1

Require Less from Memory

The Forgotten Acronym

Let us start with a story.

> **A reading accident**
>
> Peter reads an article from the proceedings of a conference. He follows the text in a linear fashion. Suddenly, he stops, places his index finger underneath a word, and rapidly scans the text he has just read, searching for something. What he is looking for is not on the page. With his left hand, he flips back one page, and then another . . . he stops again. His face lights up. Satisfied, Peter flips back to the page he was reading before this unexpected and unwelcomed reading U-turn, and sets his eyes back to where the index finger marks the place for reading to resume. What happened? A reading accident: the forgotten acronym. Peter probably encountered an unfamiliar acronym defined only once by the author at the beginning of the paper. Peter had read its definition, but time had passed and he had forgotten it.

Acronyms allow writing to be more concise. However, conciseness is unhelpful if it decreases clarity. An acronym is clear within the paragraph in which it is defined. If it continues to be used regularly in the paragraphs that follow, the reader is able to keep its meaning in mind. But, if it appears irregularly or if reading is frequently interrupted, the acronym — away from the warm nest of the reader's short-term memory — loses its meaning. Food gets cold fast when it is out of the oven; you warm it up before eating it. Similarly, keep the acronym warm in the reader's memory; redefine it regularly in your paper.

Reader curiosity or impatience also contributes to reading accidents. The reader has the unfortunate habit (from the author's point of view) of skipping entire parts of your article to go directly to a figure, or to a section in your paper that seems interesting (via the heading or subheading). If the figure caption or the heading/subheading contains acronyms, and if the reader has skipped the sections that contain their definitions, then the accident will happen.

Avoiding problems with acronyms is easy:

- If an acronym is used only two or three times in the entire paper, it is better not to use one at all (unless it is as well known as IBM).
- If an acronym is used more than two or three times, expand its letters the first time it appears on a page so that the reader does not need to flip pages back and forth. Some journals ask authors to regroup all acronyms and their definitions at the beginning of their paper so that the reader can locate them more easily.
- Avoid acronyms in visuals or define them in their caption.
- Avoid acronyms in headings and subheadings because readers often read the structure of a paper before going inside the paper.
- Be conservative. Define all acronyms, except those commonly understood by the readers of the journal where your paper is published.

The Singapore taxi driver

The other day, while I was in Singapore, I hailed a taxi. I wanted to go to a research institute located on the campus of **N**anyang **T**echnology **U**niversity (NTU). The taxi stopped. I got in and said, "Nanyang Technology University, please." The taxi driver, an old man who had clearly been doing this job for many years, replied, "I do not know where it is." His answer surprised me. The university is old and well established; surely he had taken passengers there before. I started explaining that it was at the end of the expressway towards Jurong . . . all of a sudden, his face lit up and he said with a large smile, "Ah! You mean NTU!" That day, I learned that an acronym is sometimes better known than its definition.

Notice the just-in-time definition of the acronym in the following example.

The new universal learning algorithm SVM (support vector machine) had a profound impact on the world of classification.

The Detached Pronoun

This, *it*, *them*, *they*, and *their*[a] are all pronouns. A pronoun usually replaces a noun, but sometimes it replaces a phrase, a sentence, or even a full paragraph. Like the acronym, it is a shortcut that avoids the repetition of words.

Pronouns and acronyms are both pointers. This characteristic is at the root of all problems:

1. If you point in the direction of someone who has already left the room, nobody will understand. Likewise, if the noun the

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[a] "Their" is not technically a pronoun: it is a possessive pronominal adjective, but it functions as a pronoun. In the French language, "their" (*leur*) is a demonstrative pronoun.

pronoun points to is 20 or 30 words back in the text, it may have left the reader's short-term memory; the noun–pronoun link is broken. Usually, this memory lapse is not enough to discourage readers from reading forward. They tolerate ambiguity and read on because they are hopeful that the text will become clearer later. Interpretation errors and reduced understanding are therefore likely.

