Read-out. A new component for writing models

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Abstract

In this article I aim at making plausible an automatic decision mechanism which reads out competing lemmas/lexemes. This read-out mechanism is an important component of the recursive loops of writing and therefore a correlate of the monitor. Furthermore, I address some current discussions in writing research as to the costliness of writing, cognitive versus automatized 'modules', and writing in L2. Finally, I turn to the possible assessment of writing processes in brain imaging.

Pure agraphia

Charcot's patient Nr. 2 in the Salpêtrière lectures from 1871 is a young merchant who has difficulties with writing (dominant hand) but not with speaking[1]:

> While seated comfortably at a table, Mr. L was given some paper and a pen and was asked to write with the right hand the word: Bordeaux. He picked up the pen and positioned it correctly between his fingers and held it with no apparently stiffness or discomfort, but found writing a single letter impossible. He knew which letters compose the word. He spelled aloud the letters which compose it B, o, r, etc. He picked out these letters from a newspaper but was unable to write them. "I know very well, said the patient, how the word Bordeaux is written but when I want to write with my right hand I no longer know how to do anything." With his left hand, Mr. L. was able to write very legibly and without error the word Bordeaux. Subsequently, he took the pen in his right hand, and with great effort managed to slavishly copy with his right hand the characters he has (sic) just produced with his left hand. He could copy what he could not write.

Interestingly enough, it has been brain research all along which has paid some attention to writing as a specific cognitive faculty. Sigmund Exner was the first to postulate a writing centre in the motor area of the frontal lobe in 1881. This area (Brodman Area 6) is still known as Exner's area. First efforts to localize a writing centre date back to 1856

[1] I cite a report of Pitres about Charcot's text (1884) in the English translation of Lorch & Barrière (2003: 2671).

(Marcé). Déjérine, Hermann Wilbrand, even Constanin von Monakow dealt with the topic of pure agraphia and with a writing centre in connection with this.

But critics, among them Charcot, persisted: Samuel Jackson commented on the efforts of Marcé in1866: "As a rule, when speech is quite lost, power to write is quite lost too; and when it is impaired there is usually difficulty in writing" (Lorch & Barrière 2003: 273). Charcot coined the famous sentence: agraphia is an aphasia of the hand.

Still there was a strand of brain researchers like Coslett & Heilmann and – nota bene – Antonio Damasio, who presented patients with pure agraphia. It was up to Norman Geschwind to set up the frame for practically all the discussions in language production and writing research in 1965 with a famous article in *Brain*: "Disconnexion syndromes in animals and man". In contrast to the older writing centres in the motor area of the frontal lobe, Geschwind takes keen interest in an area of the parietal lobe, the angular gyrus, which has been known to be of crucial importance for writing ever since lesion studies have been carried out. The angular gyrus "becomes a memory for written words by acting as an area for forming – and storing – cross modal associations between vision and hearing. It seems likely that this store of cross-modal associations involves more than words" (Geschwind 1965: 281).

That is how impairment of this parietal region results in the specific trouble patients with agraphia encounter: Charcot's patient Nr. 2 in the Salpêtrière lectures can read aloud words only when he tracks the letters with his writing finger. The graphomotor forms activate the phonetic forms, but there is no way of 'silent' grapheme-to-phoneme-conversion. Grapheme-to-phoneme-conversion ('cross modal associations') is exactly the job of the angular gyrus, according to Geschwind. I will return to this important point later.

Apart from the saliency historical concepts have even (or especially) in empirical science, there is an argument in favour of lesion studies like the ones mentioned: if impairment of a certain brain region results in impairment of a certain cognitive faculty, then it is a safe guess to postulate neuronal correlates for this faculty in the area in question. Up to now, these 'centres' for writing have been Exner's area (BA6) and the gyrus angularis (BA40). Exner's area is supposed to guide motor execution, the gyrus angularis is meant to guide phoneme-to-grapheme-conversion and possibly the retrieval of the 'thick' mental concepts needed for writing (Geschwind 1965: 281: "more than words").

Levelt contra Caramazza

In principle, the reliability of lesion studies or, respectively, of behavioural or imaging tools have been the subject of a debate in language production research between Alfonso Caramazza and Willem Levelt. The Dutch psychologist is the author of the 'bible' of language production research: *Speaking. From Intention to Articulation*, which was first published in 1991. Levelt is a strict advocator of the serial and discrete processing of language. The levels conceptualizer, formulator and articulator are 'autonomous specialists'. By definition, this is in stark contrast to the recursive 'back-processing' which writing research attributes to writing. That is why Levelt is particularly uninterested in the 'modality-question': are there two different output modalities, namely speaking and writing, or is there a sort of 'slave-activation' of the graphemic lexicon via the phonetic lexicon? Levelt (1989), of course, opts for the latter and proposes

