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Neuroscience and Literacy: An Integrative View

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Abstract *Significant challenges exist globally regarding literacy teaching and learning, particularly in poor socio-economic settings in countries of the Global South. In this paper we argue that to address these challenges, major features of how the brain works that are currently ignored in the educational literature should be taken into account. First, perception is an active process based in detection of errors in hierarchical predictions of sensory data and action outcomes. Reading is a particular case. Second, emotions play a key role in underlying cognitive functioning. Innate affective systems underlie and shape all brain functioning, including oral and written forms of language and sign. Third, there is not the fundamental difference between listening/speaking and reading/writing often alleged on the basis of evolutionary arguments. Both are socio-cultural practices driven and learnt by the communication imperative of the social brain. Fourth, like listening, reading is not a linear, bottom-up process. Both are non-linear contextually shaped psycho-social processes of understanding, shaped by current knowledge and cultural contexts and practices. Reductionist neuroscience studies which focus on decontextualized parts of reading cannot access all the relevant processes. An integrated view of brain function reflecting this non-linear nature implies that an ongoing focus on personal meaning and understanding provides positive conditions for all aspects of literacy learning. Assessment of literacy teaching at all its stages should include indicators that take into account these foundational features relating reading and writing to neuroscience.*

Keywords: ***Early literacy pedagogy, neuroscience, predictive processing, perception, emotion***

Introduction: The context for this paper

In this paper, we raise deep concerns about the widely quoted aspects of neuroscience used to justify the kind of early literacy teaching currently viewed as most effective for children as they begin their formal schooling. We highlight the immense significance this has for the serious challenges which exist globally regarding literacy teaching and learning, particularly in poorly served settings of the Global South. In South Africa for instance, children have performed badly on both local and international assessments of reading progress, with poor African language speaking children faring far worse than their more affluent, largely English speaking counterparts. This situation is not new and many initiatives to improve matters have been attempted by government since apartheid ended (e.g. DoE 2008, DoE 2011, Van der Berg et al 2016).

Nonetheless, most recently South African society was shocked again to learn from the 2016 international PIRLS research into comprehension that 78% of South African children could not read for meaning by the end of grade 4 (Howie *et a*l 2017). This led even to the President of South Africa calling for all children to read for meaning by aged 10 in his 2019 State of the Nation Address. Efforts have been intensified to both understand why this situation exists, and to provide viable solutions (Reeves 2017, Fleisch and Dixon 2019). These include government level action on the recognition that the years before formal school are crucial ones for laying firm learning foundations (DoE 2015, Harrison 2020).

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Moreover there is broad consensus that during their preschool years, children learn best in informal, play based ways and the curriculum for the first 4 years of primary schooling also orients towards meaningful teaching and learning (DoE 2011a). But a conceptual schism exists between curriculum statements and their teaching implications on the one hand and popular understandings about what initial literacy teaching in school must prioritise on the other. Grade R, which is simultaneously the last preschool year and /or the first primary school year, is caught at the centre of this conundrum. In this paper, we argue that to address these challenges, major features of how the brain works should be taken into account which are currently ignored in the literature.

1. The non-linear brain

The literature on neuroscience and reading encompasses two contrasting views: a reductionist view which sees the reading process in linear terms, and an integrative view which sees reading as a holistic, meaning based non-linear process. Our contention is that a 21st century perspective on literacy must include evidence about bi-directional (not just uni-directional) messages passing in hierarchical systems.

1.1 Contrasting neuroscience perspectives

Many studies present the brain regions involved in oral language (Friedericki 2017) and written language (Dehaene 2010, Wandell *et al* 2012, Kearns *et al* 2019). Some psychologically or cognitive based books give a brief presentation of the neuroscience, e.g., Deacon (2003), Shaywitz (2003), Wolf (2008), Schnelle (2010), Seidenberg (2017). Others model cognitive processes without giving a link to neuroscience proper, e.g., Tomasello (2003), Willlingham (2017). Many link language to evolution, e.g., Tomasello (2000), Donald (2001), Deacon (1998), Greenspan and Shanker (2004). We note that much of the literature which focuses specifically on neuroscience and reading has grown out of studies related to dyslexia, e.g., Shaywitz (2003). An important question is thus to what extent studies of dyslexia throw light on normal reading processes?[3]. These studies have by definition a deficit view of the reading process built in, which means their recommendations will necessarily be affected by that view[4].

In much of these writings, the link to neuroscience is limited to diagrams of active domains and pathways in the brain when phonemes, words, or non-words are read, or more accurately, decoded, as represented in **Figure 1.** These are supported by functional neuroimaging studies. While this gives useful information about neural pathways associated with reading, one should be aware they are almost never accurate representations of the full functional brain networks operating when a person reads meaningful texts, and hence they only give a very partial picture of what goes on in the brain when such purposeful reading takes place. For this reason, we term this reductionist neuroscience.

However, there has recently been a substantial change in neuroscience perspectives on brain function. Developing from earlier views on how perception works, for example Gombrich (1961), Gregory (1978), and Purves (2010), the recent hierarchical predictive processing view of action and perception espoused by Friston (2003, 2010), Clark (2013, 2016), Hohwy (2013), Seth (2013), Fabry (2017), and many others takes a more integrative view of brain function. Miłkowski *et al* (2018) claim

[3] We use the term 'normal' here to include diverse socio-cultural and linguistic practices and contexts.
[4] It is pertinent to consider how this might affect children's confidence and sense of autonomy when they live in poorly served communities. As they start their formal school learning journey, many are taught by teachers who have been educated to perceive them as lacking in school readiness skills; trusting in a remedial reading (and writing) orientation is added to this.

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that cognitive neuroscience has undergone a silent revolution based in the integration of wide perspectives with the rest of the cognitive neurosciences. This results in a view of the reading process in line with the meaning-based views proposed *inter alia* by Goodman (1967, 1982), Strauss *at al* (2009), Bever (2009, 2013, 2017), and Goodman *et al* (2016). Discussing this integrative neuroscience evidence and its relevance for literacy learning and teaching will be the main theme of this paper.

1.2 **The key features**

Specifically, we suggest that relating neuroscience to literacy should take into account four major features of how the brain works:

- First, perception is an active process based in detection of errors in hierarchical predictions of sensory data and action outcomes. Reading and writing are particular cases.
- Second, emotions play a key role in underlying cognitive functioning. Innate affective systems underlie and shape all brain functioning, including communicating by speech and writing.
- Third, there is not the fundamental difference between listening/speaking and reading/ writing that is often alleged on the basis of evolutionary arguments. They are both social and cultural practices learnt through social processes.
- Fourth, like listening, reading is not a linear bottom-up process. It is rather a non-linear contextually shaped psycho-social process of understanding in a specific context, shaped by current knowledge.

Developing this viewpoint involves taking into account how perception works in general (Gregory 1978, Frith 2007, Purves 2010, Kandel 2012) and specifically in terms of listening to language (Bever 2009, Bever and Poeppel 2010, Bever 2013, Bever 2017) and in relation to reading (Flurkey and Xu 2003, Flurkey *et al* 2008, Goodman *et al* 2016). This is enabled by cortico-thalamic circuitry (Allitto and Usrey 2003), see **Figure 2.**

Prediction is a primary way in which the neocortex functions (Hawkins 2005, Kveraga *et al* 2007). Reading, like vision (Frith 2007, Purves 2010) involves prediction in the light of previous experience and the confirmation or adjustments of such predictions in the light of new information (Smith 2004). This is nothing other than the process of hierarchical predictive processing[5] (Friston 2003, 2010, Clark 2013, Hohwy 2013, Seth 2013), which underlies how reading text with meaning actually takes place (Goodman 1967, Smith 2004, Flurkey et al 2008, Strauss at al 2009, Goodman et al 2016). This is indicated by eye-tracking and miscue studies,[6] as well as our ability to read scrambled pieces of text. Genetically determined inbuilt emotional systems functioning via reticular activating systems (**Figure 3)** stimulate and guide all cognition and learning from birth (Panksepp 1998, Panksepp and Biven 2012, Ellis and Solms 2017), and so play a key role in particular in oral and written language learning.

This all takes place in social contexts and constitutes socio-cultural and linguistic practices involving social engagement with role modelled behaviour (Longres 1990). Intentions and meanings of others drive the understanding of implied features and linkages of a text (Donald 2001, Frith 2007, Friston and Frith 2015).

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[5] Much of the literature refers to `predictive coding'. However, we do not limit ourselves to schemes designed to predict continuous variables, like the acoustic properties of a voice. Instead, we mean all forms of predictive processing, including those that deal in categorical variables like phonemes, words, and sentences, so will refer in the following to `predictive processing'. We thank Thomas Parr for this comment.

[6] Miscues are "window on the reading process" (Goodman and Burke, 1973). They uncover both the lower and higher level processes readers undertake as they read (decoding phonological and graphic information, as well as predicting. sampling, confirming, and correcting).

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1.3 Pedagogical Significance

The different views about literacy and how it is learnt arose from historical disagreements about how language learning happens and the nature of knowledge (Altwerger *et al* 2007:4). Two contrasting pedagogical perspectives have co-existed and been argued about for more than a century (Huey 1908, Chall 1967, Pearson 2004, Kim 2008, Castles *et al* 2018, Miller 2020). The central issue has come to be how and when comprehension comes about. The two perspectives relate to two models of literacy (Street 1984). One, the 'autonomous model', views literacy as constituting separate sets of skills, to be taught independent of context. The other views literacy as being based in the social practices of communities. In this model, which Street called an `ideological model', there are different forms and uses for literacy in different settings, and the basis for teaching is contextual meaning making. Understandings about teaching young children can be viewed as falling under one or the other of these umbrellas.

Reductionist neuroscience evidence is now widely used to support the perceived imperative for an early focus on structured, decontextualised teaching of skills in a hierarchical trajectory. According to this view, automatic decoding of phonic skills (recognising and sounding out letter-sound relationships) are seen as an essential prior step to comprehension because of how the brain works. This neuroscience understanding, sometimes termed '*The Science of Reading*' (Cervetti *et al* 2020), underlies a 'skills based' model[7] for literacy programmes globally (see **Figure 4**). Integrative neuroscience on the other hand underlies a 'meaning based' model[8] (see **Figure 5**) which enables initial and ongoing meaning construction, with skills taught in context through authentic literacy related experiences. This implies using relevant languages and content[9].

In this article, we argue that many well intentioned teaching programmes follow a skills based model, termed the *Simple View of Reading* (`SVR') (Gough & Tunmer 1986), which has been strengthened by the proposed ' Science of Reading'. In doing so, they may neglect to emphasise and enable crucial elements and experiences children require in the vital early stages of becoming literate, thereby restricting opportunities for good quality learning. This is most likely to affect children growing up in the Global South who live under conditions of poverty and/or who speak indigenous languages (Hoffman 2012, Bua-lit 2018, Bloch and Mbolekwa 2021), as well as those from poor linguistic and cultural 'minority' backgrounds in the North (Hemphill *et al* 2011) (we will return to this issue in **Section 7**). We propose that taking an integrative neuroscience view supports the potential for positive transformative changes in early literacy teaching.

A note on terminology In the educational body of literature on literacy, the term 'reading' has been used far more than `writing'. This reflects how these aspects of literacy tend to be viewed and taught separately. More recently, the term `literacy' is being used as a conscious umbrella term to bring more integrative socio-cultural understandings to bear (Frankel *et al* 2016). In this paper, when referring to published work we tend to use the term 'reading' as the authors often do, while in our own writing we use 'reading and writing' and 'literacy' synonymously, unless we are specifically referring to one of them.

1.3 This article

[7] Fitting in with the autonomous model noted above.
[8] Fitting in with the ideological model noted above.
[9] Although we do not deal directly with multilingualism, multiliteracies, and learning in this paper, we flag this as involving significant pedagogical issues which are impacted on directly by the views of neuroscience which underpin programs for language and literacy teaching for all children.

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To focus the discussion, we refer in particular to three works which encapsulate the reductionist neuroscience view: Dehaene (2010), as it is in many ways the ground work on reading and the brain that many others refer back to**;** Abadzi (2017), who has been immensely influential for development aid literacy programmes via her work at the World Bank and The Global Partnership for Education in the Global South (Klaas and Trudell 2010, Piper et al 2016) including South Africa (see for example Spaull & Pretorius 2016:9)**;** and Castles *et al* (2018), as this summarises the SVR and is an up to date review of the "reading wars" between the two positions on literacy and how it should be taught. In what follows, S**ection 2** looks at the brain and the contextual nature of perception, **Section 3** at how cognitive function is crucially shaped by affect (emotions), **Section 4** looks at what is `natural': what are the innate brain systems? **Section 5** considers the similar neural and psychological processes involved in meaning making and communicating by listening/speaking and reading/writing. **Section 6** looks at the resulting neuroscience perspective on learning. **Section 7** looks briefly at educational implications.

2. The brain and the contextual nature of perception

The brain works in a complex, non-linear way. The neocortex is a predictive organ (Hawkins 2005). It is the seat of perception and pattern recognition, memory based in plasticity, and sensation/action based in prediction and choice (Purves *et al* 2008, Gray 2011). Top-down causation takes place in a variety of ways: in relation to perception, attention, and motor control (Ellis 2016, 2018). Speaking and writing (oral and written language) are forms of action modulated by perception.
The key point we wish to raise here is the predictive way all sensory systems work as discussed by Gregory (1978), Frith (2007), Purves (2010), Bever and Poeppel (2010), Bever (2017), Friston (2003, 2010), Hohwy (2013), Clark (2013), Seth (2013), and many others.

