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WORKING MEMORY IN LEARNING TO WRITE: EFFECTS OF CONTEXT AND DIGITAL TOOLS' GENERALIZED USAGE[1]

***Abstract**: In this article, we present the main models of written verbal production activity that allow us to analyze and describe the processes implemented during this activity. According to these models, writers activate several types of knowledge: knowledge about the domain of the world evoked by the text to be produced, knowledge about language and texts, and pragmatic knowledge. The analysis of these models makes it possible to account for and describe the knowledge activated during the realization of this text production activity, but also the different processes implemented during this complex cognitive activity. We examine the effects of the development and generalized use of digital tools on the functioning of working memory and written verbal production.*

***Key words**: Written verbal production, models of production, activated knowledge and processes, context, digital tools.*

LA MÉMOIRE DE TRAVAIL DANS L'APPRENTISSAGE DE L'ACTIVITÉ RÉDACTIONNELLE. EFFETS DE LA GÉNÉRALISATION DU CONTEXTE ET DES OUTILS NUMÉRIQUES

***Résumé** : Nous présentons, dans cet article, les principaux modèles de l'activité de production verbale écrite qui permettent d'analyser et de décrire les processus mis en œuvre au cours de cette activité. Selon ces modèles, les rédacteurs activent plusieurs types de connaissances : les connaissances sur le domaine du monde évoqué par le texte à produire, les connaissances sur la langue et les textes et les connaissances pragmatiques. L'analyse de ces modèles permet de rendre compte et de décrire les connaissances activées lors de la réalisation de cette activité de production de texte, mais aussi les différents processus mis en œuvre lors de cette activité cognitive complexe. Nous nous interrogerons sur les effets du développement et de la généralisation des outils numériques sur le fonctionnement de la mémoire de travail et la production verbale écrite.*

***Mots clés**. production verbale écrite, modèles de la production, connaissances activées et processus, contexte, outils numériques*

Introduction

Writing is a mental activity that requires multiple skills on the part of the writer. S/he must have information about the content of the text to be produced and the knowledge about language and texts needed to put that content into words. The knowledge activated and the processes involved in processing this knowledge have been the subject of a great deal of research aimed at understanding this complex activity. Presenting the main models of such

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activity enables us to understand the progress made in comprehending and analyzing this activity, while at the same time measuring the evolution of the theoretical frameworks and research methods used.

The activity of writing requires the activation of referential knowledge about the domain evoked by the text, linguistic knowledge, concerning syntax and spelling, and finally pragmatic knowledge, adapted to the writer's intentions according to context and audience. This activity involves a number of processes which activate the content of the text to be produced, adapting the linguistic form to the writer's and the audience's purpose. These processes also include those activated during the rereading, revision and correction of the text (see Changuoy, 2010; Marin and Legros, 2006; Olive and Piolat, 2003). The various models proposed integrate the different operations implemented during text production, the contextual components and the characteristics of the writer.

Back in 2005, Thierry Olive and Annie Piolat asked the question: "What conception of working memory should we retain?". Three major publications in 1996 contain theoretical guidelines which have led to a series of particularly fruitful experiments. Depending on whether the aim is to analyze the development of writing skills or the functioning of the experienced writer, the preferred model for working memory differs. McCutchen (1996) used the theory of Just and Carpenter (1992), while Hayes (1996) and Kellogg (1996) based their models on Baddeley's (1986). It is obviously beyond the scope of this article to offer an exhaustive account of all existing models. More modestly, our aim is to describe the most frequently cited models with a research orientation that is either fundamental (Garrett, Levelt, Dell, Van Galen), applied (Hayes and Flower) or didactic and pedagogical. After a brief look at Hayes and Flower's model, we will present the most frequently cited models.

Methodology

Our aim is to describe and analyze the main models of written verbal production in order to highlight their defining characteristics in relation to the development of research on written verbal production. The first model to be proposed, that of Hayes and Flower in 1980, which serves as a reference for many studies, is presented. The authors used experiments based on concomitant verbal protocols to identify the different processes underlying written verbal production, thus determining the origin of the difficulties and making it possible to improve production. The limitations of this model are then presented, highlighting the importance and role of working memory in production. The analysis of the production activity of expert writers is then proposed with the presentation of the work of Bereiter and Scardamalia (1987) and the developmental model of Berninger and Swanson (1994). Finally, revision and planning models such as Hayes and Nash's model (1996), Flower, Hayes, Carey, Shriver and Stratman's model (1986) and Butterfield, Hacker and Albertson's revision model (1996) are described and analysed

1. The first model: Hayes and Flower (1980)

Hayes and Flower's model, developed on the basis of an analysis of verbal protocols collected during expert authors' writing activity, is essentially concerned with the functioning and constraints of the written verbal production activity and the role of working memory (WM). The authors describe the writing process in great detail, breaking it down into the sub-processes of planning, formulation and revision. Several authors then gradually developed their analysis of this initial model to present their own model. Baddeley specified the role played by working memory (WM), interfacing with long-term memory (LTM), in the text production activity. Kellogg incorporated six processes: planning,

translating, programming, executing, reading and editing. These models of the verbal production activity are of interest not only to researchers specializing in cognition and learning/teaching, but also to didacticians and educationalists, as shown by Garcia-Debanc and Michel Fayol, for example.