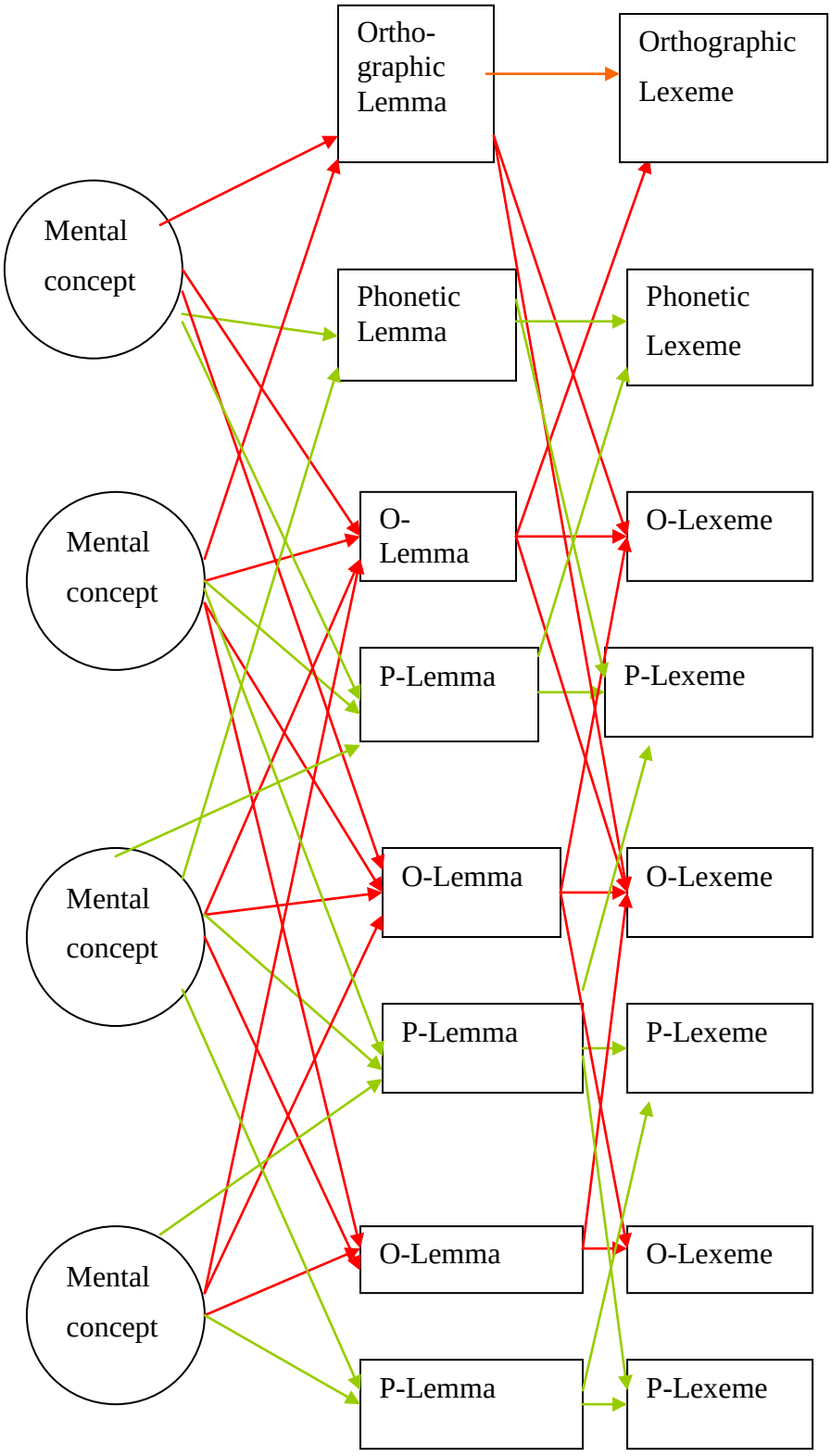
1. that the lemma level (a very early stage of language encoding prior to lexeme ('word') retrieval) is modality-independent.
2. that there is a phonological lexicon only, which in turn activates graphemic counterparts if necessary.

This phonological mediation hypothesis rests on the assumption that there is sublexical or lexical phoneme-to-grapheme-conversion, since there is no direct access to an orthographic ('graphemic') lexicon. It should be obvious that Geschwind's multimodal transformation centre comes into the picture. So, in a way, traditional lesion and case studies do confirm Levelt's phonological mediaton hypothesis.

From this perspective it is quite surprising that a 'medical' psychologist like Alfonso Caramazza has challenged Levelt's widely acknowledged model. According to his orthographic autonomy hypothesis there are two separate lexicons, the phonetic and the orthographic, which both can be activated separately. In a lucid article, moreover, Caramazza (1997) disposes of the assumption of a prelexeme level of language encoding, the lemma level, altogether. So, mental concepts activate specific orthographic or phonetic lexemes by themselves. It is no surprise that this theory is not a strong supporter of the assumption of prelexical or lexical phoneme-to-grapheme-conversion. It simply is not necessary, at least not for language production in the strict sense, because language processing has access to both lexicons.