The brain understands the world in a holistic way on the basis of the clues offered to it (Purves 2010, Kandel 2016). It has to do this in order to solve Helmholz's inverse problem, namely that we are not provided by our senses with enough data to uniquely determine what the situation 'out there' is. We have to do the best we can with what sensory data is available, even if some is missing (a nice illustration is how the middle column of images on page 140 of Dehaene (2010) effectively enables us to see the object in the right column despite missing data). *Inter alia*, this predictive processing underlies both speech and reading.

2.1 **Perception is an active prediction process**

The basic way that perception works is the same in all cases, as discussed in the case of vision by Frith (2007) and Purves (2010), in the case of speech by Bever (2013, 2017), and in the case of reading by Bever (2009) and Goodman *et al* (2016). They all proceed in the same contextual way because they are all based in the same cognitive mechanism, applied in different domains. All perception works by in advance predicting what ought to be perceived, and then adjusting the predictions on the basis of incoming data (Bever and Poeppel 2010, Yon 2019). This is stated by Clark (2013) as follows:

> *"Brains, it has recently been argued, are essentially prediction machines. They are bundles of cells that support perception and action by constantly attempting to match incoming sensory inputs with top-down expectations or predictions. This is achieved using a hierarchical generative model that aims to minimize prediction error within a bidirectional cascade of cortical processing. Such accounts offer a unifying model of perception and action, illuminate the functional role of attention, and may neatly capture the special contribution of cortical processing to adaptive success".*

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This process is facilitated by the feedback loops of thalamo-cortical circuitry (Alitto and Usrey 2003, Briggs and Usrey 2008, Kveraga et al 2007) shown in **Figure 2**, whereby we use contextual information to facilitate recognition of objects (Fenske *et al* 2006). The well-established Bayesian formulation of this process (Parr *et al* 2018) explains how the probability that what you have predicted is correct is adjusted in the light of sensory perceptions. New data comes in (as it is constantly doing), you update your current hypothesis on the basis of this incoming data through Bayes Rule, a mathematical relation which your mind automatically implements (Clark 2013). This happens subconsciously in such a way that these predictions actively and efficiently facilitate the interpretation of incoming sensory information and directly influence conscious experience (Panichello *et al* 2013).

We often fill in what we think is right (based in previous experience) even if it's not what is actually there. A good non-technical presentation is Yon (2019). Through these processes, vision works in a gestalt or holistic way[10] (Kandel 2012, Kandel 2016), whereby one rapidly sees the whole. As explained by Orbán *et a*l (2008), humans extract chunks from complex visual patterns by generating accurate yet economical representations and not by encoding the full correlational structure of the input. Thus our brains do not have to notice the parts first in order to construct the whole, rather the whole is perceived first and the parts are usually perceived later.

We have all experienced how in a new environment, we often notice the big picture first, the general outline of things before we start taking account of the details. So babies and young children who are still learning what things are also do this. Babies consciously recognizing their mother for the first time take in and respond to the whole face and the eyes, they get to know the other parts gradually later. A toddler first sees a dog or cat in its entirety, they don't have to first identify and learn the parts of the animal before they can assemble them into a whole. A plastic doll with movable parts is not perceived as a doll only once the child has learned it is made up of arms, legs, a head with many strands of hair, and a torso. A real or toy car is understood first as a whole, not by building it up from wheel to windscreen wiper, indeed in general one does not know (or need to know) what all the parts are.

A physical action aspect In many cases, this process involves physical action: the nature of the world is tested by acting on it and seeing if the outcomes are as predicted (Friston *et al* 2017). There is a cycle:

predict → perceive → act → predict (repeat)

where the boundary between the brain and the world can be characterised as a Markov Blanket (Friston 2003, 2010). Parr *et al* (2019) state that the variational perspective of cognition formalizes the notion of perception as hypothesis testing, and treats actions as experiments that are designed partly to gather evidence for or against alternative hypotheses. Thus expectations come from experience (Yon 2019). This is the neural basis of imitation that is a key part of learning (Brass and Hayes 2005).

2.2 Speech and reading are forms of perception

Understanding speech can be regarded as a form of perception - a predictive correction process based on prior knowledge (Sohoglu *et al* 2012). Written language is perceived in this way too. So if a young child has a word pointed out to her and is told that this says `cat' or `giraffe' or `Granny', she will perceive the entire word, just as she perceives an entire toy doll, car, or train. Gestalt imagery is a critical factor in language comprehension (Bell 1991). This can initially happen before a child understands the alphabetic principle. It depends on experience and context, and is why very young

[10] For up-to-date views on gestalt psychology in perception, see Wagemans *et al* (2012), Wagemans *et al* (2012a).

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children are sometimes able to read brand names such as McDonalds or Coca Cola – they are seeking the meaning of the writing they encounter in its context, and are reading the sign as a whole (Harste *et al* 1984).

For competent readers, reading is fundamentally a contextual, holistic process. Sense making of words and sentences occurs: they are generically understood through contextual dependence on meaning, rather than by stringing together the component parts to reach a cumulative point of comprehension. Contextual word recognition occurs. In English and in other languages, it is common for words to have meanings and pronunciations that are contextually dependent such as "wound", "wind": She wound the clock, his wound hurt; wind the clock, the wind is blowing hard, he planned to wind up his opponent. Reading involves filling in implied contextual information on the basis of prior experiences and cultural expectations. This happens both at a local level (Who is "she"? Where is "there"? When did this happen? and so on) and at a more global level (Does mention of an owl imply bad luck or wisdom? What does the phrase "The Holocaust" mean?, etc). This is a key part of understanding when reading (Donald 2001, Castles *et al* 2018**:** Box 1**).**

The brain subconsciously corrects errors and fills in missing words through the predictive processing process. This is the major reason that proofreading a text you have written is so difficult: you literally don't see what is there, you see what ought to be there because that is what your brain expects to see.

Letters can be identified in a top-down way through context (Willingham 2017:59-64). Decoding words 'accurately' with phonics rules (Shaywitz 2003) has extremely limited application in languages with opaque orthographies like English: "It is tough having a thought that sounds off colour", there is often a silent "e" as in "eye", "bye", "were", "queue", "quite", and so on (Strauss 2004, Strauss and Altwerger 2007). Decoding in languages with transparent orthographies is potentially easier to do, their spelling being more regular and predictable. This does not however, detract from the predictive nature of the reading process.

A physical action aspect As mentioned above, in many cases this process involves action. Talking and listening are conjoint processes learnt together by an infant as the sounds he hears and makes move from immature babbles to conventional speech (unless deaf, where a range of other cues lead to signing). Alongside this, writing and reading what is written are conjoint processes of active perception which allows movement from immature attempts to ever better approximations to mature reading and writing (Bissex 1980, Ferreiro and Teberosky 1982, Bloch 1997).

Learning to read and comprehend can happen without learning to write; it is however not possible to learn to write without reading. When learning to read and write in an integrative way, attention is on meaningful texts which are read and written in concert. These processes reinforce and support each other symbiotically.

2.3 The contrast with the orthodox view

The view outlined in Section 2.2 is different from current reading orthodoxy, which as we have said, bases itself in what is claimed as the Science of Reading. This is supported by the understanding of cortical organization of language processing shown in **Figure 1** (Wandel *et al* 2012, Castles *et al* 2018, Kearns *et al* 2019). Originating in the neuroscience work done by Shaywitz (2003) studying the brains of children with literacy learning problems, this view is strongly represented by the writings of Helen Abadzi. She states (Abadzi 2017:4),

> "*To read and make sense of a text, our brains must first link together lines perceived by our eye receptors. The visual areas of the brain register these individual features, and, with practice, they combine them into the letter shapes used in various cultures."*

But she then states as regards mathematics (Abadzi 2017:4),

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> "*…we group and automatize Arabic numerals. Thus, we see the number 2,365,678 not as a mere sequence of numbers but as chunks in a group that gives a sense of magnitude. Similarly we assemble letters and numbers into complex mathematical equations… And how does meaning arise from these grouped shapes? The brain interprets them according to needs in the environment".*

That is correct. She does not however draw the corollary that this is also what happens in reading text. In general, as in the case of mathematics, the cortex chunks the text and interprets it on the basis of environmental context, seeing whole words and phrases rather than strings of letters.
Abadzi (2017:5) makes the following statement, supported by her Figure 1 (Abadzi 2017:6) "*… The neuronal pathways originate from the visual cortex and move forward, linking sounds and subsequently linguistic processes*". This is contradicted by the studies we have mentioned above of how sensory processes work. Contrary to Abadzi's view, prediction and filling in takes place both between cortical layers (Rauss and Pourtois 2013) and via thalamo-cortical pathways (Alitto and Usrey 2003, see **Figure 2**) whereby downward feedback signals affect what one sees and hears. They are omitted from her Figure 1.

The process is not a one-way process from sensory organs to the cortical layers, and it is not a one-way process from incoming sensory data to output. That is a basic misrepresentation of how the brain actually works. Curiously she states in the next paragraph (Abadzi 2017:5) "*The evidence points to a hierarchical, cascaded, interactive model of word recognition, in which top-down feedback consolidates fast feed-forward influences via recurrent processing loops*". Indeed so. This is what underlies the real reading process. This correct statement contradicts her previous one.

Abadzi then goes on to say, "*Thus, reading involves closely timed sequences, where performance at each stage must be optimized to give reliable and timely input to the next. The meaning-related areas are at the end of this path. It is necessary to lift the print off the page before interpreting a text* " (Abadzi 2017:5). In reality (Bever 2009, Bever and Poeppel 2010, Bever 2017) we predict what will be there as we undertake detailed reading of the words on the page - in essence interpretation precedes lifting the print off the page.

Abadzi states later (Abadzi 2017:8) "*Instead, ''comprehension'' is often used to signal inferences or predictions. These require more knowledge than offered in a text*." Precisely so. That is why reading is a contextual process of interpretation, extending to a psycho-linguistic guessing game in the case of complex texts (Goodman 1967, Bever 2009).

2.4 Reading and predictive correction: jumbled words

A famous illustration of this predictive property is on our ability to read jumbled words (Seidenberg 2017:85-99, Rayner *et al* 2006). This is the subject of an informative comment by Matt Davis[11] and the thesis work by Rawlinson (1976). It is significant because it gets to the heart of the predictive reading process. It is summarized by Rawlinson[12] as follows:

> *"My conclusions, and these are open to question of course, were that: Letter features are processed through a route of letter classification/identification. Middle letter identification proceeds largely independently of position. Higher level units seem to be significant only for the beginnings and endings of words. Information from the middle letters may operate via a sampling/probability system (rather than absolute accuracy). That is, you can have sufficient letters, even though in the wrong position, for the brain to `recognise' the word. My end model was of a multiple access system `allowing some direct use of features without precise letter identification, use of word length information, and some structuring of phonemic or syllabic units, as well as incorporating a sampling*

[11] See http://www.mrc-cbu.cam.ac.uk/personal/matt.davis/Cmabrigde/.
[12] See http://www.mrc-cbu.cam.ac.uk/personal/matt.davis/Cmabrigde/rawlinson.html.

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recognition system using letters or their attributes directly.' I suggest the experiments `demonstrate the considerable flexibility of the reading process'. Stimulus sampling theories seem to apply more than simple phonetic theories of word recognition. As regards learning to read, `when the child is beginning to learn to read (s)he already has a highly refined set of skills not only for dealing with the known world but also for selecting and using information from the unknown world'. `Word recognition skills develop which are not only not taught but which develop despite sometimes fairly specific teaching in alternative skills."

This evidence strongly supports the predictive processing understanding of reading.

2.5 The centrality of social context

This predictive process is shaped by social context (Donald 2001, Frith 2003). Friston and Frith (2015) explain that in the case of speaking and listening, communication is centred on inference about the behaviour of others: *" We are trying to infer how our sensations are caused by others, while they are trying to infer our behaviour…. This produces a reciprocal exchange of sensory signals that, formally, induces a generalised synchrony between internal (neuronal) brain states generating predictions in both agents."*

This is what many call "mindreading" (Donald 2001:59-62, Frith 2007:16). Fabry (2017) gives an account of prediction error minimization that is fully consistent with approaches to cognition that emphasize the embodied and interactive properties of cognitive processes. Constant *et al* (2019) gives the predictive processing view of cognition extending beyond skulls. Literacy essentially involves the same issues, and is therefore a social practice (Street 1984).

2.6 The nature of language processing across modes

Farmer *et al* (2013) summarise how the predictive processing view extends to language processing across modes. It applies equally to spoken, written, and sign language, the latter being an important form of language where no phonemes occur. There is no divergence as to how these various language modes are handled by the brain. Berent (2020) summarises as follows: *"Linguistic principles themselves transfer across modalities. An early exposure to sign language helps because some of its rules are relevant to the later acquisition of English. Language is neither speech nor sign, but an abstract algebraic system that can emerge in either system."*

The same applies to spoken and written language. They are all realisations of the same abstract relations (Huybregts *et al* 2016). Similarly, significant aspects of learning to read and write are transferred to learning new languages (Bialystok *et al* 2005).