1. 1 Presentation of the model

This model takes into account three components of different status. The first two relate to the task environment and the role of long-term memory (LTM), while the third describes writing processes in detail.
The first of these components, linked to the task environment, includes writing constraints. The second component of the model relates to LTM. To be able to produce a text, a writer has to retrieve information from the LTM in order to organize or reorganize it by drawing up action plans. The information stored in LTM concerns referential knowledge, the type of text to be produced, the development of a text plan and pragmatic knowledge. The third component covers all the writing processes. Planning makes it possible to develop, at a conceptual level, a pre-verbal message corresponding to the ideas that the writer wants to convey. Translating transforms pre-verbal drafts into a verbal message. Finally, reviewing helps to evaluate the text (whether in progress or completed). Planning, formulation and revision are supervised by a monitor, which enables these three processes to interact.

In their revised 1981 model, Flower and Hayes described the processes in detail. Planning comprises three types of action planning relating to processing and content. The "to do" plan defines the rhetorical and pragmatic goals of the writing process in terms of the writer's intentions and motivation, and the type of text (narrative, argumentative, explanatory, etc.). The "to say" plan organizes the overall content of the text to be written, in the form of notes, a draft, a plan or an outline. The "to compose" plan is a procedural plan which helps to manage the conceptual and linguistic processing required to produce the text.

Planning is made up of three sub-processes. The first or generating sub-process retrieves the semantic content of the text from our LTM. The second sub-process, called the organizing process, selects and prioritizes this information. These two sub-processes contribute to the development of the "to say" plan. The third sub-process, goal setting, has the function of adjusting processing according to the writer's production goals, in conjunction with the "to do" plan.

Translating involves a number of processing operations which perform two functions. The first is to develop each part of the plan conceived and developed during the planning process. The second involves linguistically translating and developing the text's semantic content.

The reviewing activity involves two sub-processes, namely reading and editing. Reading enables the writer to assess the concordance or divergence between the written text and its initial aim, between the produced text and the intended text. The revision activity thus enables analysis and reduction of the gaps between the writer's intention and the text produced.

1.2. Limits to Hayes and Flower's model

Hayes and Flower's model is still a reference today (see Zoubir, 2020), even though it has been the subject of numerous criticisms, such as those of Berninger and Swanson (1994) and Hayes himself (1996). These criticisms concern, on the one hand, knowledge processing. The knowledge stored in memory and the processes of activating this

knowledge in LTM are insufficiently taken into account. Secondly, this model, developed on the basis of an analysis of an expert's cognitive functioning, does not account for the progressive construction of the novice writer's skills and ignores the developmental aspect.

Subsequent research has responded to these criticisms. The aim of the new models was to clarify the role played by working memory (WM), conceived as an interface with LTM during text production. Short-term memory or WM is a type of memory that is limited in duration and capacity. LTM, on the other hand, has no limits, either in terms of duration or the amount of information stored.

2. The role of WM

An activity as complex as producing a written text makes heavy demands on working memory (WM), which plays an essential role in mastering this activity. Writing involves the coordinated management of processes whose cognitive cost varies according to a multitude of factors. These processes, which are demanding in terms of attentional resources, require less when automated.

Working memory (WM) enables information to be stored temporarily and made operational. Writers have limited attentional resources and processing capacities; these vary according to their level of knowledge, motivation, alertness, and concentration. A subject can therefore only carry out a limited number of cognitive operations at the same time. The cost of processing cannot exceed the attentional resources available.

2.1. Baddeley's contributions

The limitations of Flower and Hayes' original model lay in the mention that the role of the constraints imposed by the small span of short-term memory in the management of the text-writing activity. Baddeley rejects short-term memory as a low-capacity module and places great importance on WM, which plays an essential role in text production. WM is at the heart of the verbal production activity, as it is the executive instance of thought. It lies between the subject's intention and the sensory organs of transmission that enable him or her to perform the graphic gestures of writing.

Baddeley's (1992) model, which is most often referred to, aims to describe the functioning of WM. It is made up of a central administrator and two 'slave' systems: the phonological loop, which manages the processing of verbal material, and the visuo-spatial cuepad, which processes the visual and spatial components of stimuli. The central administrator determines the activity of the 'slave' systems, and coordinates and prioritizes their intervention. So, when an individual is carrying out a production task, s/he must allocate all attentional resources as judiciously as possible to avoid cognitive overload. The role of the central administrator is then to allocate resources as effectively as possible to the other components of the system.