2. If you point towards a person in a group far away from you, people will find it difficult to guess whom exactly you are pointing to. When the pronoun points back to several likely candidates, the reader — whose incomplete understanding of the text does not allow disambiguation — will pick the most likely candidate and read on, hoping clarity will be forthcoming. If that likely candidate is the wrong one, then interpretation errors will follow and understanding will drop to a lower level.

3. Finally, some fingers seem to point nowhere; actually, they point somewhere, but only the person who is pointing knows where. When the pronoun points to something that is only in the mind of the author, the reader is left guessing and more often than not guesses wrongly. Understanding thus drops to a lower level.
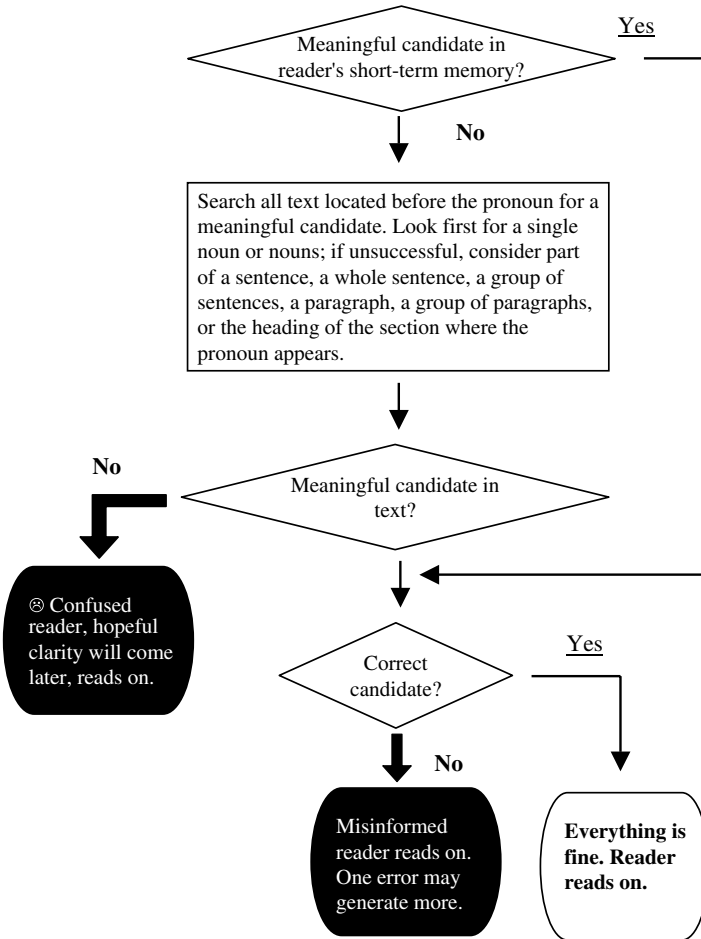
A diagram (☛**1**) helps to visualise the exploratory process followed by readers when encountering a pronoun.

The new notation ☛**1** is simply an invitation to look at visual **1.**

I do not mention whether visual **1** is a diagram, a table, or a photo because you know the difference.

Why the big black ☛ before the number? It is to help your eyes easily return to the text at the right place after you have looked at the visual. As you return, just let your eyes be guided by the dark beacon.

The diagram highlights that a reader stops searching for another candidate (i.e. antecedent) **as soon as** a likely one is found in his or her

Meaningful candidate in
reader's short-term memory?

Yes

No

Search all text located before the pronoun for a
meaningful candidate. Look first for a single
noun or nouns; if unsuccessful, consider part
of a sentence, a whole sentence, a group of
sentences, a paragraph, a group of paragraphs,
or the heading of the section where the
pronoun appears.

No

Meaningful candidate in
text?

☹ Confused
reader, hopeful
clarity will come
later, reads on.

Correct
candidate?