2.7 An integrative predictive processing view of reading

Strauss *et al* (2009) summarise the predictive processing view of reading as follows:

> *"Whereas the classical neuroanatomic view is most consistent with a bottom-up, information processing model, the emerging view supports an interactive, constructivist model. The cortex either promotes or inhibits the very input being transmitted to it from the eyes, ears, and other sensory receptors. The psychological interpretation of this neuroanatomic arrangement is that the cortex selects evidence to confirm or disconfirm its predictions. It anticipates what will be seen and heard using knowledge stored in memory. Both this new neuroanatomical view and its psychological reflection are consistent with a transactional socio-psycholinguistic model of reading. Drawing on extensive comparisons of expected and observed responses from oral reading miscue studies, this model of reading emphasizes the fundamental importance of effective and efficient prediction and confirmation in the construction of meaning."*

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This view is confirmed by eye movement analysis: the cortex tells the eyes where to look for cues from the signal, lexico-grammatical, and semantic levels of language. It is also supported by miscue studies, where records of what readers actually read aloud often differ from what is in the printed text, but often convey the same essential meaning (this evidence is discussed in **Section 5.7**). Both forms of evidence supports holistic, meaning-construction views of reading and writing, based in the memory-prediction model of brain function.

3. Cognitive function is crucially shaped by affect (emotions)

Emotions play a key role in underlying normal cognitive functioning. Innate affective systems underlie and shape all brain functioning, including communicating by speech and writing.

3.1 The key role played by emotions in normal cognitive functioning

A key factor in all brain function is the emotional systems that underlie motivation in life in general (Panksepp 1998, Damasio 1999, 2000, Panksepp and Biven 2012, Ellis and Solms 2017), and in particular for children in the classroom (Willis 2006). They are also key in language development (Greenspan and Shanker 2004: 210). Railton (2017) states

> *"Recent decades have witnessed a sea change in thinking about emotion, which has gone from being seen as a disruptive force in human thought and action to being seen as an important source of situation- and goal-relevant information and evaluation, continuous with perception and cognition.… The affect and reward system—affective system, for short— is the central locus of the learning processes, evaluative representations, and spatial mapping and simulation essential for the reasons-sensitive action guidance."*

Thus they are key to learning and to education. They are not mentioned by Dehaene (2010), Abadzi (2017), or Castles *et al* (2018).

An important feature is that all memories have an emotional tag, either positive or negative. We do not necessarily consciously acknowledge this, but negative emotional tags are one of the most serious stumbling blocks in education. This is a well-established fact in the case of mathematics education (Carey *et al* 2017). In the case of reading assessments, the Early Grade Reading Assessment (EGRA), has been developed for wide use in the Global South. It is based on the Diagnostic Interpretation of Basic Early Literacy Skills (DIBELS) in the USA, which has been criticized for the emotional upset it causes some young children (Goodman 2006). Once demotivated, it is very difficult for children to succeed. We need to pay much more attention to this as it is a potentially key factor in literacy learning problems.

A crucial distinction exists between the primary (genetically determined) affective systems and associated emotions, and the secondary (socially determined) emotions.

3.2 The primary emotional systems: intrinsic motivation

Innate affective systems (Panksepp 1998, Davis and Montag 2019) are 'hardwired emotional systems' that all babies are born with. They underlie and shape all brain functioning, and result in felt emotions. These are our evolutionary inheritance, genetically determined to be what they are because they were key to our survival in the distant past (Panksepp and Biven 2012, Ellis and Solms 2018). These primary emotional systems function via the ascending reticular activating system: diffuse projections to the neocortex from nuclei in the arousal system (roughly: the limbic system) that spread neuromodulators such as dopamine and serotonin to the cortex. A particular example (the SEEKING system) is shown in **Figure 3**.

The primary affective systems both affect immediate behaviour, and underlie brain plasticity by shaping neural connections because they form the "value system" for Gerald Edelman's Neural

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Darwinism (Edelman 1987, Ellis and Toronchuk 2005) whereby neural network weights are affected by experience. Panksepp (1998) lists seven such primary emotional systems; Ellis and Toronchuk (2013) suggest a further two, agreeing with claims by Stevens and Price (2015). We will now briefly review those that are most important for learning.

A) The search for meaning A core feature of psychology is the search for meaning (Frankl 1985). This drive is associated with the "SEEKING" system (Panksepp 1998) which is the primary hardwired emotional system all babies are born with. It is a prime motivator for all they do: exploring the world around and trying to understand it so that it becomes predictable (which is what the Predictive Processing model is about).

In particular they want to understand the meaning of what their primary caregiver does. The SEEKING system (**Figure 3**) and the search for meaning play a key role in all cognitive learning, and in particular with learning to speak, because our brains are wired to search for meaning and intention (Frith 2007), and it is language that enables the joint construction of meaning (Evans 2015). This leads us to question what happens to young children's impetus to learn when, on entering formal education, they are expected to set aside their expectation (since birth) that meaning leads learning, and replace this with working out how to give the teacher what she asks for, irrespective of the sense it makes to them. Children learning in a language they do not understand well or at all experience a massive impediment in terms of meaning construction, leading many to work out that the school cultural expectation of them is to recognise and act on the reality that understanding is of secondary significance to repeating and regurgitating.

B) The need for community and belonging The second core primordial emotional need is that of belonging to a community (Stevens and Price 2015) because we have a social brain (Dunbar 1998). In the case of babies and young children, this is what Panksepp labels the PANIC/DISTRESS system, which is to do with the strong need to be in the supportive presence of the primary caregiver, and distress when this support is removed (Panksepp 1998). In the broad context of society, it should more properly be labelled the BELONGING/AFFILIATION system, which includes both mother/child bonding and the deep need to belong to social groups (Ellis and Toronchuk 2013).

This interaction leads to the emergence of spoken language between mother and child. The importance for language development of the emotional need to interact intensely with the primary caregiver is explained clearly in *The First Idea* (Greenspan and Shanker 2004). Such intense interaction provides great richness of stimulus of language use in meaningful contexts, contrary to Chomsky's claims of lack of sufficient stimulus to enable language learning. The key contextual feature in early childhood, shaping this all, is the relation to the caregiver/s. This is all compatible with the view of how language works of Tomasello (2003:44,49,283):

> *"The glue that holds this all of these factors together is always the child's attempts to understand the communicative intentions of other persons as she interacts with them socially and linguistically … children learn words most readily in situations in which it is easiest to read the adult's communicative intentions .. usage based linguistics holds that the essence of language is its symbolic dimension, that is, the ways in which human beings use conventional linguistic symbols for purposes of interpersonal communication"*.

The kind of informal learning which is stimulated through this need for community and belonging is determined and shaped by situated cultural practices used and valued in particular environments (Rogoff et al 2016). This suggests a strong case can be made for enabling learning written language in similar ways, as demonstrated in depth in Bissex's *Gnys at Wrk: A Child Learns to Write and Read* (1980) and *Chloe's Story* (Bloch 1997). We return to this in **Section 6**.

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C) The role of play Play is one of the primary emotional systems (Panksepp 1998, Ellis and Toronchuk 2013, Ellis and Solms 2017), leading to rough and tumble play in all mammals, and to various forms of play, including imaginative/ symbolic play, in humans. Play, which evolved tens of millions of years before language,

> *"…offers a way of learning species-typical skills by detaching them from serious mode, testing them in safe circumstances in exuberant fashion so that trial and error can refine them at low risk. Play has been so beneficial in the young of so many species that it has evolved to become self-motivating, irresistible – sheer fun"(*Boyd 2018:9).

It involves children in symbolic thinking, exploring, and discovering alternative options and their outcomes, and hence leads to creative thinking and understanding (Bruce 1991). Behaving symbolically (Deacon 2003) underpins literacy learning, a 2nd order symbolic system (Vygotsky 1978). Imaginative/symbolic play arising from the PLAY system has fundamental and ongoing relevance from babyhood onwards.

Facilitating and mediating child exploration and discovery of written language through play and story which they connect to their current concerns and interests is highly motivating (Cooper 2009, Roskos *et a*l 2003, Roskos and Christie 2011). Young children learn best when their motivation is inspired and supported by encouraging ongoing intrinsically motivated learning based in exploration and play (Bruce 2015), with the incentive to do so based in personal agency.

3.3 The secondary emotions: extrinsic motivation

Secondary (social) emotions such as pride and shame are also important in mental life. They are not genetically determined due to evolutionary processes, as the primary emotions are. They are socially determined as a result of social processes and play an important role in shaping socio-cultural interactions. They piggyback off the BELONGING/AFFILIATION system which underlies socialization.

Extrinsic rewards tend to be used very early in school through marks, stars, competitions, prizes, and so on. The emotional outcome can be both positive (praise, high marks) and negative (tests failed, low marks). Affirmation is indeed a strong motivator that leads to positive behavioural outcomes, but the punitive aspects can have either positive or negative behavioural outcomes: they may result in greater effort, but they may also result in humiliation, anger, despair, and demotivation.

3.4 Emotion, stories, literacy and context

Language processing involves salience and attention in accord with the predictive processing paradigm (Zarcone *et* al 2016). Reading and writing in authentic contexts involves conveying and negotiating meaning, facts, stories, and emotions between authors and readers.

Children's attention and imaginations are activated when immersed in formal or informal contexts in the stories of their families and communities, or in imaginative adventure stories. A powerful example is the *Harry Potter* series of books which transformed the reading experiences of millions of children, and indeed motivated many to read.

Play is described as story in action by Paley (1990). This underlies the significance of stories for learning in both spoken and written language. As storytelling animals we make sense of our lives through stories (Gottschalk 2012): it is a powerful form of meaning making and social sharing. This is why we are compelled to share our stories, factual and fictitious, with one another. This encourages significant connection to children's home funds of knowledge and identity (Moll *et al* 1992, Esteban-Guitart and Moll 2013). Prediction, emotion, and the embodied mind are fruitfully entangled together in these contexts (Miller and Clark 2018).

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4. What is natural: brain plasticity and innate brain systems

The claim is made by many involved in literacy education that it is an evolutionary fact that oral language, i.e. listening and speaking, represents the only 'natural language', acquired in social contexts without teaching (Shaywitz 2003). Written language, i.e. writing and reading, is understood to be a cultural and artificial invention needing specifically structured teaching, with components initially simplified and taught separately (Wolf 2008, Spaull and Pretorius 2019:5). This stance is captured in the following statement:

> *" Reading is not a natural part of human development. Unlike spoken language reading does not follow from observation and imitation of other people"* (Willis 2008:2)[13].

By contrast, we claim that both oral and written language are equally 'natural' (Goodman and Goodman 2013)**.** Both are social constructs, developed in evolutionary terms as successive modes of symbolic communication, the latter piggybacking on the former. They can both be learnt by essentially the same social processes (**Section 6**), with the symbolism of thought realised in different ways (oral and written); and the same is true for sign language and Braille.

4.1 Naturalness of oral and written language: an innate language system?

Shaywitz (2003:45; 49-50) states, "*Reading is more difficult than speaking*.[14]*… Spoken language is innate. It is instinctive. Language does not have to be taught. All that is necessary is for humans to be exposed to their mother tongue. Although both speaking and reading rely on the same particle, the phoneme, there is a fundamental difference: speaking is natural and reading is not. Herein lies the difficulty. Reading is an acquired act, an invention of man that must be learned at a conscious level. And it is the very naturalness of speaking that makes reading so hard.".*

She justifies her views of the difference between reading and writing as follows (Shaywitz 2003:50*):*

> *"Profound differences distinguish reading from speaking … Reading is not built into our brains. There is no reading module wired into the human brain. In order for children to read, man has to take advantage of what nature has provided: a biological module for language*".

That is, she is claiming the key to the difference between oral and written language is innate properties and how they underlie brain development.

She is relying on Chomsky's idea (Chomsky 1965, 1975) of an innate language module in the brain: a *Language Acquisition Device* (LAD). But there are in fact no innate cortical modules in the brain representing evolutionary-based hard-wired knowledge of any kind; this is not possible for evolutionary, developmental, information theoretic, and physiological reasons (Ellis and Solms 2017). Rather we are provided with brains that are highly plastic and able to adaptively learn through ongoing experience with the physical, ecological, and social environment. We have learning-ready brains. What is preset is the primary emotional systems that guide action (**Section 3**).

But above all, Shaywitz fails to recognize that the process of learning to listen and talk is just as much a learning process as is learning to read and write. The implication of this view is that such 'natural', oral language is acquired effortlessly. We question this. Babies cannot talk when they are born. They learn through a complex, extensive and persistent process involving social interactions, during the first few years of life, as stated by Kuhl (2010:716)

> " *The learning processes that infants employ when learning from exposure to language are complex and multi-modal, but also child's play in that it grows out of infants' heightened*

[13] This remark illustrates the contradictory nub at the heart of this debate: the author holds this foundational view, which leads to the perceived necessity for young children to 'crack the code' in decontextualized ways. Like others who hold authority as experts (e.g. Wolf 2008), she reverts after this to a meaning based understanding and approach.

[14] This is also stated for example by van Rooy and Pretorius (2013).

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> *attention to items and events in the natural world: the faces, actions, and voices of other people*".

And the same is true for written language. Both have to be learned at a conscious level. This is discussed in **Section 6**.