All the knowledge required to perform the task is temporarily kept active in the episodic buffer memory. The central administrator acts as an interface between the WM and the LTM. It mobilizes semantic content and the processes on which it operates, and keeps these activated in WM.

Baddeley's model highlighted the important role of WM in production activities. However, his description of the functioning of WM remained global and was not explicit enough.

2.2. Process articulation in WM

Kellogg (1996), building on Baddeley's (1986) work, enriched the model with components specific to oral and written expression. He developed a model of the relationships between the different writing processes and the different WM registers. To do this, he added three superordinate instances: formulation, execution, and monitoring. Each of these systems is broken down into two processes. Formulation, seen from the perspective of Hayes and Flower's original model, includes planning and linguistic translation. Execution includes programming and executing, both of which drive the message. The linguistic representation resulting from the formulation phase is programmed before being transcribed to suit the final form of writing (handwritten or typed). Monitoring involves reading the produced text, which enables the message to be reread and checked during and after its production. The second process, editing, detects problems and, depending on the writer's decision, resolves them by proposing a new edition of the text.

During formulation, planning can give rise to multiple representations, characterized by pre-verbal propositions, abstract forms, images or sensations. The writer must then translate these different elements into written form, taking into account the context and choosing the appropriate lexical units and syntactic structures. During programming and execution, the motor system is involved in writing, whether handwritten or typed. The motor system is responsible for translating ideas. It enables the passage from virtual text to concrete text, by controlling the movements of the fingers and hand. However, the process of executing and translating ideas can be interrupted by the writer, who chooses to revise his text as s/he writes and self-regulates.

The cognitive load of these processing systems differs. According to Kellogg, formulation is the heaviest in LTM insofar as it mobilizes the planning and linguistic translation processes, unlike the execution component, which is not very heavy. But this load varies according to the degree of expertise. Graphomotor processing has its own load, making it difficult to implement planning or formulation processes.

Kellogg describes in great detail the interactions between production systems and processes, and LTM components. He emphasizes the fundamental role of the central administrator, who is involved in most editorial processes. In the case of expert writers, the execution process, which is largely automated, is not managed by the central administrator. The phonological loop would only be involved in linguistic processes, such as translation and reading. The visuo-spatial cuepad is used exclusively for planning. In fact, according to Kellogg, generating ideas and retrieving them in LTM may require recourse to mental imagery.

Each of the six processes described by Kellogg uses LTM resources. However, depending on the writer's expertise and the type of process required, this use is more or less important. According to McCutchen (1996), during processing, information from the LTM is stored in the WM, which performs two complementary roles: storing and processing information. Text production requires considerable information storage and processing. These two types of cognitive operation compete with each other, and the greater the resources allocated to processing, the less they are available for storage. The success of the writing process depends on the judicious distribution of cognitive resources between processing and storage. To achieve this, writers need to be aware of the strategies they are deploying and determine them according to the cognitive load they entail, depending in particular on their writing skills and degree of expertise.

In describing the role of WM in text development, Kellogg (1996) provides a valuable aid to understanding the mechanisms of written production. However, this

description does not account for the role of WM in the development of writing skills, nor does it provide concrete proposals for increasing WM capacity. The model does not account for the differences between good and less good writers.

2.3. WM and text writing: model evolution

Other models have been proposed (Alamargot & Chanquoy, 2001); some are based on a different conception of WM from that proposed by Baddeley (1986). McCutchen (1996), for example, based his model on the relationship between memory and writing skills to explain the increased interactivity of writing processes with expertise. Thus, in expert production, the automation of graphomotor processes and lexicon access frees up cognitive resources which are then available and can be allocated to higher-level processes. These processes, which are highly monitored, are likely to operate in parallel.

Kellogg (1999) and McCutchen (2000) use the concept of long-term working memory (Ericsson & Kintsch, 1995) to account for the activity of child and adult writers. This highly strategic register of long-term working memory, intermediate between WM and LTM, enables the writer to encode all the knowledge involved in the activity, then to retrieve and use it at low cognitive load level. However, while these proposals provide theoretical data on the dynamics of processing, the development of writing expertise and the automation of certain processes, they remain speculative for the moment and do not consider the developmental aspect of production as a function of the writer's increasing age and expertise.

