Comment on "Taking emergence seriously: The centrality of circular causality for dynamic systems approaches to development" by David Witherington.

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In this article, David Witherington examines the Dynamic Systems (DS) approach to the study of development, proposing it as a metatheory for developmental psychology. It's basic mantra is "*emergence through self-organisation*". But underlying this there is a battle between pattern and design. Witherington represents this as a contest between the *Contextualist DS perspective*, where pattern is an epiphenomenon, and exclusive power lies in a bottom-up process of emergence, and an *Organismic-Contextualist DS perspective*, where pattern offers explanation by means of constraint, and circular causality prevails. The first approach is a reductionist anti-structural stance, where causal pattern ultimately reduces to the local processes that engender it, maintain it, and remain independent of it. The second sees global patterning as no less real and explanatorily viable than the lower level elements. This is Witherington's position: "Taking emergence through self-organisation seriously entails taking both the structure of the emergence and the self and organisation of self-organisation seriously… [this] requires a full appreciation of the structure-function cycle that is circular causality." On this view both formal and final causes, each invoking abstraction, are legitimate means of explanation.

We applaud what he is doing in this paper, and agree with most of it, in particular we concur on taking emergence seriously and on the centrality of circular causality. There is no need to say more in this regard, except that this is a significant debate with important conclusions. What we aim to do in this comment is firstly to put the discussion in a wider context of the understanding of top-down causation across all the sciences. This leads to the suggestion that one should use a wider concept of mechanism than is presented in this paper: dynamic systems approaches may not encompass all that is needed. Secondly, as this is a Journal of Human Development, we will discuss some relations to developmental psychology, and in particular how this emergentist perspective has implications for views on the development of oral and written language, and specifically early reading. Witherington's paper itself does

not consider the developmental implications of his approach, but this is where it attains much significance: this is not just a philosophical argument about causation.

Firstly, as regards the wider context of causation in complex systems: taking the existence of bottom-up causation for granted, top-down causation (sometimes categorised as whole-part constraint) underlies the emergence of complexity across the sciences (Clayton and Davies 2008, Ellis 2008). The case of biology is discussed in Campbell (1974), physiology in Nobel (2008), the mind in Murphy et al (2009), and the case of society in Elder-Vass (2010). However top-down causation is not a single kind. Five different classes of top-down causation are identified and characterised in Ellis (2008). They are,

1. Algorithmic top-down causation (TD1);
2. Top-down causation via non-adaptive information control (TD2);
3. Top-down causation via adaptive selection (TD3);
4. Top-down causation via adaptive information control (TD4);
5. Intelligent top-down causation, i.e. the effect of the human mind on the physical world (TD5).

These kinds are significantly different from each other, as we explain below. It is possible there are other kinds, but in any case these certainly all exist and are effective, as can be shown by numerous examples.

Now the question is, is the categorisation of top down causation by means of a DS approach as proposed *inter alia* by Thelen and Smith (1996) and in Witherington's paper, an adequate conceptual framework for use in developmental studies? Specifically, pattern is crucial to the argument, but where does pattern come from? Where does the basis for self-organisation come from? Are dynamic systems sufficient?

The problem is that the concept of "Dynamic Systems", central to this paper, is not in fact defined here. The words seem to be being used in some vague analogical way, however there are a number of closely related but different possible definitions, with crucial distinctions between the different types of dynamic behaviour possible in each case. The mathematical concept of a *dynamical system*, see for example Katok and Hasselblatt (1995), is defined by evolution equations such that the outcome at any

later time is uniquely determined by initial conditions. This equates to TD1, and is not the same as *systems dynamics*, see for example Randers (1980), which includes positive and negative feedback loops with delays, and so equates to TD2. Such cybernetic systems underlie homeostasis and allow the dynamics to be steered by the existence of goals (Wiener 1961); so the outcome is effectively independent of initial conditions. But even the latter is not an adequate dynamical basis for simple cognitive tasks. Both TD1 and TD2 are algorithmically determined and not open to outside influences, and so they cannot be adaptive and hence cannot lead to learning.

It is when one moves to TD3 that random processes enter so that the outcome is not determined either by the initial conditions or by specific goals. Processes of adaptive selection (Gell-Man 1994; a formal description is given by Holland 1992) enable acquisition of new information, and so underlie the emergence of structure, for example through the processes of Darwinian evolution (Kauffmann 1993). This is not possible through processes of the kinds TD1 and TD2. Such adaptivity is the basis for the more complex forms of behaviour characterised by TD4, where goals are adaptively selected, allowing Pavlovian conditioning to occur, and by TD5, allowing symbolic understanding to influence behaviour so that we become a symbolic species (Deacon 1997). This capacity to understand information and symbolism, relating them to meaning, is the key difference between higher animals and inanimate matter (Roederer 2010). Thus adaptive selection opens the possibility of learning and the emergence of novel behaviour, based in neural plasticity that is influenced on an ongoing basis by outside events.