4.2 Language readiness versus a Language Acquisition Device

There is no LAD as envisaged by Chomsky on behavioural grounds. As Evans (2020) states,

> "*Everyone agrees that our species exhibits a clear biological preparedness for language… What is in dispute is the claim that knowledge of language itself – the language software – is something that each human child is born with. .. a 'language organ' … containing a blueprint for all the possible sets of grammar rules in all the world's languages."*

This is what has been called (Pinker 2003) a `language instinct'. The problem is that Chomsky proposed his LAD without taking into account the biological processes whereby the brain comes into being. If you bring biological reality into the picture by considering this, such a LAD cannot exist for developmental, genetic, and evolutionary reasons, as explained in depth in Ellis and Solms (2017).

First, there is no way that the precise details of the billions of neural connections in the neocortex can be guided by developmental processes: the refined detailed nature of the connections make that impossible. Rather the detailed synaptic connections are initially made randomly, and then refined on the basis of experience (Wolpert *et al* 2002). They are not directly genetically determined. Second, there is not a fraction of the genetic information available in the human genome needed to shape such detailed neuronal connections. It contains about 30,000 genes, which are needed to code for the entire body: heart, lungs, liver, digestive system, skeleton, skin, *etc. etc.,* and in particular to set up the large scale brain structure. There simply are not enough genes to determine the detailed cortical structure with billions of connections. In any case only a fraction of those genes are specifically human genes that can conceivably be associated with grammar. Third, setting aside these two critical issues, it is not remotely plausible that the kind of detailed grammatical structures investigated by Chomsky would have been of such a vital importance that they would have resulted in evolutionary selection because they affect survival probabilities so crucially. Selection for an overall language capacity, yes that is critical: but for this kind of detailed grammatical structuring, no way. Because of the predictive processing nature of language perception (Section 2), minor grammatical errors do not harm understanding of the message being conveyed and are not needed for survival. As discussed above, the brain automatically makes the needed corrections.

These considerations are decisive (Ellis and Solms 2017): there is no genetically determined LAD. The real situation is that we possess a language ready brain with a generic symbolic capacity (Deacon 2003) which in suitable social contexts learns to understand both spoken and written language, or sign language in the case of deaf people. Evans (2014, 2020) develops this all in a clear way, emphasizing how as more data is collected, the claims of grammatical universals have weakened over time. There are however two further arguments to consider: Chomsky's Poverty of Stimulus argument, and the issue of where language universals come from.

4.3 The Poverty of Stimulus argument

There are three counters to this claim that there is not sufficient evidence provided to children to be able to learn the grammatical rules of their home language.

First, as pointed out by Lewis and Elman (2001), Chomsky's (1975) poverty of stimulus argument fails to hold once stochastic information is admitted. The properties of language in question is shown by them to be learnable with a statistical learning algorithm. They show that simple recurrent networks are able to provide the correct generalizations from the statistical structure of the data. Furthermore, Pullum and Scholz (2002) detail how the linguistic nativist position is not supported by

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the data. Amodei *et al* (2016) show how statistical learning can be done in practice via an end-to-end deep learning approach. This is in line with the predictive processing view. Friston *et al* (2020) propose that the neuronal correlates of language processing and functional brain architectures should emerge naturally, given the right kind of generative model. Note that learning these statistical patterns is not the same as a learning a set of rigorous grammatical rules as envisaged by Chomsky, which in the end are the source of the alleged problem. Rather one learns statistical associations (Hoey 2005) underlying Systemic Functional Linguistics (Halliday 1993).[15]

Second, is there in fact a poverty of stimulus? We claim there is not in normal situations, where massive stimulus is provided by the main caregivers, as emphasized by Greenspan and Shanker (2004). Rogoff (2003:69) describes human beings as 'biologically cultural' and states,

> *"Whether or not they regard themselves as explicitly teaching young children, caregivers routinely model mature performance during joint endeavours, adjust their interaction and structure children's environments and activities in ways that support local forms of learning"*.

The stimulus which occurs crucially involves the strong emotional link discussed in Section 3, as well as continuous demonstrations of (culturally) conventional or mature speech in action, to which children gradually adjust their immature speech attempts. These are the basis for statistical learning processes. Third, this ability to learn either spoken or written language through such interactions is significantly strengthened when these interactions are laden with affect, as discussed in **Section 3**. This enhances the motivation to transact with and understand the message being conveyed, and hence to grasp the grammatical patterns by which it is conveyed.

4.4 Language universals

Where then do language universals come from? A plausible view is that they are due to essential syntactic limitations that must necessarily apply to any language whatever due to the requirement that it be an adequate symbolic system for representing the world around. They arise due to fundamental semiotic constraints on any symbolic representation of our experiences and environment, as explained in detail by Deacon (2003, pp. 112, 118):

> "*Many of these core language universals reflect semiotic constraints, inherent in the requirements for producing symbolic reference itself… these constraints shape the self-organisation and evolution of communication in a social context. .. combinations of words inherit constraints from the lower order mediating relationships that give words their freedom of mapping. These classes of constraints limit the classes of referentially consistent higher order symbol constructions*"

That is, they arise because language must provide a meaningful representation of the world around us in order to be useful. Tomasello reinforces this view (Tomasello 2003:18).

4.5 In summary

There is not the fundamental difference between listening/speaking and reading/writing that is often claimed on the basis of evolutionary arguments and the alleged existence of a LAD in the brain. They are both social practices driven by the communication imperative of the social brain (Dunbar 1998), learnt through socio-cultural processes. We pursue this further in Section 6.3.

[15] We will not deal with the key issue of alternative views of the nature of linguistics here. They are summarised by Peter Fries in Ellis and Solms (2017), pp.125-133, based on the work of Feldman, Halliday, Hoey, and others.

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5 Making and conveying meaning: Listening and speaking, reading and writing

Language includes listening, speaking, signing, reading, and writing. Although oral language came first in human evolution, as discussed in the previous section, neither of them is 'pre-wired' into the brain. It is not a coincidence, then, that there are important similarities in the way each of them function to make and convey meaning. Both receptive parts of language (listening and reading) are non-linear, neuro-psycho-social processes of understanding, shaped by current knowledge and context.

5.1 Spoken language: Meaning making in context

The first and foremost point about spoken language is

LAN(s): *Through speech, patterned sounds convey information, meaning, and emotion*.

This enables complex communication in socio-cultural contexts, where listening and speaking is a joint socially based interaction involving shared attention, prediction, and modelling other people's minds (Frith 2007).

The basic problem is how we understand a linear stream of symbols representing a hierarchical structure. We have to flatten the hierarchical structure into a linear structure. Thus (Bever 2013) *Sentences are externally serial (i.e., "horizontal"): derivations are internally hierarchical, (i.e., "vertical"). That is, the computational domain of a derivation can embrace entire clauses and sentences, while the immediate processing appears to be one word after another."* We have to learn how to handle this for both spoken and written language, where the issue is the same. In the case of oral language, Bever (2017) states it thus:

> *"A sentence in everyday use combines a stream of sound, with rhythm and pitch variations, with memorized units of meaning, an organizing structure that recombines those meaning units into a transcendental unified meaning that includes informational representations, general connotations, and specific pragmatic implications unique to the conversational context. In other words, each sentence is a miniature opera of nature."*

Ding *et al* (2016) explain that in speech, hierarchical linguistic structures do not have boundaries that are clearly defined by acoustic cues and must therefore be internally and incrementally constructed during comprehension. This is the predictive processing process that underlies listening to speech. Cortical activity at different timescales concurrently tracks the time course of abstract linguistic structures at different hierarchical levels, such as words, phrases, and sentences. This is how the brain handles the problem flagged by Castles *et al* (2018): ``*The segmentation of an acoustic signal does not correspond in any straightforward way with segmentation at the phoneme level: In continuous speech, phonemes overlap and run together".*

From a larger perspective, understanding speech involves a 'psycholinguistic guessing game' such as is characterised by Goodman (1967), Tovey (1976), Flurkey *et al* (2008) in the case of reading (Bever 2009). It usually has a major social component (What does this refer to? Where did that take place? Why are they saying this? Is there a hidden agenda? and so on). The predictive processing underpinnings of this process are explained by Friston and Frith (2015), enabling the process of ``mind-reading'' mentioned earlier: a key social skill leading to a theory of mind (Conte *et al* 2019).

5.2 Written Language: Meaning making in context

The first and foremost point about written language, parallel to **LAN(s)** above (Section 5.1)**,** is

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LAN(w): *Through written text,[16] printed symbols convey information, meaning, and emotion*.

This enables complex oral and written communicative transactions in social contexts (Vygotsky 1978, Rosenblatt 1982) across distance and time.[17] Infants and young children struggle to begin a 'natural' process of learning if they are in a cultural and linguistic context that contains few relevant role models, resources, and materials, with consequent limited purposes for reading and writing which they are not invited to participate in and are not drawn to. They are enabled to begin this process effectively by observing and joining in personally relevant activities involving writing and print in relevant languages, be these in homes, community settings, or school contexts. Thus we suggest that the statement "reading is unnatural" could usefully be replaced by

"*Reading and writing are cultural practices, and culture is natural*. "

This is illustrated by a Polish colleague who tells of his induction into reading as follows: he had a brother who was 4 years older than him, and at that time, school started when children were 7 years old. He was 3 when his brother started to learn to read, sitting in their common room at a small table in the middle of the room. The older brother would be reading the letters and words aloud, running his finger below the line of print. Our colleague would be kneeling on a chair at the other side of the table following his brother's finger. Within a year (by age 4) he had learnt to read fluently - upside down! Only later did he learn to read with the 'normal' orientation. No formal basic skills teaching occurred in this self-motivated, socially contextualised process.

This is one of many cases that demonstrate that it is not absolutely necessary to have formal teaching in order to learn to read. It is well documented that children can learn the fundamentals themselves under appropriate conditions (Clark 1976, Buckingham and Castles 2019). Indeed up to 5% of children are such "precocious readers" (Olson *et al* 2006)**.** We are not claiming here that teaching is not necessary, but that there are various roots of literacy (Goodman 1992) which are taught formally or informally (Rogers 2008), but do not require a rigid order or type of teaching to be learned.

Predictive reading Similarly to when processing spoken language, when reading complex texts there is never enough information in a sentence to fully convey the intended meaning. Thus in order to read or to listen, we use prediction and then comparison with incoming data, as in the case of all other senses, and in agreement with the predictive processing model of the mind. Competent readers do not read by assembling phonemes into words and words into phrases as Shaywitz (2003) claims. They read phrases as a whole in a way that makes sense in terms of context and making meaning overall, predicting what text will come next as they do so (Goodman 1967, Bever 2009).

The three cueing systems Readers predict meaning using the 3 cueing systems (**Figure 6**): semantic, directly involving meaning, grapho-phonic, the look and the sound of the language, and syntactic, its grammatical structure (Goodman 1967, Goodman and Burke 1973). Each are drawn on as needed to understand the text, even when using a language which has transparent orthography, such as Spanish or Xhosa. This is because these systems work together to support the essence of reading. We suggest that when children are taught to rely only on decoding as an initial strategy, and are forced to concentrate on word level accuracy, their drive to make meaning can be interfered with and hindered.

[16] And their extensions to electronic versions. **LAN(w)** should be interpreted in this way, where "printed" includes hand written and electronic versions of the same text.
[17] This is beautifully described by Carl Sagan here: https://www.youtube.com/watch?v=MVu4duLOFGY.

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And for most children in African language settings, this becomes more of a challenge when they have to transfer their initial efforts at reading into an additional language like English with it's opaque orthography, much of which is difficult or impossible to sound out.

A basic problem: seeing the written page In *The Grand Illusion* (Goodman *et al* 2016), the authors comment on how our impression of seeing a whole page of text in front of us when reading is an illusion – a construction of the mind – because in fact our eyes see only a small part of the page clearly, and see nothing at all in the blind spot. Gregory and Cavanagh (2011) describe the latter:

> `` *The natural blind spot occurs where axons passing over the front of the retina converge to form the head of the optic nerve, and where retinal blood vessels enter and exit the eyeball, resulting in a hole in the photoreceptor mosaic … Each eye has a surprisingly large blind region, about 4° of visual angle, the width across your four fingers held at arm's length. …. Surprisingly, we are normally unaware of these natural blind spots. They are either filled in perceptually (a remarkable phenomenon) or they are ignored and so not seen."*

The predictive processing model strongly supports the first option: the brain fills in the missing text, enabled by saccades: the constant movement of the eye focus across the written pages (Dehaene 2010: 13-15, Goodman *et al* 2016). Conversely, this illusion of seeing a complete page when reading provides strong evidence that the predictive processing model of reading text is correct.

5.3 The two routes to reading

There are two neural routes allowing reading: a direct one and an indirect one (Taylor *et al* 2013). This is described by Castles *et al* (2018) as follows (page 17):[18]

> ***"****The fact that word reading involves more than just alphabetic decoding is reflected in all major theories of skilled reading. …. The important point is that all of the models converge in that they represent two key cognitive processes in word reading: one that involves the translation of a word's spelling into its sound and then to meaning, and one that involves gaining access to meaning directly from the spelling, without the requirement to do so via phonology.…. This dual-pathway architecture for deriving meaning from printed words is also apparent in the neural implementation of the reading system".*

The dual pathways[19] are indicated in **Figure 1.** In symbolic form they are,

> **Dorsal (Decoding) Pathway:** {Graphemes} ➔ {Phonemes ➔ {Morphemes},
> **Ventral (Direct) Pathway:** {Graphemes } ➔ {Morphemes}.