3. Models related to the development of writing

Writing is subject to the writer's skills, which evolve as the writer develops. The fact that certain cognitive operations are automated frees up WM resources for other mental operations. This is the case with graphomotor transcription, which is heavy in terms of cognitive resources in young children. The load of certain processes, such as writing alphabetic letters, decreases with the expertise of the writer. Very high in young children, it becomes negligible in adults. To measure the importance of the transcription load for beginner writers, a strategy has been developed: the double task (Olive & Piolat, 2003). This involves putting an adult in a complex writing situation where, for example, s/he has to write a text using only capital letters. The attentional resources mobilized by this double task are subtracted from those still available to carry out the entire writing task.

3.1. Production by expert writers: Bereiter and Scardamalia's research (1987)

Bereiter and Scardamalia's model describes the writer's evolving skills corresponding to two strategies for using knowledge by novice and expert writers: the knowledge telling strategy and the knowledge transforming strategy.

On the one hand, young writers use the knowledge telling strategy. This strategy involves retrieving knowledge from the LTM and transcribing it directly into words, without reorganizing the linguistic form or conceptual content. The texts produced in this way are made up of juxtapositions of sentences that reflect the writer's knowledge structure.

More expert writers, on the other hand, are not satisfied with simply transcribing their knowledge. They resort to the knowledge transforming strategy, which implies the ability to reorganize this knowledge in order to make it compatible with the thematic and rhetorical constraints linked to a specific intention. This transformation of content and linguistic form implies the development of skills for planning text content to achieve increasingly complex goals. It is akin to a problem-solving activity with a high cognitive

load, requiring an increase in the span of short-term memory to keep the constraints of the task active. The knowledge transforming strategy is acquired gradually, and is available around the age of 16. Writers who have become capable of taking additional constraints into account are able to produce more elaborate texts than novice writers. In addition, the analysis that expert writers make of the communication situation and the reorganization of knowledge that they carry out enables them to acquire additional skills during the writing activity.

This model represents a considerable advance in our understanding of writing activity as a whole, but it remains general in scope. Other models develop finer, more specific analyses by studying in greater depth the writing processes under development in novice writers.

3.2. Berninger and Swanson's (1994) developmental model

Berninger and Swanson's (1994) developmental model concerns the development of writing processes in novice writers. It describes the gradual development of writing skills in children aged 5 to 10. The authors distinguish three developmental phases linked to three text production processes, as modelled by Hayes and Flower: planning, formulation and revision. However, the focus of Berninger and Swanson's research on young writers led them to modify the model by changing the order of the processes involved in novice writing.

The first process they focus on is formulation, which they break down into two sub-processes, namely execution (transcription) and text generation. In accessing text production, young children first use the execution sub-process, which is more easily accessible: they are capable of mechanically copying a word even though they do not yet have any word or text generation skills, which they gradually acquire once the execution process is fully automated. The second process is revision, which very young writers do in a limited manner; it is limited to surface corrections, mainly involving spelling and punctuation. The third process, planning the text to be produced, occurs later in the development of production skills and becomes progressively more complex as the child ages (see Piolat, 2004).

The developmental model is essentially concerned with the activity of formulation, and attaches less importance to planning and revision; these processes are modelled more specifically on the text production of expert writers.

4. Planning and revision models

4.1. Planning models

The analysis of the planning process, initially defined by Hayes and Flower (1980) and Flower and Hayes (1980) has been extended in subsequent models. Flower, Shrivey, Carey as well as Haas and Hayes (1989) looked at the activity of adult writers and distinguished several planning strategies concerning processing and content.

According to these authors, expert writers are able to combine the "to do plan" and the "to say plan" described by Hayes and Flower (1980), making it possible to establish a higher-level "constructive" planning strategy. This plan then controls the entire writing process and each of its stages. Constructive planning would constitute a "network of working goals" making it possible to plan all the components of writing (content, how to develop it in relation to its audience, etc.).

However, constructive planning has a high cognitive load, which is why authors envisage the possibility of writing a text using more economical and more local processes where the development of the text's content can be guided, for example, by the application of a text plan or schema (schema-driven) or by the writer's knowledge of the domain (knowledge-driven).

4.1.1. Hayes and Nash's (1996) model

Hayes and Nash (1996) proposed an analytical definition of planning in writing after taking stock of all the definitions associated with this process in the various models. They broke down this overall planning, which they call planning in writing, into a hierarchical set of planning activities with different types of skills. They contrasted process planning, which focuses on the writer's procedural knowledge, with text planning, which focuses on the content of the text and its influence on the recipient.

Text planning involves both planning by abstraction, which generates ideas without linguistic specification, and language planning, which produces a text that conforms to the rules of syntax. Language planning is equivalent to the formulation stage of Hayes and Flower's (1980) text production model. Abstract planning is subdivided into two types of planning, i.e., non-content planning and content planning, the former referring to the "to do plan" and the latter to the "to say plan" of Hayes and Flower's original model.