Yes

No

Misinformed
reader reads on.
One error may
generate more.

**Everything is
fine. Reader
reads on.**

☛**1. Process for finding a suitable candidate (antecedent) for a pronoun.**
This diagram explores the process followed by readers looking for a candidate
(antecedent) for a pronoun. The writer should consider three important facts:
(1) Readers decide the meaningfulness of the match between a pronoun and its
candidate. Therefore, their knowledge of the topic is part of the process, and
little knowledge may mean greater ambiguity. (2) Readers stop looking for a
candidate as soon as they think they have found one (preferably in their short-
term memory). They do not have the energy, the time, or the will to stop and
analyse whether the pronoun candidate they chose is the correct one. As a result,
errors occur more frequently if the candidate is so distant from its pronoun
that it no longer is in memory. (3) Readers continue reading whether they
have identified the correct candidate or not. Being unable to find the candidate
may be less "damaging" to the understanding than continuing reading with a
"corrupted" understanding because, in the first case, the reader seeks to increase
understanding, while in the second case, the reader is lulled into a false sense of
understanding.

short-term (working) memory. The choice of candidate is influenced by the reader's knowledge: the more superficial the knowledge, the more error-prone the choice will be. Authors who wish nonexperts to read their paper should be aware that pronouns present dangers.

In the following example, try and determine what the pronoun "*their*" refers to. The three candidates are in bold. Had the sentence been clear, this task would have been instantaneous. You will probably struggle; but if you do not, ask yourself how much does knowledge of the field assist you in making the correct choice.

> *The cellular automaton (CA) cell, a natural candidate to model the electrical activity of a cell, is an ideal component to use in the simulation of* **intercellular communications**, *such as those occurring between cardiac cells, and to model* **abnormal asynchronous propagations**, *such as* **ectopic beats**, *initiated and propagated cell-to-cell, regardless of the complexity of THEIR patterns.*

It is difficult to determine the plural noun pointed to by "*their*" because the sentence segment "*regardless of the complexity of their patterns*" could be moved around in the sentence and still make sense.

> *. . . to use in the simulation of intercellular communications, regardless of the complexity of their patterns . . .*
>
> *. . . to model abnormal asynchronous propagations, regardless of the complexity of their patterns . . .*
>
> *. . . such as ectopic beats, regardless of the complexity of their patterns . . .*

Communications, propagations, and beats can all display complex patterns. Let us decide that in this text, "*their*" represents the "*abnormal asynchronous propagations.*"

The ambiguity can be removed in different ways. First, one could simply omit the detail if it is not essential, or make that point later in the paragraph. The long sentence would then be seven words shorter.

> *The cellular automaton (CA) cell, a natural candidate to model the electrical activity of a cell, is an ideal component to use in the simulation of **intercellular communications**, such as those occurring between cardiac cells, and to model **abnormal asynchronous propagations**, such as **ectopic beats**, initiated and propagated cell-to-cell.*

One could also rewrite the sentence to make the pronoun disappear.

> *The cellular automaton (CA) cell — a natural candidate to model the electrical activity of a cell — is an ideal component to use in the simulation of intercellular communications, such as those occurring between cardiac cells, and to model the cell-to-cell initiation and propagation of abnormal asynchronous events (such as ectopic beats) with or without complex patterns.*

Finally, one could repeat the noun instead of using a pronoun.

> *The cellular automaton (CA) cell, a natural candidate to model the electrical activity of a cell, is an ideal component to use in the simulation of intercellular communications, such as those occurring between cardiac cells, and to model abnormal asynchronous events, such as ectopic beats, initiated and propagated cell-to-cell, however complex the propagation pattern may be.*

In science, clarity overrides elegance; therefore, repeat to avoid ambiguity.