Read-out: a modification of the classical writing model

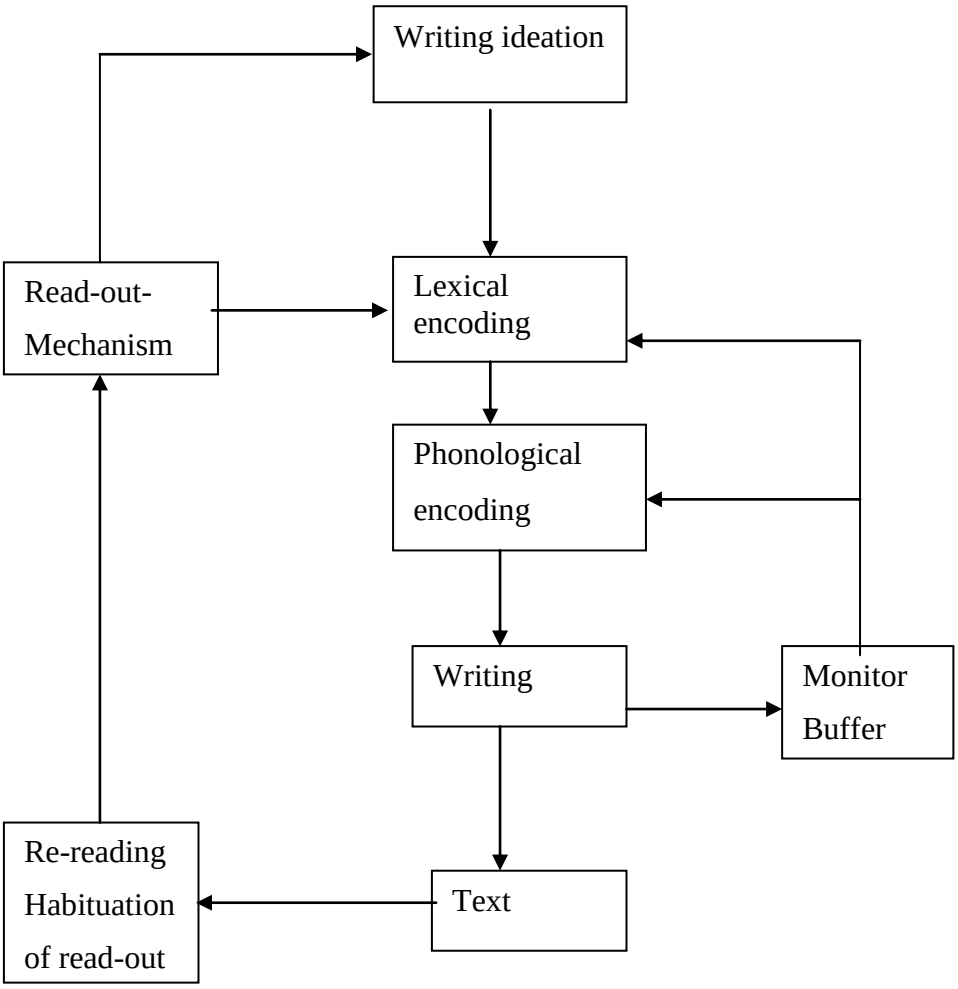
Model on lexical level with modality-specific lemma nodes



In principle I am a clear advocate of Caramazza's orthographic autonomy hypothesis. That means that there is an orthographic lexicon by itself. Moreover, as demonstrated in the model, I assume that there is competition for selection between 'orthographic' lemmas and orthographic lexemes as well as between 'phonetic' lemmas and phonetic lexemes. Thus, I opt for the competition-model and against the serial-discrete model. Still, I do not wish to dispose of the lemma-level. Rather, I would like to postulate that there is modality-specific information 'tagged' to the lemma indicating what output-modality is to be used. Kees de Bot (1992) has introduced this interesting turn of Levelt's modality-independence thesis for the case of L1/L2 production of bilinguals. That means: on lemma-level, a dual-route of encoding is initiated as to output-modality speaking or writing. Since I focus on the 'lexical phase' of encoding, the 'dual route' thesis does not encompass the syntax level of language production, in Merrill Garrett's words the functional/positional level. Suffice it here to mention that the filling of slots of a frame 'from left to right' does not seem to be the predominant way the output-modality writing encodes on the phonological and the motor level. Rather, there are empty slots in frames which are filled incrementally ('backwards'): especially positions of attributes are marked by blanks in some texts and are filled in after the noun has been written.

The basic idea of the writing model I am proposing here is that there is an automatic mechanism which 'reads out' the competing 'orthographic' lemmas and orthographic lexemes, but not the competing 'phonetic' lemmas and phonetic lexemes. This read-out mechanism initiates recursive loops just as the monitor does. But, of course, on this 'early' level of language processing there is no cognitive awareness, selections of the read-out-mechanism are automatized. Still, the read-out does 'learn' in the sense of habituation. This is accomplished by 'signposts' in the text which I call cognitive markers. During re-reading epochs these cognitive markers are traced and habituation of read-out is initiated.

Model of Writing 1



Why should there be an automatic selection mechanism with the orthographic lexicon, but not with the phonetic lexicon? Simply because planning, processing, monitoring, motor execution and revising result in the specific cognitive load of writing in contrast to speaking. Also, with 'orthographic' lemmas and orthographic lexemes there might be higher competition (more lemmas/lexemes are activated) due to the 'density' of mental concepts. The 'preverbal message' (Levelt) tends to be more complicated when writing is the output modality. So, there needs to be an alleviating mechanism at an early level of language processing which compensates for the cognitive load of writing. Otherwise writers would sit pondering over every word they are writing, or listing possible alternatives on the paper – which in fact they do when the read-out is flawed. This is due to the specific recursive loops of writing which seem to enhance incremental processing, including 'backwards' processing. So, if there was no automatic selection

mechanism determining a 'path' of language encoding, nodes on the lexeme- or lemma-level would be activated again ad infinitum because of the recursive loops of writing.