These different types of planning are characterized by the nature of the processing and mental operations that writers are supposed to carry out. Within this hierarchy, these authors distinguish three types of planning methods. The first of these methods, planning by abstraction, comes into play at the moment of generation and organization of ideas, which it structures without taking into account the linguistic translation of the content. The second method, or planning by analogy, enables knowledge stored in memory to be transposed by reactivating it. For example, knowledge of the stages of the narrative outline enables writers to call up a pre-established structure and activate it to produce their own text. The third method, or planning by modelling, concerns all the elements necessary for the linguistic formalisation of the writing, as they appear, for example, in the formulation process. Producing a sentence involves mentally planning all its components by establishing a model of the sentence.

4.2. Revision models

Text production is not always complete at the end of the writing process. Writers can go back over their text to improve it. This procedure, known as revision, involves making any necessary changes to a text that has been written or is being written. Several models have been developed to reflect different approaches to revision. They are presented chronologically according to their increasing degree of complexity.

4.3.1. Bereiter and Scardamalia's (1983) revision model

The CDO (compare, diagnose, operate) procedure developed by Bereiter and Scardamalia considers the action of the writer on his text. S/he is supposed to compare the written text with the text s/he has mentally planned, by evaluating the gap between an intentional text, the representation of this text and the version actually written. The diagnostic process leads him/her to identify the origin of the discrepancies between the desired text and the written text. Finally, the operate process aims to implement the changes required by the two

previous processes. However, this model does not make explicit the cognitive operations involved in text revision.

4.3.2. Flower, Hayes, Carey, Shriver and Stratman's (1986) model

The aim of this model is to clarify the functioning of the mental processes and operations involved in revision. It lists the knowledge involved in processing information. Revision thus appears to be a deliberate activity that the writer may or may not undertake, depending on his or her objectives, the state of progress of the text and his or her writing skills.

The choice of revision strategy is linked to the writer's understanding of the problem detected after rereading the text. The aim is to read in order to understand, evaluate, identify, and sort out the essential problems. Several solutions are then available: ignore the difficulty, postpone the effort to solve it, look for information in memory or in the text to better understand the problem, rewrite a fragment of the text or revise it while preserving the first layer of writing.

The Flower et al. model takes into account the diversity of modifications made by a writer rewriting certain aspects of his/her initial text. These modifications concern the type of operations carried out to achieve this goal (addition, deletion or substitution of words, groups of words or sentences, modification of part of the text, etc.). They occur at a given textual level, either on the surface of the text or in depth, at a given point in the text (beginning, middle or end) and in a phase of its composition (development of the outline, draft, final version or during a specific revision stage).

Flower et al.'s revision model marks an important step forward in research. It studies the revision process in its specificity and independently of its interactions with the other processes of written production.

4.3.3. Butterfield, Hacker and Albertson's (1996) revision model

This model involves two components. On the one hand, it includes the environment of the writer or of the task, which encompasses the rhetorical and pragmatic dimensions of production, as in Hayes and Flower's model (1980) (instructions, theme, communicative aim, revision issues, etc.). Secondly, it takes account of the processing system, distinguishing the WM from the LTM, where controlled processing takes place. These processes ensure the establishment of a representation of texts and the rhetorical problems associated with them, the detection and diagnosis of textual problems and the establishment of strategies to resolve them. On the other hand, the LTM register frees up WM resources by storing textual material that has already been revised.

The LTM is characterized by a dual level of functioning, namely the cognitive level and the metacognitive level. The cognitive level stores the knowledge (referential, linguistic and self-evaluative) and strategies required by the revision activity and the representation of the text being revised. Strategies for evaluating the text to be revised include rereading a difficult passage, going backwards, making predictions about the text in preparation and comparing several revision options. Similarly, control-regulation strategies ensure that the information conveyed by the text is synthesized and clarified, enabling the text to be corrected. Automated procedures are performed in LTM with a low cognitive load in WM. In contrast, the deliberate and controlled procedures that take place in the writer-reviser's WM are constrained by its limited resources.

The metacognitive level stores "knowledge models" and "models about knowledge". By comparing them with the text, the writer can understand and analyze the strategies and knowledge used to produce the text. Monitoring ensures the transfer of cognitive

processing to the metacognitive level. This thus enables the writer-reviser to carry out a metacognitive analysis of the processes carried out at the cognitive level. Conversely, monitoring ensures the transfer of metacognitive reflection to a level of operationalization of cognitive processing.

The function of metacognitive skills appears essential in the activity of writing a text. Indeed, writers' difficulties in revising their text are not exclusively attributable to the inadequacy or absence of the required knowledge and strategies; they may also be determined by the metacognitive impossibility of monitoring and coordinating knowledge and strategies that are nevertheless available.