Only the second is readily available to people who are deaf.

Note that this is characterized by Castles *et al* as theories of *skilled* reading. It is our contention that the direct path is also possible for emergent readers, and indeed is a powerful 'natural' way that they can learn to read (Gray 2013) under favorable social, linguistic, and cultural conditions. This is what will be developed further in **Section 6**.

[18] See also Rastle *et al* (2001), Buckingham and Castles (2019), Willingham (2017:57, 65).
[19] Note that this is not the same as the dual stream model of speech processing discussed by Hickok and Poeppel (2007), Hickok (2012).

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5.4 Memory Issues

Memory limitations are claimed to justify the need for an essential initial skills focus, to reach automaticity and fluency with letter-sound combinations (most recently, for the South African context, see Ardington *et al* 2020). For example, Abadzi's statement about memory are that,

> *"*[in terms of] *working memory capacity, we are constantly performing in a very narrow timeframe of about 12 seconds. We must recognize letters and other items within a few milliseconds, otherwise we cannot hold the messages they convey in our minds long enough to interpret them or make decisions; by the end of a sentence, we forget the beginning…. Higher-order skills emerge only after the very basic skills are tied to the point of automatic and fluent performance"* (Abadzi 2006: 585). "*Novice readers who make conscious decisions about letters can only read small amounts of text and may have to read a message repeatedly to understand its meaning*" (Abadzi 2006:586).

The problem here arises due to focusing learner's attention on the imperative to attend to combining and memorizing the small details, which appear meaningless. Of course this will overburden working memory. Attending to meaning using the three cueing systems described above orients learners towards reading words, phrases, and sentences holistically. These are stored in working memory as chunks, solving the problem of memory overload. Attending to combining letters into sounds should only be done when necessary in service of this process: *"…a language user engages in the process of seeking meaning through the grammatical structures. He (sic) uses the surface structure, the sequences of sounds and letters, only as signals or means of getting at, or inducing or recreating, the deep structure*" (Goodman 1982:55).

Abadzi's assumption of working memory overload (also see Adams 2001) which is claimed to restrict young learners initial focus (and which is why she claims they have to focus on the letter sounds first) is also challenged by Merlin Donald. He states that the laboratory studies that this assumption is based on look only at the lower limits of conscious experience (Donald 2001: 47). Working memory in real life is much larger than this and supports the remarkable capacity we know young children have for introducing and memorizing new vocabulary and sayings as they learn language in imaginative, meaningful contexts.

5.5 The autonomous, context- free linear model

The reading model proposed *inter alia* by Abadzi (2006) and Castles *et al* (2018) is a skills based, 'bottom up' linear model. According to Castles *et al* (2018)**,**

> *"What does the product of successful orthographic learning look like?... First, according to* Perfetti (1992*), it involves having developed fully specified, rather than partially specified, internal representations. By full specification, Perfetti means that the input code is sufficient to uniquely identify the word to be read, without the necessity for discriminating between several competing partially activated candidates... in these circumstances, the correct word is specified completely by the input code, context does not need to be used to assist in the identification of the word…. … skilled "lexical" retrieval is effectively modular, and is only very minimally influenced by factors other than the input code".*

This says that reading does not proceed along the hierarchical predictive lines that all perception uses, as discussed above: it is a linear decoding process uninfluenced by context. They confirm this view by stating,

> *"Consider once again the example of the word `face'. Successful discrimination of this word from the many other words in English that differ from it by only one letter (e.g., fact, lace, fame) requires the reader to develop a very precise recognition mechanism, one that attends to all of the letters in the word and their order. Otherwise, identification accuracy and access to meaning will be compromised."*

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There is no recognition here that a competent reader does indeed recognise a word by its context, even if the word is mangled (**Section 2.4**). Of these various options, only the word `face' will make sense in many contexts.

This requirement of strict precision contrasts sharply with an understanding where the status of reading as a form of perception is recognised, following the same principles as all other forms of perception: missing data is filled in according to context by a predictive model (Section 2). This also contrasts strongly with what Castles *et al* state later: *"Inferences need to be made beyond what is overtly stated to establish meaning within and between sentences, and need to draw on background knowledge."* Just so. This contextual process assists in word and letter discrimination (Willingham 2017: 60-63). The hierarchical predictive approach, see e.g. Friston *et al* (2017a), is in complete contrast to this linear model. It is enabled by predictive generative processes dependent on context. This is simply not a bottom up linear reading process. Friston *et al* (2017a) state,

> *"The key thing to take from these results is that the agent can have precise beliefs about letters without ever seeing them... it is not necessary to sample all the constituent letters to identify a word. Conversely, there can be uncertainty about particular letters, even though the subject is confident about the word."*

This key fact is opposite to any approach which is based in supposing that getting all the details right first is the core of the reading process. This is not needed for the communication task that is the central purpose of reading (Friston *et al* 2020).

The Simple View of Reading **T**he influential *Simple View of Reading* (SVR) (Gough and Tunmer, 1986) is supported by this linear model. The SVR is summarised by Castles *et al* (2018) thus:

> *"The Simple View of Reading posits that reading comprehension R is the product of two sets of skills, "decoding" D and "linguistic comprehension" C: $R = D \times C$. The logical case for the Simple View is clear and compelling: Decoding and linguistic comprehension are both necessary, and neither is sufficient alone. A child who can decode print but cannot comprehend is not reading; likewise, regardless of the level of linguistic comprehension, reading cannot happen without decoding. ... Early in development, reading comprehension is highly constrained by limitations in decoding. As children get older, the correlation between linguistic and reading comprehension strengthens, reflecting the fact that once a level of Decoding mastery is achieved, reading comprehension is constrained by how well an individual understands spoken language."*

But first, decoding as such is only necessary for one of the two reading pathways (Section 5.3): it does not occur in the Ventral (Direct) Pathway. So it is not in fact necessary in order to read. Second, comprehension early in development is constrained by decoding only if reading is taught by methods centred on decoding, rather than in ways based in meaning (Section 6.3). Third, functional dependence does not imply linearity. Because of the predictive processing way the brain operates, if one accepts a functional relation R = R(D,C), a more plausible relation for the Dorsal (Decoding) Pathway might for example be $R = D \times C^2$. This would be more in line with the ability to successfully read jumbled words. In any case, it is not clear that that capacity can in fact be accounted for by this model.

Decoding First This view is closely associated with the dominant view that decoding must take place first, as stated for example by Patael *et al* (2018): "*The ultimate goal of reading is to understand written text. To accomplish this, children must first master decoding, the ability to translate printed words into sounds.*". But they then carry on, "*Although decoding and reading comprehension are highly interdependent, some children struggle to decode but comprehend well, whereas others with good decoding skills fail to comprehend. The neural basis underlying individual differences in this*

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discrepancy between decoding and comprehension abilities is virtually unknown." Indeed their very careful study show that such a discrepancy is real. We suggest the resolution is that the premise is false: when reading takes place by the ventral pathway, such a discrepancy is to be expected. Decoding does not take place first; the brain acts in a predictive way, as discussed above.

5.6 Neuroscience evidence and reading: reductionist research methods

When considering the neuroscience evidence supporting either of these views, one should be very aware of the strengths and limitations of the evidence provided. Because evidence for skills-based reading models is based on a reductionist view of brain function, it necessarily incorporates the limitations of that view.

More specifically, books like Deheane (2010) have the following limitations. They study parts of the processes involved in reading, but not the integral process of meaningful reading. Thus they can only provide evidence about isolated aspects of the reading process, not how they are integrated to enable the process as a whole. Even then the studies are really limited: Castles *et al* (2018) state "*most of the work on spelling-sound relationships has been conducted with monosyllables; researchers are only just beginning to consider spelling-sound relations in letter strings with more than one syllable*". This is hardly sufficient to determine how meaningful language works. Related to this, there is a lot of data on reading nonsense words and phonemes. This gives no data on the process of reading meaningful text. That aspect is missed by all brain imaging studies which look only at how phonemes or pseudo-words are processed.

An example of such limitations is a study by Cattinelli *et al* (2013), who performed a new meta-analysis based on an optimized hierarchical clustering algorithm which automatically groups activation peaks into clusters. They focussed exclusively on experiments based on single words or pseudowords from the following four classes of tasks: reading, lexical decision, phonological decision and semantic tasks. But you can't do a real semantic task based on single words or pseudo words. This kind of study can only determine isolated parts of the reading process, not the real reading process. It is useful for the former but should not be taken to give information on the latter. It simply does not have the needed data and should not be treated as such.

5.7 Neuroscience evidence and reading: holistic research methods

Goodman and colleagues have done extensive work putting the study of real reading on a scientific basis, as summarised in Flurkey and Xu (2003) and Flurkey *et al* (2008). The latter state,

> ``*The emerging concepts from [current] research clearly indicate that the higher cortical structures control the transmission of information from the deeper structures. This interpretation is contrary to the classical teaching, in which deeper sensory relay stations determine what will eventually reach the cortex. The emerging view has profound implications for psychological models of mental life. Whereas the classical neuroanatomic view is most consistent with a bottom-up, information processing model, the emerging view supports an interactive, constructivist model. The cortex either promotes or inhibits the very input being transmitted to it from the eyes, ears, and other sensory receptors. … the cortex selects evidence to confirm or disconfirm its predictions. It anticipates what will be seen and heard using knowledge stored in memory. Both this new neuroanatomical view and its psychological reflection are consistent with a transactional sociopsycholinguistic model of reading. "*

This is precisely the predictive processing view discussed above.

Evidence is of various kinds. First, *eye tracking studies* Evidence for this view comes from eye movement analysis of fixations, omissions, and backtracking. Since the most conspicuous motor

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behavior in silent reading is eye movement, studying it allows us to "see" the silent reading process (Flurkey *et al* 2008, Seidenberg 2017:62-70). We do not in fact read every word (Goodman *et al* 2016). Second, *miscue analysis* When combined with miscue analysis from oral reading, it is clear that cortical instructions tell the eyes where to look for cues from the signal, lexico-grammatical, and semantic levels of language - the three cueing systems (Flurkey *et al* 2008, Goodman *et al* 2016). Third, g*arbled words and phrases* The way that we can read sentences when words are mis-spelled or missing, or when letters are re-arranged within a word (Section 2.4) is strong evidence of how reading works. Fourth, *letters are sometimes identified in a top-down way,* based on the what the probable word is (Willingham 2017: 60-63). Fifth, *inferring meaning and pronunciation*. We often have to infer in a top-down way what part of speech a word is and what it means through context (e.g. "plane", "flies"). Sometimes the way a word sounds may depend on context (e.g. "wound" has multiple meanings and pronunciations). This is a common feature of many languages, irrespective of orthographical features.

As regards *brain imaging studies*, Flurkey *et al* (2008) comment that the subjects in the various brain imaging studies of reading at the time they wrote had not been given phonological processing tasks embedded in a context that requires meaning construction. Such studies have more recently been done by J S Hutton and co-workers, who have applied MRI studies to better understand the influence on structural and functional brain networks of home reading environments supporting emergent literacy. They are obtaining information on neural processes related to real reading processes,[20] and the skills and attitudes preparing a child for such reading, see Horowitz-Kraus and Hutton (2015), Horowitz-Kraus *et al* (2017), Hutton *et al*. (2015, 2017, 2020).

All this emerging data provides strong evidence for the meaning-construction view of reading. The transactional socio-psycholinguistic character of reading is an instantiation of the non-linear, integrative memory-prediction model of brain function discussed above. Following on Sherman and Guillery (2006), Flurky *et al* (2008) emphasize the role in these processes of thalamo-cortical circuitry, in agreement with Alitto and Usrey (2003).

6 Learning oral and written language

What about the nature of learning to understand and use oral and written language? The similarities between the processes involved in oral speech and written communication suggest that there should be important similarities in the conditions babies require to learn to listen and speak, and young children require as they learn to read and write (Holdaway 1979, Cambourne 1995). Without role models who interact with them and surround them with demonstrations of language being used for various purposes, babies would not have the social context that supports and shapes oral language development (Hof 2006). The same applies to learning to read and write.

6.1 The basic principles

The following can be claimed to be a set of basic principles underlying learning both spoken and written language.

a) Constructing and Conveying Meaning In learning to speak, the foremost thing babies have to learn is that *spoken words convey meaning and emotion and information and stories*[21] (this is **LAN(s)**, Section 5.1). This empowers the drive to understand and to attempt to speak, as they try to make sense of and predict the world around – and the need for communication with a significant other. Similarly, in learning to read and write, the foremost aspect to learn is that *written words*

[20] Friederici (2017), in particular pp.121-141, presents such studies in the case of oral language.
[21] We mean here stories in their broadest sense, incorporating the narrative form.

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convey meaning and emotion and information and stories (this is **LAN(w)**, Section 5.2). This again powers the intrinsic motivation to explore print.

b) Joint social processes Learning to speak and understand and learning to read and write are both joint socially based processes involving attempted efforts and feedback, and with a strong affective component. This means each is as 'natural' as the other (Goodman and Goodman 2013, and Section 4): neither *has to* take place in a formal educational context (Bissex 1985, Taylor 1983, Bloch 1997). The processes are culturally shaped, with carer/teacher expectations themselves being shaped by the adult's own prior experiences and understandings (Heath 1983).

c) Successive approximations Both socially based processes involve successive approximation enabled by the social and educational contexts the child encounters. She learns phonological and phonetic principles; the relationships between sounds and meaning in the case of spoken language, and graphemic and alphabetic principles with written language; writing is based in letters drawn from an alphabet. In each case learning is a process of experimentation and successive approximation, with errors corrected by feedback through demonstrations of conventional forms.

d) Building on existing strengths When they learn to speak, read and write, children draw on all of their learning strengths to move from the known to the unknown (Bruce 2015). This includes their understandings, knowledge, and uses of oral language, its vocabulary, metaphors, and grammar in one or more languages, as they begin to include written language in their communicative repertoire.