Since my model borrows from connectionist models I would like to adapt an interesting idea of Gary Dell's (1986) in his seminal paper introducing the term spreading activation. Dell postulates that adjustments on one processing level are made according to higher level knowledge (Dell 1984: 299). That means that the kind of processing language relies on is interactive between levels. Moreover, it uses a kind of supra-information which transcends the "autonomous specialists" conceptualizer, formulator and articulator (Levelt) on the one hand and the automatically generated content which is mapped from one level to the next on the other. There is a "built-in editor" (1984: 300) which 'reads out' activated nodes on the higher levels and applies (and possibly) inhibits generative and insertion rules on the current level. That seems to be very close to what I term read-out. This mechanism does not belong to the processed content and it is not a part of the set of generative rules which govern the selection of activated nodes or insertion rules which govern the filling of slots. Especially intriguing is Dell's use of the term 'knowledge', which presupposes some kind of accumulation and storage of information *about* the processing of the current preverbal message. This is the kind of 'learning' and storing of information which I termed habituation of read-out.

In order to clarify the term cognitive marker I present a German text by a Rumanian PhD-student of history (see next page). We see clearly that there are two different kinds of erasures. The lines through 'Paulinus' I term eliminating erasure, the diagonal scratches I call marking erasures. It is obvious that the latter initiate a recursive loop which eventually (the third time) results in an (almost) perfect sentence with a clear line of argument. This is not just a matter of cognitive revising, but of feedback loops on the level of retrieval of mental concepts and their first encoding stages. Thus, the read-out mechanism has been facilitated by habituation, meaning: during the third writing epoch lemmas/lexemes which have already been activated are 'layered', resulting in the encoding of a complex string of 'arguments'. Cognitive markers like the mentioned marking erasures trigger habituation of read-out during re-reading epochs.

– die Wichtigkeit der Quellen, auch wenn es nur Briefe der Bischöfe handelt, sie können trotzdem Daten überliefern die nicht auch für die Kirchengeschichte wichtig sind.

– ~~das Paulinus die~~ diese Propemptikon eine zuverlässige Quelle ist,

für die Zuverlässigkeit dieses Gedichtes steht

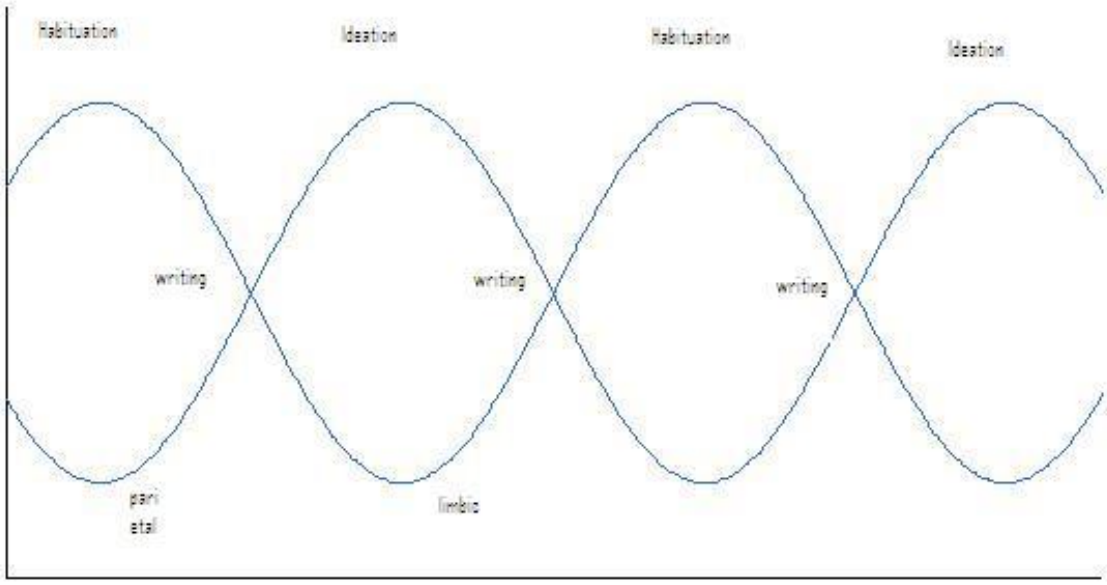
man kann diese Quelle also schon als zuverlässig nehmen, Paulinus hatte eigentlich keine ~~Probleme~~ geographische Probleme für die östlichen Provinzen, es ist doch Schüler von Ausonius und Ausonius hatte einige Verwandte ~~in~~ in

Especially writers employing an all-at-once strategy tend to place cognitive markers in the text when the read-out-mechanism does not manage the selection of one of competing lemmas/lexemes. That means that sometimes alternative formulations are written one on top of or behind the other; a change in handwriting may occur (usually the wider, more spacious the writing becomes the more the read-out is flawed). Often there are subsequent marking-erasures of these passages. Sometimes little sketches or abbreviations or remarks in L1 (for L2-writers) can be found, which serve as cognitive markers.

Emotions, working memory, and the cognitive tip of the iceberg

If there is a non-sequential 'all-at-once' process of lemma/lexeme-selection, further encoding, monitor, motor execution *and* read-out-mechanism respectively habituation of the read-out-mechanism, then first of all the sequential models of classical writing research are challenged (which is in fact what I wish to do). Secondly, the question of working memory comes into the picture, and thirdly, issues concerning writing in L2 need to be addressed.

Model of writing 2 (event related)



Instead of separating phases of writing, re-reading and planning-epochs I would like to define writing as a temporary interplay of read-out and ideation. So, this is a 'probabilistic' account of writing which is dependent on 'medium-base-line' activation

of ideation and read-out. When read-out, resp. habituation of read-out peaks, then the possibility of a writing epoch is low (rather, the possibility of a re-reading epoch is high). When ideation peaks, likewise, the motor act of writing probably will not occur. The sine-curves are, of course, idealized progressions marking, again, probabilistic accounts of cognitive activity during 'writing'. This model emphasises that writing is not an epoch in a linear progression of phases of planning, translating, reviewing. Rather, writing is activated by the interplay of two 'cognitive' faculties reaching medium-baseline.