5. Effects of digital systems and tools on WM and written verbal production

According to Gaëtan de Lavilleon, a neuroscientist, co-founder and chairman of the Cog'X[1] agency, and a specialist in experimenting with transformations in corporate working methods and innovation, "With digital technology, our working memory is quickly saturated"[2]. Indeed, as Legros et al. (2009) have long reported, research in cognitive psychology has shown that learners in written production situations mainly use the "knowledge telling strategy" (Bereiter & Scardamalia, 1987), and the quality of their text depends essentially on their "knowledge base" (Fayol, 1996). In a more recent study on writing in a second language, Gayed et al. (2022) described how such writing involves considerable cognitive stress, such as translating from L1 to L2 and engaging with digital mediating artifacts to help complete the writing task. This cognitive stress hinders learners from focusing on higher-level writing tasks such as organization and revision, which are essential for developing writing proficiency. Cognitive WM resources are spent on low-level writing tasks (word production, translation) at the expense of allocating time to higher-level writing tasks. Gayed et al.'s research highlighted that AI-based writing applications such as AI KAKU aimed to reduce the cognitive barriers faced by English as a Foreign Language (EFL) learners when producing written text in English. This would potentially allow EFL students to produce more and improved output than without assistance by reducing some of the cognitive load associated with the L2 writing process.

In addition, learners in writing situations lack the metacognitive knowledge essential for effectively regulating the revision of their text (Daiute & Kruidenier, 1985). This is why the digitization of society and the widespread use of digital systems and tools in production tasks are overturning knowledge representations and learning/teaching paradigms, and in particular models of written verbal production, which means that teacher training needs to be adapted and completely overhauled (Legros, 2021). Overall, the use of artificial intelligence and digital systems and tools can have both positive and negative effects on working memory and written verbal productions. While the efficient use of working memory can increase the potential of a learner's cognitive abilities in learning through multimedia (Teng & Zhang, 2023), intensive digital media use has been implicated in reducing working memory capacity and psychological problems (Korte, 2020). Similarly, while verbal working memory is important for language comprehension and production (Schwering & Macdonald, 2020), it is also supported by learning to represent items as actions (Cochrane & Green, 2023). Therefore, it is important to use digital systems and

[1] https://cogx.fr/

[2] https://www.lesechos.fr/idees-debats/leadership-management/avec-le-numerique-notre-memoire-de-travail-est-vite-saturee-1245842

tools judiciously and with an understanding of their potential effects on working memory and written verbal productions.

Conclusion

Research in psychology has shown that learners in written production situations essentially use the "knowledge telling strategy" (Bereiter & Scardamalia, 1987). As a result, the quality of their texts depends heavily on their "knowledge base" (Fayol, 1996). Moreover, they lack the metacognitive knowledge needed to regulate their text efficiently during revision (Daiute & Kruidenier, 1985). Hence the aims of research by Bounouara, who studied (i) the effect of reading resource texts to enrich pupils' referential and linguistic knowledge base, and to facilitate the implementation of the planning and drafting processes, and (ii) the effect of using a self-assessment grid on the development of metacognitive skills during evaluative reading, replanning and rewriting (see Bounouara and Legros, 2009). Today, with the widespread use of digital tools and systems, as well as artificial intelligence, research needs to focus on how to reduce the cognitive load of some of the low-level WM processes in order to enhance the higher-level ones, in particular in writing activities.

References

Alamargot, D., & Chanquoy, L., 2001, *Through the models of writing*, Dordrecht-Boston-London, Kluwer Academic Publishers

Baddeley, A., 1986, *Working memory*, Oxford, Clarendon Press/Oxford University Press.

Baddeley, A.D., 1992, *La mémoire humaine, théorie et pratique*, Grenoble, Presses Universitaires de Grenoble.

Bereiter, C., & Scardamalia, M., 1983, Levels of inquiry in writing in writing research. In P. Mosenthal, S. Walmsley, & L. Tamor (Eds.), Research on writing: Principles and method (pp. 3-25), New York, Longman.

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

Berninger, V.W., & Swanson, H.L., 1994, Modification of the Hayes and Flower model to explain beginning and developing writing, In E. Butterfield (Ed.), *Advances in Cognition and Educational Practice, vol. 2: Children's Writing: Toward a Process Theory of Development of Skilled Writing* (pp. 57-82). Greenwich, CT, JAI Press.

Bounouara, Y., & Legros, D., 2009, "Aides textuelles et métacognitives à la production d'un texte argumentatif en FLE, *Communication and Argumentation in the Public Sphere, 7* (Actes du colloque international *Communication and Argumentation in the Public Sphere,* Third Edition - "Dunărea de Jos" University, Galaţi, Romania*,* 26-28 March.