6.2 **Learning oral language**

How does learning oral language take place? Castles *et al* (2018) state (Section 1, page 8):

> **LEARN(o):** "If a child is exposed to a rich oral-language environment, that child will almost certainly learn to understand and produce spoken language."

This reflects statements by Shaywitz (see **Section 4.1**). Such an environment involves enormous numbers of everyday verbal interactions, initially with carers, who guide the ongoing reciprocal interaction, experimentation, practice, and play as babbling emerges and, over time with ever better approximations of the accepted speech of the particular community, becomes a form of conventional spoken language. This has three dimensions. The child must learn the motor control involved in speaking: shaping the tongue and lips, controlling breathing, and so on. She must also learn to apply phonological principles which transform sounds into words and sentences. And she must learn how and when to use the grammatical, lexical, and cultural and linguistic conventions to convey the meanings of her speech community.

Shaywitz (2003) and Castles *et al* (2018) claim that oral language does not have to be taught because learning to speak is a natural process. This claim is widely accepted now by policy makers, academics, and language specialists as being based in undisputable scientific evidence. But why is it natural, given the complexity of the task? We suggest that it is because it takes place through the predictive processing kind of interaction emphasized in this article, which is one of trial and error followed by feedback and correction. It involves an informal and superbly effective teaching process because babies have the kind of conditions they require to learn as family members speak constantly and consistently to and around them. Babies want to understand and be able to express themselves too; caregivers and others have high expectations that babies are capable of learning to listen and speak, and talk to them as if they already understand as they try to meet their needs and moods.

As we have intimated, from our viewpoint, the key issue overlooked by many is that *this IS a teaching environment.* It is an *informal* teaching environment (Lave and Wenger 1991, Rogoff *et al* 2016), involving the necessary conditions which support learning (Cambourne 1995). In terms of the

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discussion in the next section, this is a wonderful example of "natural learning" (Holdaway 1979) corresponding to the need to create a meaningful, holistic teaching environment.

6.3 Learning written language

How does learning to use written language happen? It can take place in both formal teaching environments and in informal environments, as in the case of spoken language.

A skills based or a meaning based orientation? This can be either a skills based process, emphasizing the parts first and then building them up to create wholes, as summarised in **Figure 4**, or a holistic, meaning-based process, emphasizing recognition of wholes while also appreciating and attending to the parts which constitute the whole, as summarised in **Figure 5**. In both cases knowing how to use the letters of the alphabet is central.

A reductionist skills based approach insists on getting the details right, first before moving on to use reading and writing for authentic reasons (hence the widely used phrase, 'learn to read, then read to learn'). A holistic meaning centred approach supports learning through successive approximations to conventional reading and writing, rather than insisting that these be rigorously corrected from the outset.

According to Castles *et al* (2018) "*The fundamental insight that graphemes represent phonemes in alphabetic writing systems does not typically come naturally to children. It is something that most children must be taught explicitly, and doing so is important for making further progress in reading."* The key issue here is the phrase "*come naturally to children".* But what is understood as natural depends on cultural context (Rogoff 1990). If you live in a highly literate environment that uses and displays as normal writing in a language you are comfortable using, what comes naturally is quite different than if you do not. And what does "*taught explicitly"* mean? If a mother teaches her child to spell her own name on a sheet of paper, is that explicit teaching?

We would suggest yes. It is not part of an explicit teaching *program*: but it is teaching nonetheless, just as is being taught to say her name in the case of spoken language. It is just as natural in both cases, given appropriate conditions. In other words, to learn to read children have to read and be read to (Smith 2004), while to learn to write, they have to write – and read too - as potential authors, guided by teachers and others who write themselves so that as they begin to write, they come to see themselves as writers (Smith 1983). As we've suggested, learning to decode in languages with regular orthographies can arguably be done more quickly than in more irregular languages such as English, because of the regular phonics patterns, but this principle remains. In parallel to **LEARN(s)** in Section **6.2,** one can claim the following is plausible:

> **LEARN(w):** *If a child is exposed to a rich, contextually relevant written-language environment, which involves regular satisfying reading and writing interactions with significant others, including shared attention to the details of the process, that child is highly likely to learn to understand and produce written language.*

Summary: The similarities between learning spoken and written language

On this basis, our view is that learning spoken and written language are underpinned by very similar processes, as indicated in the box below (Bloch, in Ellis 2016:448):

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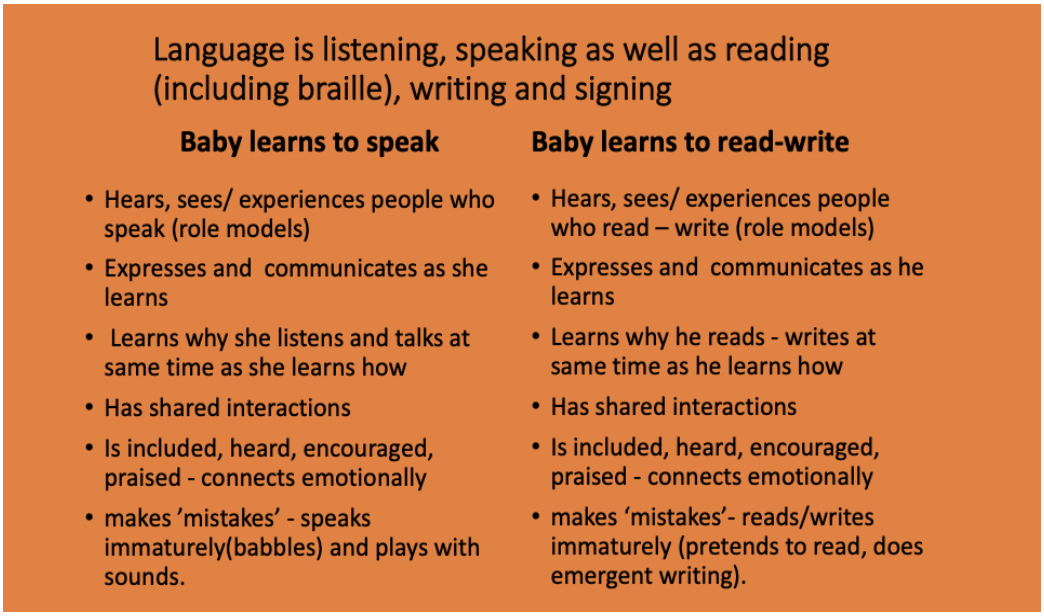

The predictive processing viewpoint, and more generally the way perception functions, can be claimed to support learning both processes here in terms of how the brain works.

6.4 Contexts for learning

As we have explained, because spoken and written language are both learned in socio-cultural contexts, the often existing teaching gulf between them should be unnecessary. Considering the integrative body of neuroscience discussed above, which factors do they suggest would detract from and which support learning to read and write with meaning?

Factors which detract from learning to read and write meaningfully The drive to search for meaning can be minimized, deflected, or hidden when phonics automaticity and fluency must be mastered as an initial imperative. Children learn from such activities the implicit message that reading has little to do with personal interest. This is particularly so for children with little or no access to compelling fiction and non-fiction material in their chosen languages, and no reading and writing role models to interact with. Many children are presented with limited vocabulary books, which have been 'levelled', rather than materials which stimulate curiosity, challenge imaginations, and encourage problem solving. These 'readers' [22] consist primarily of words using the grapheme-phoneme correspondences that children have already been taught (Castles *et al* 2018). This is in spite of the fact that reading widely is agreed to be key to developing a rich vocabulary. Such materials don't necessarily hinder the progress of children who are exposed elsewhere to emotionally satisfying texts which conjure awe and excitement. But children who have to rely on school for such enrichment may wait for so long that they sometimes give up and never get what they need.

Phonics based methods are acknowledged to possibly delay the relation to meaning until automaticity and fluency have been attained. The result is often mind-numbing boredom and in many cases consequent bad behaviour and disinterest. Telling children that this will change once they have learned to read does not necessarily help: the experience of meaninglessness is real. Assessment using non-words (Castles *et al* 2018:19) and meaningless phonemes reinforce the message that reading is not related to anything personally useful or interesting. In the UK it is currently mandatory to teach

[22] A wonderful diatribe against such books is given in the section on Education in *Let us Now Praise Famous Men* by James Agee (Houghton Mifflin 1988): pages 289-307

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and carry out phonics tests (Clark 2020). This can be problematic. Research is revealing quotes such as this from a school principal saying (Clarke 2020, *p. 33)*

> *"Our children who were reading for meaning would try to make sense of the nonsense word on the test and therefore failed the phonics test".*

A real problem is created when this part-to whole emphasis becomes the entire aim of teaching reading and writing. Dehaene makes this explicit when he says (Dehaene 2010:200):

> ``*The child's brain, at this stage, is attempting to match the general shape of the words directly onto meaning, without paying attention to individual letters and their pronunciation – a sham form of reading*."

He defines reading inadequately. He wants the parts to work rather than the whole and characterizes as 'sham' reading that which is both the intention of proficient readers, and the plausibly the way that young children can best learn language. He shuns precisely what children need to do to avoid the memory bottleneck that Abadzi alleges (**Section 5.4**). He also dissuades teachers from encouraging children from making attempts at conventional reading: *''Children need to understand that only the analysis of letters one by one will allow them to discover a word's identity"* (Dehaene 2010:229). This contradicts Friston *et al* (2017a).

Dehaene's authoritative advice to educators (p. 230), where everything is planned to the last graphene, is a recipe for rigidity. He makes statements against including illustrations in books (p. 229) or word posters on the wall. This bleak view of early literacy teaching completely ignores the affective dimension of the mind and the impressive linguistic, imaginative and intellectual capabilities of young children.

Factors which support learning to read and write meaningfully Such factors involve holistic teaching methods from preschool onwards which value and encourage authentic, purposeful writing and reading, used and learned simultaneously. These should include play, imaginative thinking, and extending the use of stories across the curriculum in multimodal explorations.

Teachers can be oriented towards teaching phonics and other skills as and when needed by children as they use print (**Figure 5**). Regular, interactive experiences with worthwhile[23] texts should begins early and continue to be supported and valued in the interests of deepening children's engagement and motivation to read and write throughout the primary school. Castles *et al* (2018) states,

> *"The single most effective pathway to fluent word reading is print experience: Children need to see as many words as possible, as frequently as possible … statistics point to the huge value of fostering a love of reading in children and a motivation to read independently.*"

We agree, but suggest that an assumption in this statement be made visible: this requires the presence of a well-informed, interactive role model who reads aloud well and frequently to children, enabling thinking and conversations about the substance of the books.

This cannot be taken for granted. We thus add that this love of reading and motivation to read independently should be stressed as a highly desirable characteristic to be encouraged as a priority for all early literacy teachers. Similarly, teachers have to know that one of their ongoing tasks is to draw children's attention to the detailed features and conventions of written language, and how to do this effectively. This can happen in the context of writing and reading daily - with and for children – thereby creating authentic opportunities for children to put their growing knowledge and skills to use.

[23] We use the term 'worthwhile' to suggest the benefits of teachers and teacher educators engaging in an ongoing investigation of available and desirable books, with discussion about what 'worthwhile' means in diverse cultural contexts. It points to the extraordinarily important role adults have in curating the texts children encounter, and also to the consequent learning from and about children who explore the books.

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This encourages adult and child agency as writers and readers and provides the chance for teachers to show their respect and interest in these composing and communicative attempts.

Teachers, families and children need access to compelling, varied, and relevant reading material. Castles *et al* (2018) state **"***Children will value the activity of reading more if they have opportunities to read texts that they are interested in, that their friends are reading, or that are of some practical use to them".* Indeed. This speaks to the relevance of publishing original and translated children's literature in indigenous languages (Bloch 2018:166); also prioritising ways to illuminate and develop teachers and children's opportunities to explore literature and respond to the substance of stories so that this becomes a highly valued aspect of literacy learning. There is a need for comfortable and comforting places for reading and writing with children, in the spaces they occupy and spend time. One of us (CB) co-initiated a 'reading for enjoyment campaign'[24] in South Africa (Bloch 2015) which included mentoring community literacy activists, materials development, an advocacy process and community-based and after school reading clubs. With millions of stories developed and shared in a bilingual newspaper supplement, the entire campaign works to support a love of reading between adults and children and deepening and stimulating reading and writing cultural practices.

6.7 In summary

Ellis and Solms (2018) summarise as follows:

> *"How then is spoken language learned? Through ongoing experience of the use of language in meaningful contexts* (Tomasello 2003), *developing an Embodied Construction Grammar* (Feldman 2008), *particularly via mother-child bonding and the child's search for meaning in this developing relationship* (Greenspan and Shanker 2004). *This then continues to the understanding of written language in a meaningful context as well, as is described in Chloe's Story* (Bloch 1997). *In linguistic terms, language emerges through collocations, colligations, and lexical priming, based in functional webs as characterised by* Pulvermüller (2002, pp. 82-87), *with grammar an outcome of lexical structure* (Hoey 2005), *as a word-object association matrix based in a neural network can provide syntax almost for free* (Solé 2005). *This is largely compatible with a Functional Linguistic Grammar approach* (Halliday 1977, 2003).