Of course, there is the intriguing question as to how this 'psychological' model could be transferred to brain localisation. As Rüdiger Seitz points out lucidly in his article, the angular gyrus (or more generally: the upper half of the parietal lobe) is still a prime candidate for a writing centre, possibly including more than grapheme-to-phoneme conversions which, in my model, are not absolutely necessary (because of autonomous access to the orthographic lexicon). The parietal lobe has been suggested as the moderator for episodic memory. So, hypothetically, the angular gyrus and the supramarginal gyrus would be candidates for the 'ideation centre' of writing.

For the read-out-mechanism, in turn, I assume that the 'limbic circuit' (including the amygdala and the frontal part of the cingulate gyrus) are of importance. This is for the simple reason that in the kind of automatic decision making which the read-out mechanism carries out the prime candidates for these processing 'agencies' are emotions, especially so-called basic emotions. Ever since Darwin and William James emotions are supposed to 'short-cut' cognitive decision-making. From creativity research we know that there is a positive-mood creativity link, and according to the hedonic contingency hypothesis (Hirt et al. 2008) subjects tend to avoid topics in writing assignments which threaten to change their positive mood. The thesis would be that the writing behaviour of subjects can be manipulated by techniques of mood-induction. Especially the read-out will be facilitated, resulting in a higher quality of text, more marking erasures (qualitative design), a larger number of words, shorter pauses between letters (quantitative design). For the quantitative design key logging tools like Inputlog are suitable.

Alternatively, the read-out-mechanism could be primed and reaction times to the stimuli (beginning of writing/speaking epoch) could be assessed in a classical behavioural design. Whalen's and LeDoux's work proves that the amygdala can be primed by

emotional faces and eye-whites (masked primes). The basic idea would be to 'prime' the limbic circuit with emotional stimuli (sentences or words) in contrast to neutral stimuli (sentences or words). Since the read-out is facilitated by emotional priming, I expect shorter reaction times with St emot Write (emotional stimulus for writing) in contrast to St neut Write, St emot Speak, St neut Speak, meaning: pictorial or word stimuli with high emotional valence and/or arousal tend to strengthen the modality-effect.

Block-design for RT-experiment

I

St emot (sentence) 1	Speak
St emot (sentence) 2	Write
St emot (sentence) 3	Speak
St emot (sentence) 4	Write
St emot (picture) 1	Speak
St emot (picture) 2	Write
St emot (picture) 3	Speak
St emot (picture) 4	Write

II

St neut (sentence) 1	Speak
St neut (sentence) 2	Write
St neut (sentence) 3	Speak
St neut (sentence) 4	Write
St neut (picture) 1	Speak
St neut (picture) 2	Write
St neut (picture) 3	Speak
St neut (picture) 4	Write

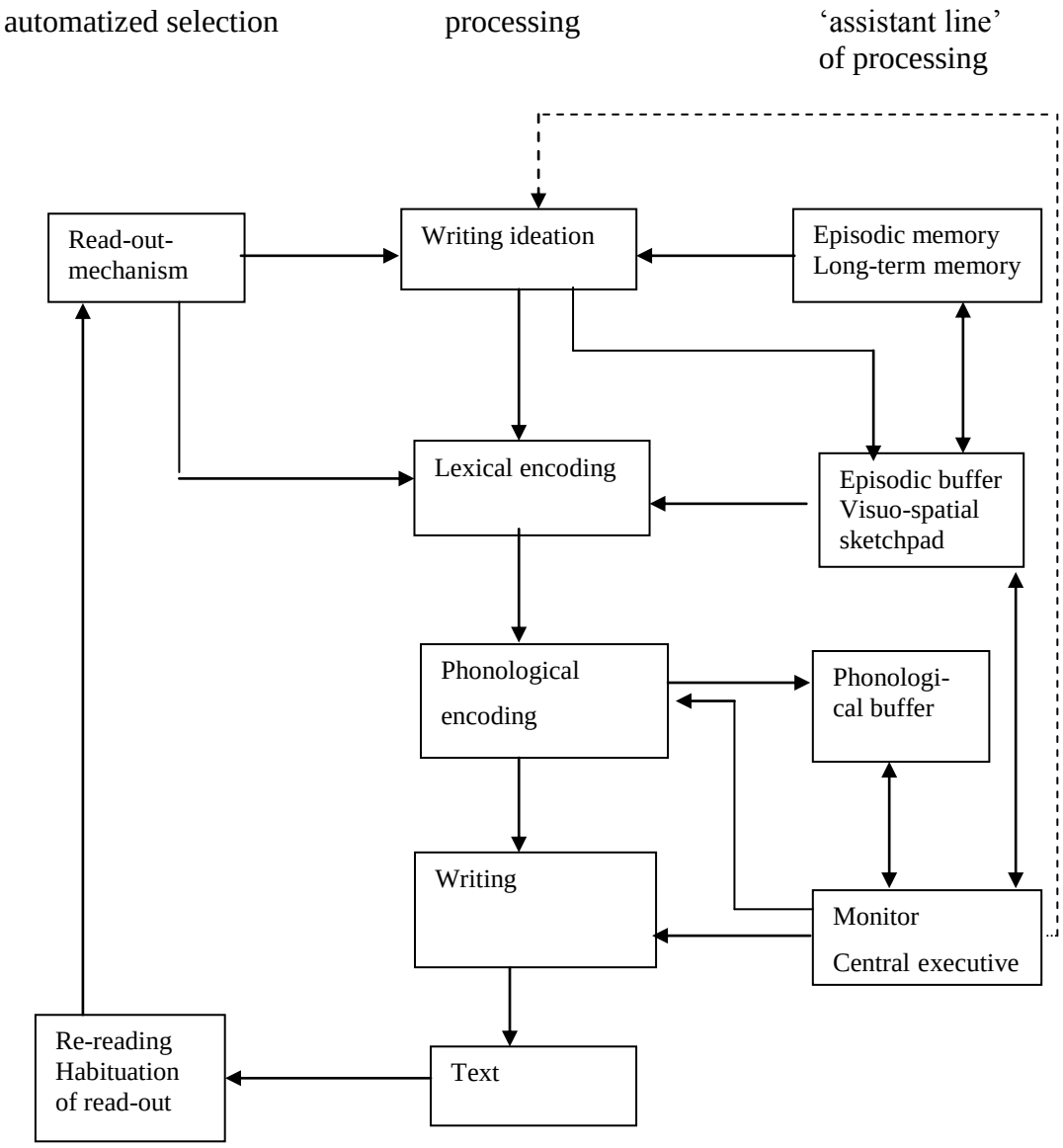
Hypothesis:

RTs will be shorter with St emot Write in comparison to St neut Write, St emot Speak and St neut Speak due to facilitation of read-out.

As to the 'costliness' of writing in the sense of cognitive (over-)load: in principle, I accept this popular position in writing research. But I wish to add some remarks to it. An amazing fact about expert writers is that they return to a phrase which had been interrupted due to a flaw in read-out after having written half a page in 'search-mode'. This means that the working memory has stored the truncated formulation and activates

it again after a large span of unrelated writing activity. Writers juggle cognitive demands not because they apply the most promising writing strategies, but because writing per se alleviates cognitive loads. Information storage can be externalised, the 'spacialization' of graphemic images on the paper/screen aids cognitive processing, the activation of graphomotor-forms 'feeds back' to earlier processing levels of language production. Subjects in Matsuo et al. (2003) succeeded in counting Kanji-strokes faster when they were permitted 'empty' finger movements. As early as 1871, Charcot pointed to a kind of facilitation of the retrieval of phonetic lexemes by the activation of graphomotor forms. One of the core ideas of Lev Vygotski, finally, was a feedback effect of writing on 'inner speech'.

Model of writing 3



There is a second twist to the matter: Baddeley refined his model of working memory in 2000, adding a component called episodic buffer. The episodic buffer is a slave system just like the visuo-spatial sketchpad and the phonological loop. But the interesting thing is this: the episodic buffer as well as the visuo-spatial sketchpad, slave systems of the central executive to be sure, also serve as buffers for long-term memory/episodic memory, which in turn is a major contributor to writing ideation (see model). The phonological loop serves as a buffer solely for the central executive. The idea is basically to commingle what Levelt calls buffer with what Baddelely & Kellogg call slave system, resulting in a line of 'assistant processing' on the one hand and in a 'semi-automatized' control of and feedback to language encoding and possibly retrieval of mental concepts.

The central executive, of course, is heavily taxed by writing ideation, monitor and motor execution. But the specific feedback loops of writing facilitate 'downgrading' the information to the slave systems. Also, there is a high level of automatization even with complex cognitive activities during writing. Finally, peaks of writing ideation and of read-out – which burden the slave systems, not the central executive – do not occur during writing epochs, as has been postulated. So, in a way, writing does free the working memory (the central executive) from heavy cognitive loads which the slave systems store and feed back to automatic processing.

Issues in writing research

As Barbier & Spinelli-Jullien point out in this issue, writing in L2 employs the same cognitive or automatic faculties, but there are some interesting questions as to the interplay, concomitance or autonomy of the activation of L1 and L2. Advocates of the modality-hypothesis seem to encounter some difficulties with the 'interplay-models' current in most bilingual research. After all, it boils down to the questions: do bilinguals have one or two orthographic lexicons and, if the latter is the case, is there cross-lexicon-activation? Michel Paradis (1987) favours the subset-hypothesis, stating that there might be just one mental lexicon, but separate activation of L1 and L2 *de facto*, depending on situational context and other external factors. Some researchers opt for the parallel distributed processing paradigm and establish cascade models with dual activation of L1 and L2 lemmas/lexemes. Competing lemmas/lexemes (L1/L2) are

selected by ‘rules’ which are insensitive to the language the preverbal message is encoded in. There might even be a Levelt-like ‘doubled’ discrete seriality. Barbier & Spinelli-Jullien stress that writers in L2 go back to L1 when there is need for planning or concept retrieval. Bilingual writers often ‘reach back’ to L1 when they are looking for clues on how to go on. In my eyes, that does not necessarily imply dual activation of L1- and L2-lexemes. Rather, it implies switching to a different lexicon with different activation patterns of competing orthographic lexemes.