Bounouara, Y., & Legros, D., 2009, "Vers une didactique cognitive du FLE en contexte plurilingue algérien", *in* D. Legros & A. Mecherbet (Eds.), *Cognition et didactique de la compréhension et de la production d'écrit en FLE/S en contexte plurilingue et diglossique* (pp. 142-150). Tlemcen: Konouz Edition. https://docplayer.fr/54235858-Cognition-et-didactique-de-la-comprehension-et-de-la-production-d-ecrit-en-fle-s-en-contexte-plurilingue-et-diglossique-sous-la-direction-de.html.

Butterfield, E. C., Hacker, D. J., & Albertson, L. R., 1996, "Environmental, cognitive, and metacognitive influences on text revision: Assessing the evidence", *Educational Psychology Review,* 8(3), 239–297. https://doi.org/10.1007/BF01464075

Chanquoy, L., 2010, "How to make a revision task easier? A study of text revision from 3rd to 5th grade", *British Journal of Educational Psychology*, 71, 1, 15- 41.

Chanquoy, L., & Alamargot, D., 2002, "Mémoire de travail et rédaction de textes: Evolution des modèles et bilan des premiers travaux", *L'Année Psychologique,* 102, 363-398.

Chanquoy, L., & Alamargot, D., 2003, "Mise en place et développement des traitements rédactionnels : Le rôle de la mémoire de travail", *Le Langage et L'Homme,* XXXVIII, 2.

Cochrane, A., & Green, C.S., 2023, "Working memory is supported by learning to represent items as

actions", *Atten Percept Psychophys* 85, 1649-1660, https://doi.org/10.3758/s13414-023-02654-z
Daiute, C., & Kruidenier, J., 1985, "A self-questioning to increase young writers' revising processes", *Applied Psycholinguistics*, 6, 307-318.
Dell, G.S., 1986, "A spreading-activation theory of retrieval in sentence production"; *Psychological Review*, 93, 283-32.
Ericsson, K.A. & Delanay, P.F., 1998, "Long-term working memory as an alternative to capacity models of working memory in everyday skilled performance", *in* A. Miyake & P. Shah (Eds.), *Models of working memory* (pp. 93-114). Cambridge, Cambridge University Press.
Ericsson, K.A., & Kintsch, W., 1995, "Long-term working memory", *Psychological Review,* 102, 211-45.
Fayol, M., 1997, *Des idées au texte : Psychologie cognitive de la production verbale, orale et écrite*, Paris, PUF.
Fayol, M., 2007, "L'approche fonctionnelle de la production verbale écrite. Où en sommes-nous *?", in* M. Kail, M. Hickmann & M. Fayol (Éds), *Apprentissage des langues premières et seconds*, Paris, CNRS.
Flower, L. & Hayes, J.R., 1981, "A Cognitive Process Theory of Writing", *College Composition and Communication*, 32, 365-387. http://dx.doi.org/10.2307/356600.
Flower, L. S., Hayes, J. R., Carey, Shriver K., & Stratman J., 1986, "Detection, diagnosis and the strategies of revision", *College Composition and Communication*, 37, 16-55.
Flower L.S., Schriver K., Carey L., Haas C., Hayes J.R., 1989, *Planning in writing: The cognition of a constructive process, Technical Report N°34,* Center for the study of language, Berkeley (CA) et Pittsburgh (PA).
Gaonac'h, D., & Fradet, A., 2003, "La mémoire de travail : développement et implication dans les activités cognitives", *in* M. Kail & M. Fayol (Eds.), *Sciences cognitives et école.* Paris, Presses Universitaires de France.
Gaonac'h, D., & Larigauderie, P., 2000, Apprentissage et développement dans l'activité de rédaction de textes. https://www.researchgate.net/publication/280023756_Apprentissage_et_developpement_dans_l%27activite_de_redaction_de_textes.
Garcia-Debanc & Fayol, M., 2002, "Des modèles psycholinguistiques du processus rédactionnel pour une didactique de la production écrite", *Repères,* 26.27, 293-315, https://www.persee.fr/doc/reper_1157-1330_2002_num_26_1_2409.
Gayed, J. M., Carlon, M. K. J., Oriola, A. M., & Cross, J. S., 2022, "Exploring an AI-based writing Assistant's impact on English language learners", *Computers and Education: Artificial Intelligence, 3, 100055.*
Garrett, M.F., 1980, "Levels of processing in sentence production", *in* B.L. Butterworth (Ed.), *Language production* (Vol. 1: Speech and talk, pp. 177-220). New-York: Academic Press.
Hayes, J. R., 1996, "A new framework for understanding cognition and affect in writing", *in* C. M. Levy & S. Ransdell (Eds.), *The science of writing: Theories, methods, individual differences and applications* (pp. 1-27). Mahwah, Lawrence Erlbaum Associates.
Hayes, J. R., & Flower, L. S., 1980, "Identifying the organization of writing processes", *in* L. W. Gregg & E.R. Steinberg (Eds.), *Cognitive processes in writing* (pp. 3-30). Hillsdale, Lawrence Erlbaum Associates.
Hayes, J. R., & Nash, J. G., 1996, "On the nature of planning in writing", *in* C. M. Levy & S. Ransdell (Eds.), *The Science of Writing* (pp. 29-55). Mahwah,: Lawrence Erlbaum Associates.
Kellogg, R. T., 1996, "A model of working memory in writing", *in* C. Levy & S. Ransdell (Eds.), *The science of writing: theories, methods, individual differences and applications* (pp. 57-71), Mahwah; Lawrence Erlbaum Associates.
Korte M., 2020, "The impact of the digital revolution on human brain and behavior: where do we stand?", *Dialogues in clinical neuroscience*, *22*(2), 101-111. https://doi.org/10.31887/DCNS.2020.22.2/mkorte
Legros, D., 2021, "La formation des formateurs à l'ère de de la numérisation de la société et de la mondialisation. Les leçons de la pandémie ; Les apports des sciences cognitives", *Multilinguales*, 9 / N° Spécial, 185-204, https://www.asjp.cerist.dz/en/downArticle/13/9/2/170671.