> **Search for the following words in your paper:**
> ***this, it, they, their,* and *them.***
> **If you were the reader, could you easily identify**
> **what the pronoun refers to without ambiguity?**
> **If you could not, remove the pronoun and**
> **repeat the noun(s)/phrase it replaces. An**
> **alternate route consists in rewriting the whole**
> **sentence in a way that removes the need for the**
> **pronoun.**

The Diverting Synonym

Bis repetitas placent

That day, I could not understand why the paragraph I was reading was so obscure. The usual culprits were absent: the grammar was correct and the sentence length was average for a scientific article. I had noticed that words were repeated, but repetition usually clarifies and does not blight understanding. I decided to try and remove some of the repeated words. I then discovered the problem: four synonymous expressions.

1. *Known or predefined location.*
2. *Predefined location information.*
3. *Preprogrammed location information.*
4. *Identifiable position information.*

The author could have continued the game and added a few more synonymous expressions:

5. *Identifiable location information.*
6. *Predefined position information.*
7. *Preprogrammed position information.*

After removal of the synonyms, the structural problems appeared clearly. The paragraph was thus easier to rewrite.

Your language teacher may have told you to avoid repeating nouns within a sentence or in consecutive sentences. The advice given was, "Use synonyms, demonstrate your knowledge of the vast English vocabulary." In science, however, synonyms confuse readers, particularly those not familiar with the specialised terms used in your field. Therefore, avoid synonyms. Make your writing clear by consistently using the same keywords, even if it means repeating them. As an added benefit, you will lessen the demands on the memory of your readers: fewer new words also means less to remember.

The Distant Background

The Macintosh factory

When I moved to Cupertino, California, in 1986 to work at the headquarters of Apple Computer, I visited their Macintosh factory in Fremont. Every day, truckloads of components and parts came in, just enough for one day's production; and every day, containers of Macintoshes were shipped out. The net result: no local storage, no warehousing. I was witnessing a very efficient technique: just-in-time (JIT) manufacturing.

Traditionally, the background material the reader needs to understand your contribution is written in the first part of your article. If this background material is not used immediately, the memory will have to store it for later use. Unfortunately, the memory warehouse is small and the warehouse keeper is quite busy.

The variable types

There are two types of variables in a computer programme: global and local variables. Global variables are declared at
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> (*Continued*)
>
> the beginning of a programme and are known through-out the programme. Local variables are known only within the subroutine where they are declared. This interest-ing concept allows the computer to manage its memory space more efficiently. Global variables require permanent storage, whereas local variables free up their temporary memory storage space as soon as the programme exits the subroutine. Could this wonderful concept apply to writing?

Parking all background material in the introductory sections of your paper increases the demands on the reader's memory. Back-ground material comes in two forms: the global background, appli-cable to the whole paper; and the local or just-in-time background, useful only to one section or paragraph of your paper. The just-in-time background imposes no memory load: it immediately precedes or follows what it makes clear. Here is a just-in-time example:

> *Additional information is readily available from "context" — other words found in the vicinity of the word considered.*

In this example, the word "*context*" is defined as soon as it appears.

When a heading or subheading in your paper contains a word requiring an explanation, explain it in the first sentence under the heading, in a just-in-time fashion.

Lysozyme solution preparation
Lysozyme, an enzyme contained in egg white, . . .

In this subheading, the word "*lysozyme*" is unusual. The writer defines it in the first sentence of the section.

The English language offers many ways to add just-in-time information. The "*lysozyme*" example uses an apposition — an expression that clarifies what comes before it. Kept short, appositions are very effective. Kept long, they are ineffective, as the following sentence demonstrates.

> *Lysozyme, a substance capable of dissolving certain bacteria, and present for example in egg white and saliva but also tears where it breaks down the cell wall of germs, is used without purification.*

Appositions are also ineffective when they slow down reading, which happens quite often when many are found midsentence.