Cross lexicon activation does not seem to be a prerequisite for this kind of second-track generation of mental concepts, rather there should be some kind of switch mechanism which Paradis (1987) locates in his seminal early work on bilingual aphasia in the supramarginal gyrus, next to the angular gyrus in the upper parietal lobule – interestingly enough with respect to the *locus* of a writing ideation centre. Once the mental concept is generated (and partially encoded) in L1, the language-switch mechanism ‘transfers’ the concept to L2; then the concept is encoded in L2. In my view, there is no short-cut on the lexical or on the functional/positional level (sentences). Put in another way: the epistemic value of writing is neither diminished nor facilitated by writing in L2 in comparison to writing in L1. There might be a processing surplus with respect to the generation of mental concepts. My sceptical stance towards the one-lexicon hypothesis stems from Kees de Bot’s (1992) thesis that there is information tagged to the lemma as to what language it is going to be encoded in. If this prelexical processing command exists, then there can be no double activation of L1 and L2 lexemes.

On the whole, I think it has become clear that I wish to stress automatized components and processes of writing: that is components which are not subject to problem solving strategies. In fact, these automatized modules – read-out and ‘assistant line’ of processing – are not in the range of strategies at all. Still, orchestration-theories of writing or the all-at-once strategy definitely point to these modules and might elicit activity there. But, after all, controlled (language) learning has always had the Utopia of ‘natural input’ or ‘constructivist’ learning in sight. When it comes down to automatized processing which cannot be monitored by cognitive faculties there is hardly any controllability as to learning contents or progression.

Still, I think that these automatized modules make writing the epistemic act it is. That means that due to the permanent habituation of the ‘system’ and due to the ‘non-

seriality' of processing, including several storage modules, dense mental concepts are generated. With this term I point to the possibility of multimodal concepts which bear affectual, spatial, aesthetic, narrative, and 'logical' remnants stored in long-term or episodic memory. The specific re-processing of writing seems to facilitate this kind of 'layering' of modes with mental concepts. After all, it is the generation of these concepts and their encoding in language which is the academic or artistic value that writing, in contrast to speaking, may be justified in claiming.

A giant leap for writing research? Brain imaging

Writing research has so far avoided close contact to brain imaging. This is for obvious reasons. First, techniques and statistics in this branch of experimental science are highly complex. Second, there are serious problems in relation to movement artefacts in the scanner, as Rüdiger Seitz points out in this volume: image data are distorted by head-movements on the part of the subject. Third, there is a strong Levelt-oriented branch, especially at some Max Planck institutes, which has 'inherited' disinterest in the modality hypothesis.

Since functional Magnetic Resonance Imaging (fMRI) evolved from older techniques of 'brain imaging' (MRI, PET) at the beginning of the nineties there have been about a dozen studies on writing; especially Japanese research groups and American-Chinese collaborations focus on this matter, probably because of the cultural value of writing in these societies. So, the technique can be adjusted to the specific research interests of the 'writing-community'. I would like to introduce some questions and possible answers concerning experimental design and technical adjustments.

The problem with stimuli is the kind of controllability desired in behavioural or imaging-experiments. Brain activity is extremely noisy, i.e. it is hard to find out what areas are actually activated in contrast to a baseline or a control condition. Experimental design needs to be fine-grained in such a way that there is high probability that stimuli elicit precisely the cognitive activity in question, and assessment techniques need to be adjusted in such a way that the likelihood is increased that the neural activations measured correlate to the cognitive activity. The writing of complex texts (creative, academic) is hardly elicitable and definitely cannot be assessed. There are stimuli with tachistoscopic design related to the 'creative functioning test' (Gudrun van der Meer): a

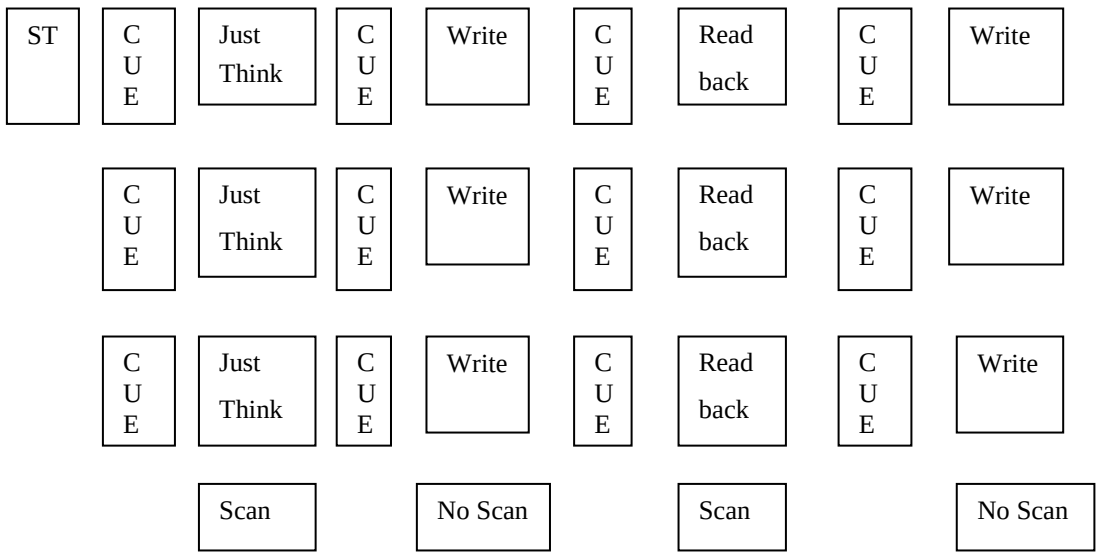
picture gradually building up in six steps or ‘dissolving’ in six steps. Ideational flexibility is measured by how fast and sustainably subjects come up with constructions of meaning in relation to the truncated picture. This design would elicit the kind of dense mental concepts I am interested in with writing. But for one thing it is practically impossible to measure reaction times with this kind of tachistoscopic design; moreover, because complex cognitive activities are noisy there is no way to localise activity in an ‘ideation-centre’ of writing.