In order to make the move from TD3 to TD4 and TD5, which are higher-level versions of TD3, one must extend the hierarchy from one of physical structure and scale to one of structure and causation, see Figure 1, where higher levels of cause can for example be mental or emotional states, social agreements, or legislative rules (which clearly are all causally effective in the real world). Indeed symbolic systems – such as language and money – have physical effects. Non-physical higher level entities can change the structure of lower level entities in the hierarchy; for example (Miller 2010) loneliness (a non-reducible higher level state) has a direct impact on the immune system (a top-down effect), and hence on health (a resulting bottom up effect). Through these processes, top down influences (such as ethical stances and

social roles) can change behaviour, particularly by shaping individual and common goals, this all being enabled at the lower levels by changing neural connectivity.

It is important to note that adaptive selection does not only take place on evolutionary timescales: it also takes place on developmental and functional timescales. For example evolution impacts development which impacts behaviour, and vice versa, leading to feedback loops between evolution and ecology (Schoener 2010). In particular adaptive processes of learning happen in the mind on an ongoing basis, enabled by brain plasticity which is based in processes of Neural Darwinism (Edelman 1989). Accordingly, adaptive selection is not only the basic way information enters biology through Darwinian evolution on timescales of hundreds of thousands of years and upwards, it is also the way plant and animal development adapts to the specific local environment, and the way that information shapes the mind through ongoing learning processes on scales of minutes to years. Learning leads to rationality that underlies the causal role in the real world of plans and goals, and also develops the values that determine which goals are acceptable and which not (Murphy and Ellis 1996). Changes in these values influences the way that culture changes and shifts.

Without further explanation being given, `Dynamic Systems' in Witherington's paper seems to include only TD1. The idea of autopoeisis, while important in terms of emphasizing reciprocal causal effects between an entity and its environment, is not we think sufficient; the key requirement is some source of variation followed by adaptive selection, and that is not what is normally comprehended by the concepts of dynamic systems. However adaptation is only mentioned in the context of Terrence Deacon's types, and is not thereafter identified as the core feature of developmental processes.

Hence we would propose that in order to gain adequate explanatory depth, one must add to the mantra mentioned above, so that it becomes "*emergence of structure and information through a combination of self-organisation and adaptive selection*". Perhaps this is intended to be included in the idea of "Dynamic Systems"; but then that should be stated very clearly when the concept is introduced. In any event, adopting this revised mantra will in my view strengthen the basic ideas of the paper, by identifying a more powerful general mechanism to underlie what is proposed.

Secondly, we turn to the implications of this understanding for Developmental Psychology, and use reading development as a specific example of how the interaction between top-down and bottom-up approaches seriously impacts the way young children are taught in primary schools.

As always, structure and function are correlated at all levels of biological organisation (Reece et al 2010), so psychological correlates mirror this circular interplay of bottom-up and top-down functioning of the underlying physical systems. A crucial basic activity of the mind is prediction, as emphasized by Jeff Hawkins (2004), based in guessing, experimentation, and feedback from the results, the whole process leading to learning (yes, it is a process of adaptive selection). Consequently higher level expectations and understandings shape the way perceptions function at a lower level. This top down action is illustrated nicely in the case of vision by Purves (2010), who discusses how context shapes sensory perception, as well as our understanding of what is going on: a process of top-down causation from the cortex to the visual system. Everything is different if the shadow in the dark turns out to be a lonely cat rather than a burglar hiding there. This happens in all our senses; the key feature driving this is the search for meaning (Frankel 1984), which is emotionally underpinned by the SEEKING SYSTEM identified by Panksepp (1988).

Now the same processes take place in relation to the development and use of oral and written language, that is, in learning to listen, speak read, and write. In reading, a process of prediction and sampling of text takes place, driven by the search for meaning and anticipation of what is to come. Thus reading is a psycholinguistic guessing game (Goodman 1967). Context drives the detailed understanding and interpretation of the text, and even the way individual words are pronounced, as shown by detailed studies of how children learn to read and write (Bissex, 1980, Bloch 1997) and by miscue analysis and eye movement studies (Goodman 1969, Elbe 2008). This process also happens for example in listening to music (Patel 2008), and in vision (Purves 2010: in each case expectation shapes experience.

This understanding of reading as a linguistic process leads to what is known as the *whole language* or *emergent literacy* approach to teaching reading and writing, advocated by Kenneth Goodman, Steven Krashen, and others, see Goodman (2005) Krashen and Terrell (1983), Hall (1989). The key element in transforming children into readers is helping them realise that the text has the power to convey emotion and meaning; all else – the grammatical and other technical details of how it happens - centres round this meaning-making activity. Thus learning to read is best envisaged as a top-down process of transacting meaning, developed and supported by learning detailed grammatical structures over time through a trial and error procedure that is again a form of adaptive selection. The full process has bottom up and top down elements, but the driver – the process of comprehension – is a creative top-down activity. The same process of predicting, guessing, and making meaning applies to emergent writing, where, in contexts where they experience the power of print, young children move from scribbles to writing (Bloch 1997), just as babies' babbles become talk through a similar process. They learn by participating in holistic events that they join in at the level that they are able to, according to their stage of development.