> *The cellular automaton (CA) cell,* **a natural candidate to model the electrical activity of a cell**, *is an ideal component to use in the simulation of intercellular communications,* **such as those occurring between cardiac cells**, *and to model the abnormal asynchronous propagations,* **such as ectopic beats**, *initiated and propagated cell-to-cell, regardless of the complexity of their patterns.* [1 sentence, 57 words]

The sentence above is long because it is attempting to describe two things at one time. Reading would be faster if the sentence was divided into two homogeneous parts:
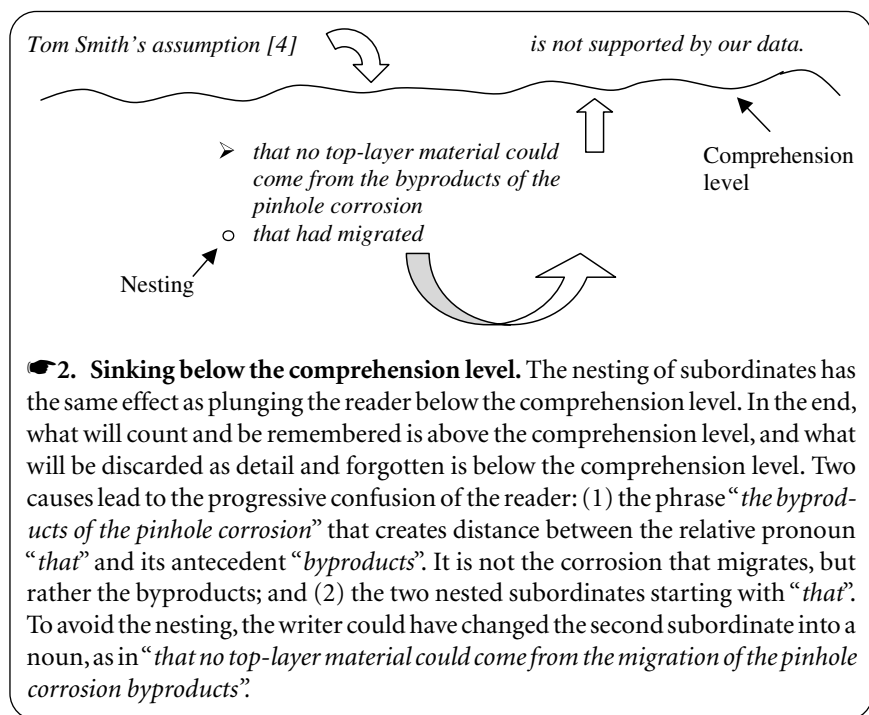
> *The cellular automaton (CA) cell is used in the simulation of intercellular communications because it can model the complex evolution of cell-initiated and cell-propagated signals in time and space. CA is therefore used here to model the electrical signals of cardiac cells, including those leading to abnormal asynchronous propagations such as ectopic beats.* [2 sentences, 54 words]

The Broken Couple

> ### The hot tap
>
> Do you remember the last time you stood still, hands under the hot water tap, waiting for the water to become warm, wasting cold water down the sink? Felt frustrated? When reading a sentence in which the verb never seems to arrive, has it occurred to you that your reader may also "waste" or ignore the words that separate the subject from its verb?

Details inserted between the main components of a sentence burden (burden comes from the old French *bourdon*, a "hum or buzz" — but do we need to know that!) the memory because they move apart two words that the reader expects to see together, such as the verb ("*burden*") and its object ("*the memory*") in this sentence. Such details

Tom Smith's assumption [4]   *is not supported by our data.*

➤ *that no top-layer material could come from the byproducts of the pinhole corrosion*
○ *that had migrated*

Nesting

Comprehension level

☛**2. Sinking below the comprehension level.** The nesting of subordinates has the same effect as plunging the reader below the comprehension level. In the end, what will count and be remembered is above the comprehension level, and what will be discarded as detail and forgotten is below the comprehension level. Two causes lead to the progressive confusion of the reader: (1) the phrase "*the byproducts of the pinhole corrosion*" that creates distance between the relative pronoun "*that*" and its antecedent "*byproducts*". It is not the corrosion that migrates, but rather the byproducts; and (2) the two nested subordinates starting with "*that*". To avoid the nesting, the writer could have changed the second subordinate into a noun, as in "*that no top-layer material could come from the migration of the pinhole corrosion byproducts*".

are often wasted, like cold water from a hot water tap. Separating the subject and the verb, as illustrated in ☛**2**, can be devastating.