So, there is a trade-off between ‘ecological setting’ and controllability. That is why I suggest ‘classical’ stimuli like sentences or pictures which are standardized with Snodgrass/Vanderwart-variables. As described above, stimuli will be emotional, because read-out should be facilitated. The emotional values of the stimuli can be assessed with the Berlin Affective Word List. Elicited writing activity encompasses one to three words.

A second problem is related to the probabilistic change of cognitive activities during writing. In order to concentrate on regions of interest prompts are installed which govern writing activity as to the classical ‘phases’.

Block-design I

Target (picture, word)
Cues: Red light: just think (8 sec)
Green light: write (8 sec)
Blue light: read back (8 sec).
Green light: write (8 sec)



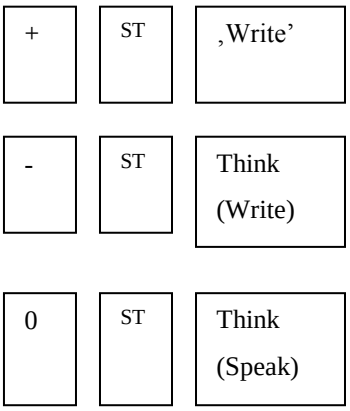
In this design the basic idea would be to discard data derived from writing epochs focussing on neuronal activity during planning and rereading epochs. Because of stimuli and prompts there is high probability that related cognitive activity correlates with writing.

Hypothesis: Just-think epoch will trigger activation in upper parietal lobe and limbic circuit (read-out). Read-back-epoch will activate the limbic circuit only (habituation of read-out).

Block-design II

+++ 'Write' ('empty' finger movements)
--- Think as if you were to write
000 Think as if you were to speak

With these prompts different cognitive activities related to writing are elicited.

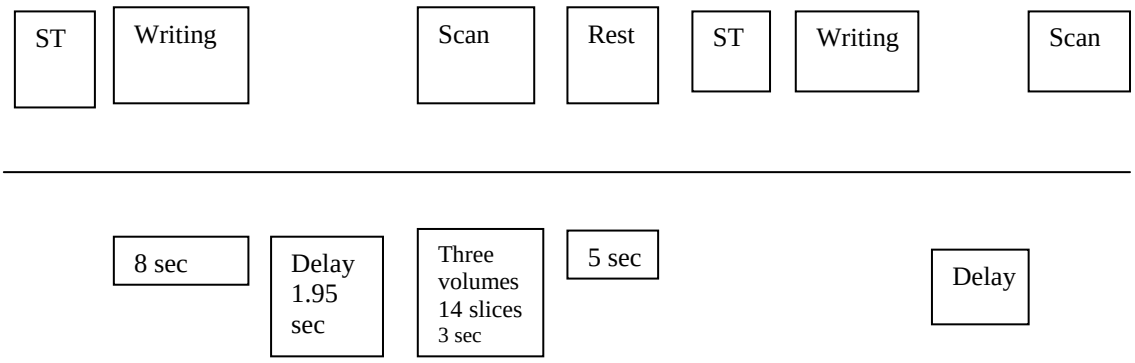


All conditions are scanned here because writing is either not executed (---) or 'empty' (+), meaning movements with right index finger.

Hypothesis: Activation of the limbic circuit with + and -, but not with 0.

Block-designs are of high statistical reliability (in behavioural and imaging-experiments), but they have been subject to criticism because they 'lump' together time courses of activated voxels (voxels are 'data points' in the three-dimensional brain, meaning they 'represent' activated brain tissue in the image generated by fMRI; often one voxel covers 1 mm^3 of brain tissue). That is why event-related designs with writing

are extremely desirable. With event-related design, though, there is the serious problem of artefacts. That is why I opt for sparse temporal sampling. Sparse temporal sampling is a technique of 'omitting' phases of motor-activity and scanning fast and 'simultaneously' after motor-activity has ceased. The underlying assumption is that the hemodynamic decay (the 'fading' of the signal as to 'normalization' of blood flow in neuronal tissue) plateaus for up to eight seconds after the activity has stopped. This sluggishness of the hemodynamic decay is of utmost importance for event-related designs of writing research.



Hypothesis: 'Interplay' of activation of read-out (limbic circuit) and ideation (parietal lobe) as described above.

Conclusion

I have attempted to point to writing as a specific orchestrated activity – cognitively, emotionally – which originates specific processes in the way mental concepts are retrieved and encoded into language. This interest in the recursive and automatic processing writing seems to facilitate results in re-designing 'classical' models. Empirical data suggest that there is an automatic decision mechanism which reads out competing mental concepts which are in the process of being encoded into language. There might also be an 'assistant line' of processing via the buffers of working memory. All of this seems to be in accordance with theories which stress the episodic character of knowledge-constituting during writing. Consequently, I do not think that this 'stream' of associations and these combinations of concepts need to be semantic in every case. Item context and item detail with writing in contrast to speaking point to episodic

memory as the prime source of writing ideation. This position would also take account of the emotional tinge writing often is connected with.

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