Reading can take place via either of the dual pathways (Taylor *et al* 2013, Castles *et al* 2018, Kearns 2019) discussed in Section 5.3 and shown in **Figure 1**:

Dorsal (decoding) Pathway : {Word spelling} ➔ {Sound} ➔ {Meaning},
Ventral (direct) Pathway: {Word spelling} ➔ {Meaning}.

In our view it is not necessary that in the process of learning to read, one must learn the decoding pathway first before mastering the direct pathway**.** Because *gestalt* perception is possible, one can start with the direct pathway (the whole), coming to incorporate learning how the parts (decoding) work as a natural process as familiarity is gained.

7 Implications of Integrative Neuroscience for early literacy teaching and assessment

Neuroscience understandings have strong implications for early literacy teaching programmes. It is hugely problematic that a restricted, reductionist body of neuroscience evidence has come to be accepted largely uncritically as being the true and unquestioned basis for teaching. We illustrate this

[24] Nal'ibali, see https://www.nalibali.org/.

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by the following confident statement about how reading should be taught in South Africa, which is indicative of many:

> "*Unlike learning to speak, decoding does not come naturally; it is a method that must be taught systematically. It is important to emphasize that reading is produced by the product of vocabulary and decoding: If one has a perfect vocabulary but has not been taught the method of decoding one will not be able to read at all. Letter recognition and phonemic awareness are mastered through systematic teaching and consistent practice. This leads to the next stage of reading acquisition: word recognition. Through practice and appropriate progression from simpler sounds and words to more complex ones, word recognition becomes established leading to the next phase of reading acquisition: fluency. It is only once decoding and word recognition have become fluent, even to the point where it becomes automatic and unconscious, that it is possible to reach the ultimate goal of reading comprehension*"(Taylor et al 2019: 20).

We have explained above why this assumption is highly questionable. It's important to consider what this might mean for young children's learning when such a decontextualised teaching method replaces the play-based, participatory, transformative early language and literacy teaching requirements in the early years before school recommended by the Department of Education (DoE 2015, PIECCE 2020). Moreover the CAPS Curriculum which follows for the Foundation Phase also *"aims to ensure that children acquire and apply knowledge and skills in ways that are meaningful to their own lives"* (DoE 2011a:4). It values "…*encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths*". Proposing an integrated approach (DoE 2011a: 8), indigenous knowledge systems, human rights and social justice are valued (p5).

There is also actually recognition that there should be no abrupt shift: Grade R teachers should be mediators, rather than facilitators:

> *"A mediator makes the most of incidental learning opportunities that arise spontaneously through a range of child-centred activities, such as free-play in the fantasy corner or block construction site, and teacher-directed activities such as a story 'ring' or other 'rings'. Issues relating to language as well as social, emotional and other forms of development such as fine and gross motor present themselves naturally in the routines and activities of a quality Grade R daily schedule"* (DoE 2011a*:20-21).*

All of the above points suggest a holistic, meaning based orientation to literacy teaching, in contrast to Taylor *et al* (2019: 20). But this is interrupted due to the contradictory pedagogical message about teaching reading. It leads teachers to prioritise skills, until these have been mastered by children. This is logical if you believe that without this mastery, a child has no chance of comprehension: your view is that comprehension can only happen as a consequence of it - and, in any case you know you have to test children on these skills. Your initial success at teaching reading depends on you ticking these skills off your 'to do' literacy list.

Yet a close look at **Figure 5**, shows that the common 'either-or' formulation about skills teaching or holistic teaching which characterises debates is unnecessarily divisive. In the meaning based approach, the alphabetic principle, phonemic awareness, phonics, and decoding are always taught intentionally as part of an entire process, in which the main orientation is on the substance of the text, i.e. what it is about, it's meaning.

Indicators A large literature involves indicators for assessing reading progress. We will not take it further here except to make one crucial comment:

> **The key issue of indicators***: Assessment systems of reading progress can only measure the features its indicators are capable of measuring. Evidence-based teaching and assessment of reading should use meaning-based indicators that take the foundational features discussed in this paper into account, including the affective state of the classroom and the social context within which learning takes place.*

The problem is evident from Castles *et al* (2018), see their Myth 1 (Box 2): "*Nonwords are primarily used… to index children's phonics skills independently of their word knowledge*". If testing phonics

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skills is a key assessment method, goal displacement will take place. Teaching will inevitably make passing these tests a main educational goal. A related issue is the current emphasis on speed in reading tests, queried in an important paper by Dowd, and Bartlett (2019). A strong response is given by Abadzi and Centanni (2020) in a paper claiming that fast and effortless reading is indispensable for comprehension. But their paper ignores the predictive processing nature of perception, so is simply not based on current neuroscience.[25] They state "*Innumerable behavioural studies highlight speed as a prerequisite for comprehension*", but none of the three papers they cite to support this contention appear to actually make that claim. Subjecting young children to this kind of stress is at best unnecessary, at worst harmful. Moreover, the millions of adults around the world currently reading competently did not have to go through this in order to learn to read!

It can be argued that none of this might matter much in the mainstream parts of societies in the Global North, where reading and writing promotion and cultural practices and the associated resources are so 'normal' that they render invisible the flow of interactions which nurture the beginnings of literacy in young children. These children have the experiences and contexts within which to situate formal school literacy teachings and assessment. However, it matters a lot in settings where families and teachers live in poor conditions with limited or no access to critical resources and where early literacy teaching and assessment starts with the basic skills model.

In South Africa, like many other countries which were colonized, it is common for teachers (and librarians) to have experienced an education system which minimized or negated the value of reading and writing using their home languages and the educational worth of the African storytelling tradition. With few or no 'charged encounters with books' (Wissman 2019:15) to nurture the growth of reading habits, relatively few can be expected to take on more than an instrumental attitude towards literacy teaching and assessment. Yet if comprehension and progress in real reading rather than phonics skills is the aim (Davis *et al* 2020), then assessment must start and continue with relevant holistic indicators. These might include Concepts of Print (Clay 2000) from the emergent literacy pre-school measures, continue on to Running Records (Clay 2000, 2013), Miscue Analysis (Goodman *et al* 2005), as well as evaluating and tracking motivation to read and write (Conradi et al 2014). These assess at the level of the individual learner. But what assessments are done at the level of broad context? Here, indicators which gauge opportunities to learn and what makes an enabling environment should also be included: for instance, do teachers read and write regularly and meaningfully with children? Which language/s do they use? What do they read and write, and what is the nature of the available reading materials? Is there adequate space, do children have adequate nutrition? Are teachers finding positive ways to connect children's home funds of knowledge and funds of identity to their learning? (Moll *et al* 1992, Esteban-Guitart and Moll 2013). If we do not do this, we assess children unfairly, because we lack evidence about vital print related factors which are integral to literacy learning.

Conclusion

In conclusion, we suggest that a widespread conceptual shift needs to take place in the early stages of literacy teaching at school: from teachers appreciating that making meaning and comprehension is the end of a necessary process of skills teaching that takes place without considering meaning and context, to appreciating that teaching literacy should begin with and continue to focus on children's understanding and meaning making. How can this come about? In the highly print saturated settings of the UK, there is fresh evidence about the importance of ensuring that teachers read for pleasure and are readers in their own right (Cremin et al 2008, Cremin 2020). They need to experience the power

[25] It is therefore ironic that they state in their abstract "Researchers and journals have the ethical obligation to publish studies that reflect contemporary reading research".

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of reading for themselves in order to motivate the children they teach. Integrative neuroscience evidence indicates that meaning is central to cognition. Therefore this is an important way to awaken a desire in teachers to teach children by harnessing the wealth of pleasure, enriched language and other opportunities literature holds for and learning (Krashen 1989, Arizpe and Styles 2016, McQuillan 2019). Additionally, encouraging teachers to pay close attention to children's consistent drive to make meaning has transformative potential to build relationships which are caring and dignified. This orientation re-legitimates and revalues authentic language use and learning through stories (Sugiyama 2017) and symbolic play (Vygotsky 1978, Egan 1989, Stanley 2012, Nicolopoulou *et al* 2015, Bloch and Mbolekwa 2021); this is where young children have power and voice. Teachers can be educated to teach skills as part of and within processes which encourages children's views and participation, igniting curiosity in them and the desire to learn. Apart from being pedagogically sound, this is educational justice. We return to Abadzi (2017) to emphasize the point:

> *"Should instruction focus on reading comprehension early on? Middle-class children often process quickly and have rich vocabulary; so, in high-income countries, literal comprehension may be too simplistic. Instead, ''comprehension'' is often used to signal inferences or predictions. These require more knowledge than offered in a text. Poorer students have more limited vocabulary and expression, and they may lack the academic language to deal with classroom conversations."* (Abadzi: 2017:8).

This begs the question of what role teaching has in this situation. Abadzi continues:

> *"To teach the poor efficiently, we must make learning easiest on their brains. The research suggests that, when time is scarce, reading components could be taught sequentially. The sequence could roughly follow that of the reading stimuli as they go through the brain. Teachers must focus instruction and practice on the early visual processes and speed those up in order to facilitate complex cognition. Middle-class reading instruction, such as the simultaneous teaching of the ''five pillars''[26], may slow down and complicate the acquisition of this quintessentially visual skill. The answer to the twenty-first-century reading crisis may lie in second-century practices, such as decoding, that apparently most human brains could perform"* (Abadzi 2017: 11).

But as we have shown, early visual processes are not the bottleneck. The extreme position taken by Abadzi implies that the brains of poor (African language speaking?) children are different than those of more affluent ones and are unable to deal with complexity. Apart from being insulting, it misleads teachers and learners down imaginative and intellectual cul de sacs.

The body of integrative neuroscience discussed in this paper gives robust support to the view that all young children's brains are capable of handling complexity and learning meaningfully, outside of exceptional cases. All teachers need overt and vigorous systemic support to provide precisely the richness of experience and vocabulary that Abadzi mentions is available for middle class children only. For this to happen, the current reliance on evidence from the 'Science of Reading' needs to be interrogated critically. The neuroscience understandings we emphasize in this paper should be central to this endeavour.

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[26] These 5 pillars were identified by the National Reading Panel (2000) as phonemic awareness, phonics, reading fluency, vocabulary and reading comprehension.

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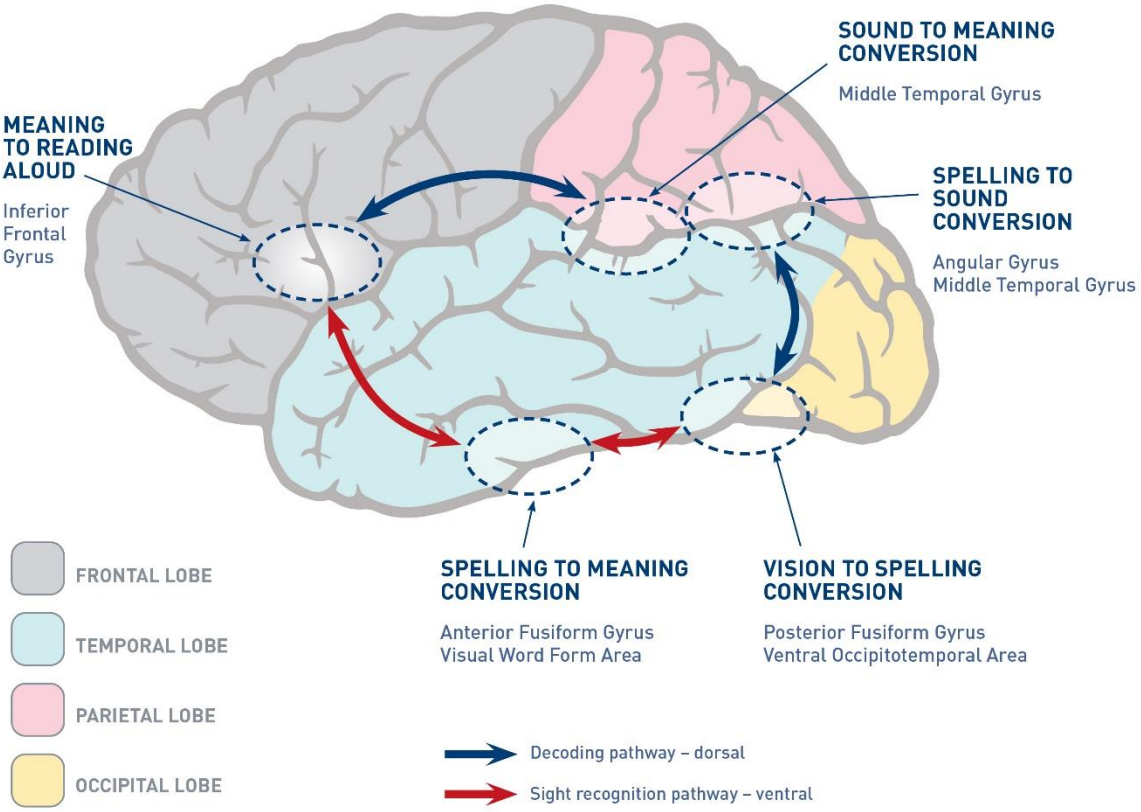

Figure 1: Brain pathways associated with reading. *A dorsal pathway underpins phonologically mediated reading, and a ventral pathway underpins direct access to meaning from print. The Visual Word Form Area (VWFA) is used "as a word letterbox"* (Dehaene 2010*) but is also used for other purposes* (Vogel 2012, 2014, Moore 2014, Martin 2019). *Many further cortical areas will be involved when meaningful reading occurs, for example reading stories with an emotional impact, and the brain engages with that meaning in its social context. Standard neuroimaging studies do not emphasize these further areas because they do not deal with the reading of meaningful texts For analogous diagrams in the case of oral language, see* Friederici (2017:107,109,124,128,135).

