *What writers know: The language, process, and structure of written discourse*. New York: Academic Press.

Olive, R., Kellogg, R. T., Piolat, A. (2002). The triple task technique for studying the process of writing. In G. Rijlaarsdam (Series Ed.) T. Olive & C. M. Levy (Vol. Eds.), *Studies in writing: Volume 10: Contemporary tools and techniques for studying writing* (pp. 31-59). Kluwer Academic Publishers: Dordrecht.

Ong, W. (1975) The writer's audience is always a fiction. In T. J. Farrell and P. A. Soukup (2002). (Eds.) *An Ong Reader: Challenges for further inquiry/Walter J. Ong* (pp. 465-478). Cresskill, NJ: Hampton Press.

Ong, W. (1978). *Literacy and orality in our times*. In T. J. Farrell and P. A. Soukup (2002) (Eds.) *An Ong Reader: Challenges for further inquiry/Walter J. Ong* (pp. 405-428). Cresskill, NJ: Hampton Press.

Pascual-Leone, J. (1987). Organismic processes for neo-Piagetian theories: A dialectical causal account of cognitive development. *International Journal of Psychology, 22,* 531-570.doi: 10.1080/00207598708246795

Piolat, A., Olive, T., & Kellogg, R. T. (2004). Cognitive effort during notetaking. *Applied Cognitive Psychology, 18*, 1-22.

Plimpton, G. (1989) (Ed.). *Women writers at work: The Paris Review interviews*. New York: Penquin Press.

Ransdell, S. & Levy, C. M. (1996). Working memory constraints on writing quality and fluency. In C. M. Levy & S. E. Ransdell (Eds.), *The science of writing: Theories, methods, individual differences, and applications* (pp. 93-106). Mahwah, NJ: Lawrence Erlbaum Associates.

Ransdell, S., Levy, C. M., & Kellogg, R. T. (2002). Effects of secondary task demands on writing. *L-1: Educational Studies in Language & Literature, 2,* 141-163.doi: 10.1023/A:1020851300668

Rijlaarsdam, G., Braaksma, M., Couzijn, M., Janssen, T., Kieft, M. Broekkamp, H., & van den Bergh, H. (2005). Psychology and the teaching of writing in 8000 and some words. Pedagogy--Learning for teaching, BJEP Monograph Series II, 3, 127-153.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.

Rymer, J. (1988). Scientific composing processes: How eminent scientists write journal articles. In D. A. Jollife (Ed.) *Advances in writing research, volume two: Writing in academic disciplines*. Norwood, NJ: Ablex.

Sadoski, M., Kealy, W. A., Goetz, E. T., & Paivio, A. (1997). Concreteness and imagery effects in the written composition of definitions. *Journal of Educational Psychology, 89*, 518-526.doi: 10.1037/0022-0663.89.3.518

Scinto, L. F. M. (1986). *Written language and psychological development*. Orlando: Academic Press.

Schmidt, R. A. & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science, 3*, 207-217. doi: 10.1111/j.1467-9280.1992.tb00029.x

Schunk, D. H., & Zimmerman, B. J. (1997). Social origins of self-regulatory competence. *Educational Psychologist, 32*, 195-208. doi: 10.1207/s15326985ep3204_1

Shermis, M. J., & Burstein, J. (2003). *Automated essay scoring: A cross-disciplinary perspective*. Mahway, NJ: Lawrence Erlbaum Associates.

Sommers, N. (1980). Revision strategies of student writers and experienced writers. *College Composition and Communication, 31*, 378-387. doi: 10.2307/356588

Sowell, E. R., Thompson, P. M., Holmes, C. J., Jernigan, T. L., & Toga, A. W. (1999). *In vivo* evidence for post-adolescent brain maturation in frontal and striatal regions. *Nature Neuroscience, 2*, 859-861. doi: 10.1038/13154

Ste-Marie, D. M., Clark, S. E., Findlay, L. C., & Latimer, A. E. (2004). High levels of contextual interference enhance handwriting skill acquisition. *Journal of Motor Behavior, 36*, 115-126. doi: 10.3200/JMBR.36.1.115-126

Tomlinson, B. (1990). Ong may be wrong: Negotiating with nonfictional readers. In G. Kirsch and D. H. Roen (Eds.), *A sense of audience in written communication* (pp. 216-230). Newbury Park, CA: Sage Publications.

Traxler, M. J., & Gernsbacher, M. A. (1993). Improving written communication through perspective-taking. *Language and Cognitive Processes, 8*, 311-334.doi: 10.1080/01690969308406958

Vandenberg, R., & Swanson, H. L. (2007). Which components of working memory are important in the writing process? *Reading and Writing, 20*, 721-752.doi: 10.1007/s11145-006-9046-6

Van Waes, L., & Schellens, P. J. (2003). Writing profiles: The effect of the writing mode on pausing and revision patterns of experienced writers. *Journal of Pragmatics, 35*, 829-853. doi: 10.1016/S0378-2166(02)00121-2

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wallace, D. L; Hayes, J. R; Hatch, J. A; Miller, W., Moser, G., & Silk, C. M. (1996). Better revision in eight minutes? Prompting first-year college writers to revise globally. [References]. *Journal of Educational Psychology, 88*, 682-688. doi: 10.1037/0022-0663.88.4.682

Wishbow, N. A. (1988). Studies of creativity in poets. Doctoral Dissertation, Carnegie Mellon University.) *Dissertation Abstracts International, 51*, 0491A.

Wellman, H. M. (1990). *The child's theory of mind*. Cambridge, MA: MIT Press.

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: The truth about false belief. *Child Development, 72*, 655-684.doi: 10.1111/1467-8624.00304

Zimmerman, B J., & Kitsantas, A. (2002). Acquiring writing revision and self-regulatory skill through observation and emulation. *Journal of Educational Psychology, 94*, 660-668. doi: 10.1037/0022-0663.94.4.660

Author Note

This article is based on the keynote address given September 20, 2006 in Antwerp at the biannual Writing Conference, sponsored by the European Association for Research on Learning and Instruction (Special Interest Group-Writing). The author thanks Luuk Van Waes and two anonymous reviewers for their helpful suggestions on an earlier draft of the article.