Another couple of neighbours are best kept close: the visual and its full explanation. We no longer live in the days of silent movies. A visual must "tell all" by itself, without the need for text outside of its caption. Unless visuals are self-contained, the reader has to constantly shuttle back and forth between text and visual. Therefore, explain visuals **fully** in their caption.

You would do well to use the just-in-time principle and keep the following couples happily wedded:

• An unfamiliar word and its definition	• A verb and its object
• An acronym and its definition	• Background information and the text it clarifies
• A noun/phrase and its pronoun	• A visual and its complete caption
	• A verb and its subject

In summary, acronyms, pronouns, abusive detailing, background "ghettos", cryptic captions, and separated phrases all take their toll on the reader's memory.

Memory registers

I remember studying the structure of the Intel 8085 micro-processor back in 1981 (carbon-14 could not tell my age any better). I discovered that rapid access to memory is so critical to the overall speed of a microprocessor that the central processing unit (CPU) has its own dedicated memory registers right on the chip, or under the same

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(*Continued*)

roof, so to speak. Storing and retrieving data from these internal registers is ultrafast compared to the time spent retrieving data from external memory. Like the CPU, do keep syntactically or semantically closely related items on the same page, in the same paragraph, in the same sentence, or on the same line. The reader will appreciate the increase in reading speed and the ease of understanding.

The Word Overflow

Our working memory is very similar to the rewriteable electronic memory. To be retained in memory, the information needs to be rewritten a number of times (it is therefore a slower process than the reading process). Furthermore, the current used to "imprint" the memory is greater than the current used to read its contents. The current, in the reader's case, is attention. It takes a great deal of attention. The process is also slow. Have you ever been able to absorb complex road directions without asking the person to repeat them? Going too fast creates an overflow. Working memory is not very elastic; it can be overstretched by a sudden word overflow.

"*The main difference between the new micro molding machine design and the conventional 'macro' molding machines with reciprocating screw injection system is that by separating melt plastication and melt injection, a small injection plunger a few millimetres in diameter can be used for melt injection to control metering accuracy, and at the same time a screw design that has sufficient channel depth to properly handle standard plastic pellets and yet provide required screw strength can be employed in micro molding machines.*"[b]

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[b] Zhao J, Mayes RH, Chen GE, Xie H, and Chan PS, "Effects of process parameters on the micro molding process", *Polymer Eng Sci* **43**(9):1542–1554, 2003. © 2003 Society of Plastics Engineers.

This last sentence has a grand total of 81 words! Its syntax is acceptable and the meaning is clear enough for a specialist familiar with the machine, but the working memory necessary to process it is too large for most readers. Restructuring the sentence, breaking it down into logical segments, helps to reduce the demands on the working memory.

> *In conventional "macro" molding machines with reciprocating screw injection, melt plastication and melt injection are combined within the screw-barrel system. In the new micro molding machine, screw and injector are separated. The redesigned screw still has enough channel depth and strength to handle standard plastic pellets; but the separate injection plunger, now only a few millimetres in diameter, can be used to control the metering accuracy.*

The rewritten paragraph has three sentences instead of one, and 66 words instead of 81. As a result, because our memory can handle it, clarity is increased.

In conclusion, if you want the reader to sail through your paper with minimal memory load, identify and remove the causes for overload.

 Read your introduction again. Can you push background details closer to what they really explain? Are the sentences that feel long also ambiguous? Are details keeping apart elements of a sentence that should be closer?