Figure adapted from Taylor *et al* (2013), Rastle *et al* (2001), and Kearns *et al* (2019), under the expert guidance of Professor Roland Eastman (former Head of the Neurology Department, University of Cape Town).

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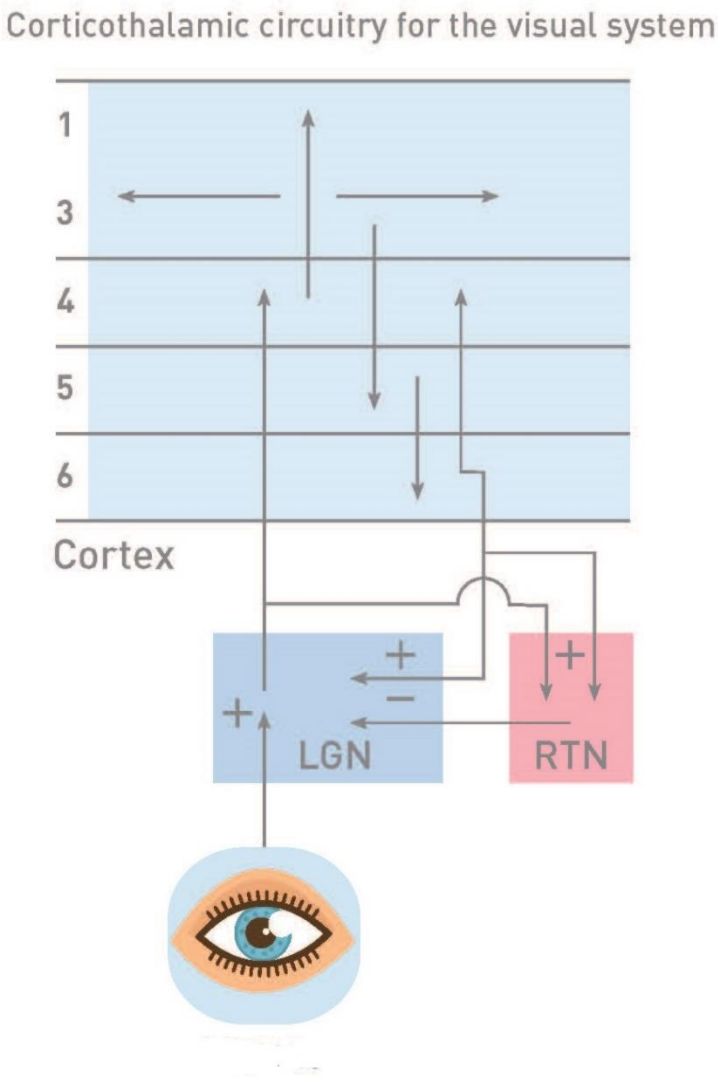

Figure 2. Corticothalamic circuitry for the visual system. *Information flows from the eyes via the optic tract to the Lateral Geniculate Nucleus (LGN) in the thalamus and then via excitatory projections to level L4 in the visual cortex and on to levels L3-L1. Predictive information flows down from L3 to L5 and L6. Neurons in L6 send excitatory feedback to the thalamus and the reticular nucleus (RTN). The feedback axons terminate on relay neurons in thalamic relay nuclei, as do inhibitory projections from the RTN*

Figure adapted from Alitto and Usrey (2003).

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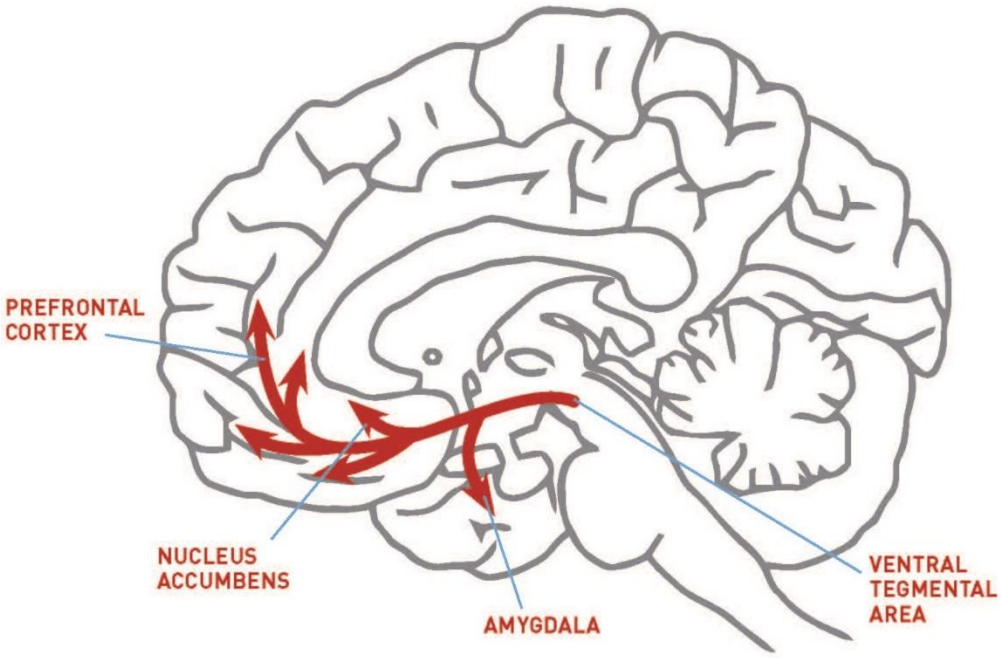

Figure 3 *The SEEKING system is one of the ascending systems that project diffusely to the cortex from nuclei in the excitatory systems, conveying neuromodulators such as dopamine and epinephrine to the neocortex. These reticular activating systems underlie Gerald Edelman's Neural Darwinism* (Edelman 1987) *as well as Panksepp's primary affective systems* (Panksepp 1998.)

Figure source: Mark Solms.

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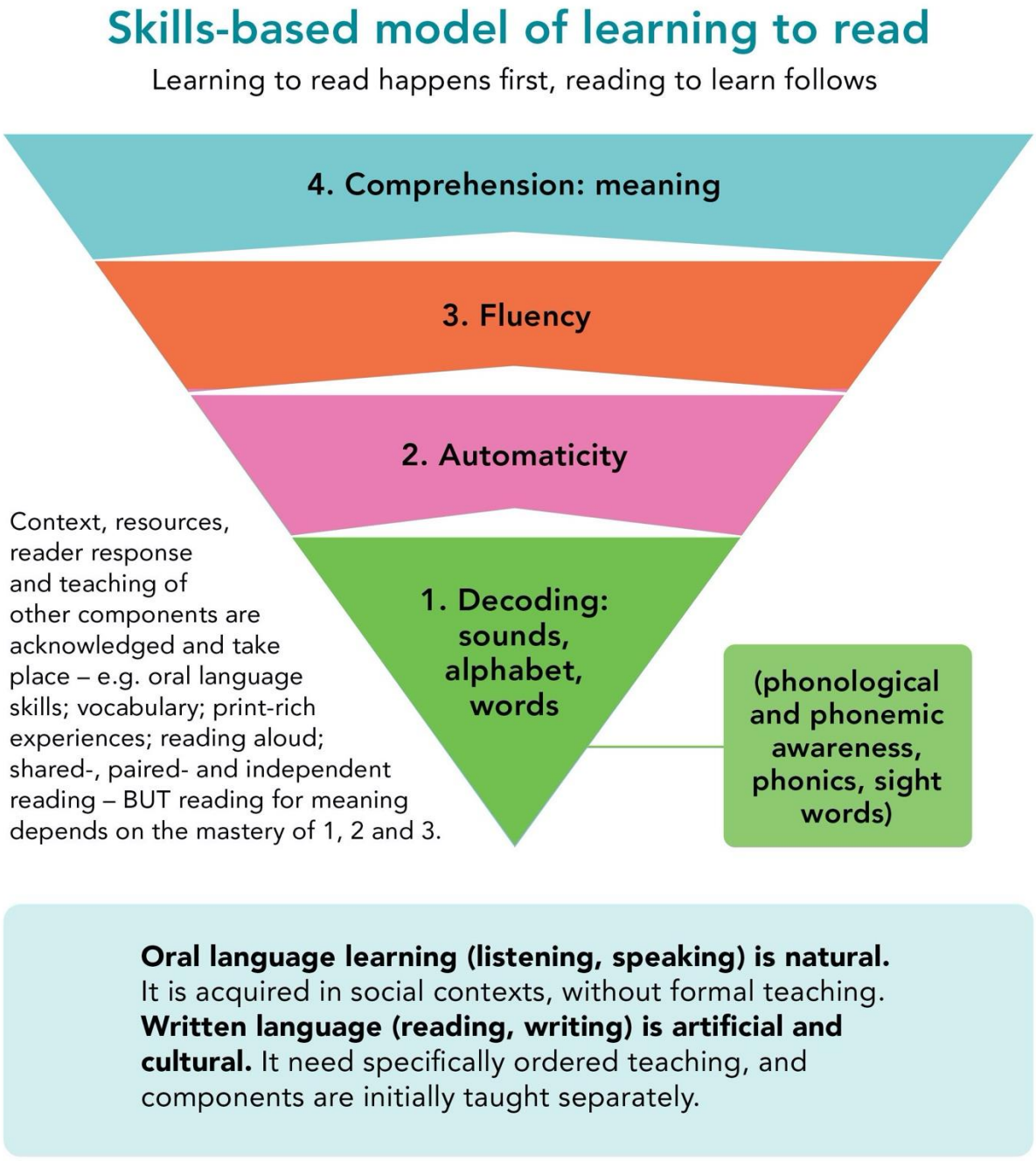

Figure 4: Skills based model of learning to read.

Figure source: Carole Bloch.

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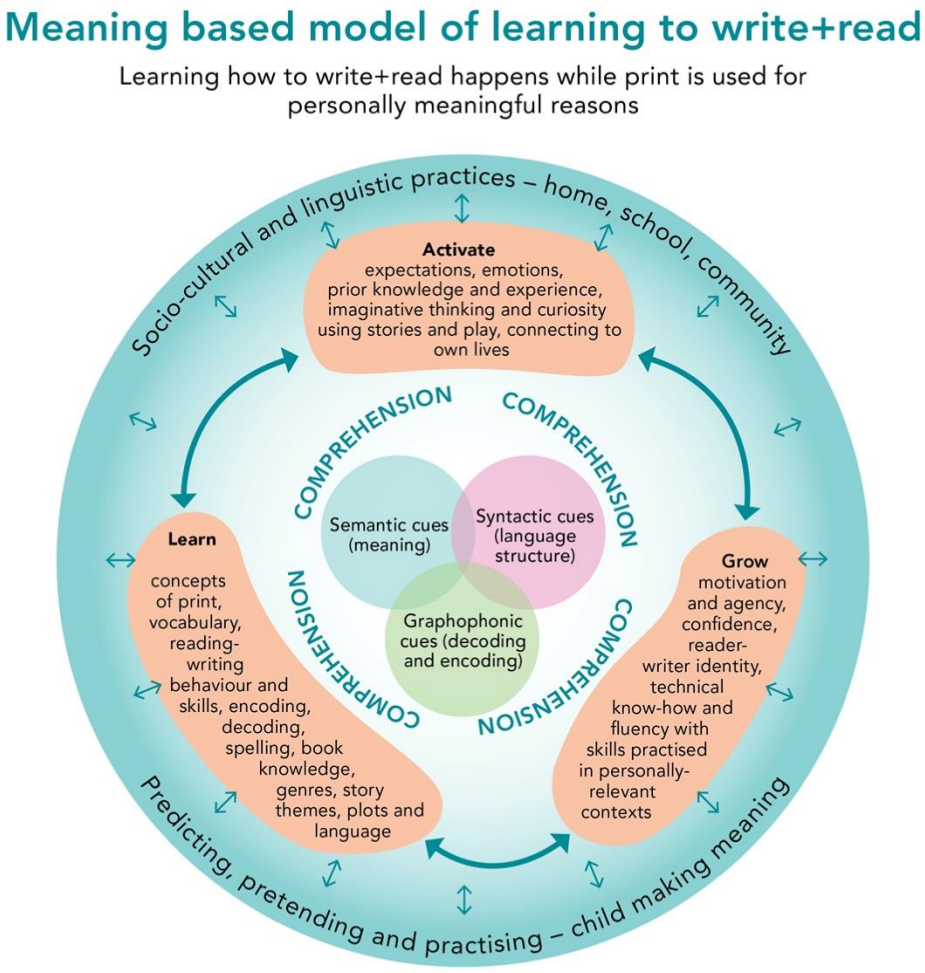

Figure 5: Meaning-based model of learning to jointly read and write
Figure source: Carole Bloch.

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