Legros, D., 2022, "Cognition et didactique du FLE. Effets de la prise en compte du fonctionnement cognitif de l'apprenant sur l'apprentissage/enseignement du FLE et en FLE", *Passerelles*, 11, 19-30, https://www.asjp.cerist.dz/en/PresentationRevue/531.

Legros, D., Bounouara, Y., Acuna, T., Benaïcha, F.Z., Hoareau, Y., & Sawadogo, F., 2009, "TICE et Cognition de la Littératie plurilingue. Vers un modèle intégrateur", *Synergies Algérie,* 6, https://gerflint.fr/Base/Algerie6/legros.pdf.

Levelt, W.J.M., 1989, *Speaking: From intention to articulation*. Cambridge, MA, MIT Press.

Marin, B. & Legros, D., 2006, "Révision et co-révision de texte à distance. Vers de nouvelles perspectives pour la recherche et la didactique de la production de texte en context", *Langages,* 164, 113-125.

Marin, B. & Legros, D., 2008**, "**Psycholinguistique cognitive de la production de textes", *in* B. Marin and D. Legros, *Psycholinguistique cognitive*, 6, 95-113.

McCutchen, D., 1996, "A capacity theory of writing: Working memory in composition", *Educational Psychology Review, 8*(3), 299–325. https://doi.org/10.1007/BF01464076

McCutchen, D., 2000, "Knowledge, processing and working memory: Implications for a theory of writing", *Educational Psychology Review,* 35 (1), 13-23.

McCutchen, D., 2006, "Cognitive Factors in the Development of Children's Writing", *in* C. A. MacArthur, S. Graham, & J. Fitzgerald (Eds.), *Handbook of writing research* (pp. 115-130), The Guilford Press.

Olive T. & Piolat, A., 2003, "Activation des processus rédactionnels et qualité des textes", *Le Langage et l'Homme* : *Logopédie, Psychologie, Audiologie*, XXXVIII, n° 2, 191-206.

Olive, T. & Piolat, A., 2005, "Le rôle de la mémoire de travail dans la production écrite de textes", *Psychologie Française* 50 (3): 373-390 https://www.researchgate.net/publication/247280001.

Piolat, A., 2004, "Approche cognitive de l'activité rédactionnelle et de son acquisition. Le rôle de la mémoire de travail", *LINX (Linguistique Institut Nanterre Paris X), 51*, 55-74.

Piolat, A. & Pélissier, A., 1998, *La rédaction de textes. Approche cognitive*. Neuchatel, Paris, Delachaux & Niestlé.

Scardamalia M., & Bereiter C., 1983, "The development of evaluative, diagnostic and remedial capabilities in children's composing", *in* M. Martlew, (Ed.), *The psychology of written language: A developmental approach* (pp. 67-95). London, Wiley.

Schwering, S.C. & MacDonald, M.C., 2020, "Verbal Working Memory as Emergent from Language Comprehension and Production", *Frontiers in Human Neuroscience.* 14:68. doi: 10.3389/fnhum.2020.00068.

Teng, M. & Zhang, D., 2023, "The associations between working memory and the effects of multimedia input on L2 vocabulary learning", *International Review of Applied Linguistics in Language Teaching*, *61*(3), 1021-1049**.** https://doi.org/10.1515/iral-2021-0130**.**

Van Galen, G.P., 1991, "Handwriting: issues for a psychomotor theory", *Human Movement Science*, 10, 165-191.

Zoubir, S., (2020, "L'écriture des commentaires dans le processus de correction de la production de l'écrit", *Multilinguales* [Online], 13, http://journals.openedition.org/multilinguales/5043/.

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