This contrasts strongly with the widely touted phonics based approach (Adams 1990), where the focus is on the building blocks, to be learnt first, and only assembled to make meaningful sentences once one has mastered the micro rules that are supposed to underlie written language production. But firstly, English does not work this way – it is not a strictly phonemic language (Strauss and Altwerger 2007). Secondly, the mind does not read in this way – it grasps phrases and sentences as wholes, functioning as components of meaningful hypotheses as to one's life situation, and the detailed parts of the structure do not matter greatly at a first approximation. Indeed, in reading one usually only actually reads part of the text, skipping much of it with the mind filling in the details of what is not actually read; which is why background knowledge in the language is so significant and why one can easily read text that is misspelled and understand text that is ungrammatical. One skips and mentally fills in all the time, as can easily be demonstrated by studying how the eye moves as one reads (Elbe 2008). And thirdly, this micro-based approach has the strong potential to destroy the desire of children to read because of the boredom of being forced to endlessly learn seemingly meaningless rules. Driving the process bottom up (the phonics approach) omits the heart of what language is about: namely making

meaning. The associated continual testing, involving repeating meaningless made-up phonemes, persuades children this is a meaningless activity that has nothing to do with anything useful in their lives. This can demotivate them and undermine their wish to attend to literacy lessons at school, particularly if they have not experienced the power of print elsewhere.

So significant is this issue that a struggle between what are in effect bottom-up and top-down processes of teaching language comprehension and production has grown over time into the "language wars" with political dimensions and major sums of money at stake. It has huge implications for millions of children who are and will continue to be subjected to inadequate teaching methods due to an incorrect view of the way the mind works, that neglects the crucial top-down aspects (Strauss 2005). My contention is that the holistic viewpoint put in Witherington's paper supports the holistic approach to literacy of Goodman, Krashen, and others. One should note here that the recent book by Dehaene (2009) claims that neuroimaging studies support phonics based approaches. This is not the case: the brain studies he presents are relevant only to limited aspects of the process of reading and writing, relating only to how the brain handles phonemes; they do not relate to the core function of language, namely creating and conveying meaning, which involves many more areas than are involved in decoding phonemes. The relevant brain imaging studies needed to understand how language is comprehended in a holistic way have, as far as we known, not yet been done. Incidentally, Dehaene's representation of the whole language approach in a diagram in that book is totally misleading: it merely illustrates a 'whole word' teaching method. His presentation simply does not comprehend what the whole language teaching approach is about. Because brain imaging studies have not been conducted on the reading process, they cannot thus show that the phonics approach to teaching reading is superior (Strauss, Goodman and Paulson 2009).

The deep message of this work is that you can't ignore biological issues in developing the implications of this paper for human development. We will just mention briefly two other aspects of this complex interaction of bottom-up and top-down causation with both mental and physical aspects.

Firstly, while there is crucial top-down causation in sensory perception, reading, and writing, there is an equally crucial bottom-up action from the emotional systems which underlie the functioning of the intellect, as made clear for example by Damasio (1995, 2000). The concept of a purely rational life, as advocated by some, is an illusion: this is simply not the way things work (Ellis 2007). Rather, combining Neural Darwinism (Edelman 1989) with Affective Neuroscience (Panksepp 1998), it is plausible that hard-wired primary emotional systems drive secondary emotions and higher cognitive functions through a process of Affective Neural Darwinism (Ellis and Toronchuk 2005). If this is the case, then a key issue is what those primary emotional systems are: for they shape developmental processes. Stevens and Price (2000) make the case that there are two primordial emotional systems that we share with all higher animals, and whose malfunctioning is responsible for most psychiatric problems: namely an affiliation system and a ranking system. The former is certainly crucial in child development, see *The First Idea* by Greenspan and Shanker (2004) for a discussion of how the development of language is driven by mother-child bonding and their intense desire to understand each other. Furthermore the play system is crucial in creative endeavours, and hence is of fundamental importance in education in general and in language development in particular (Christie 1991). Developmental studies should take this kind of issue into account.

The second issue is how this all relates to genes and our evolutionary history. Claims have been made that our genetic heritage has led to hard-wired modules that shape our developmental processes, and that this implies that while spoken language is natural because it is built into our brain through the existence of genetically-determined language modules, the same is not true of reading and writing, which are (in evolutionary terms) unnatural activities and so have to be learned by a process of tedious hard slogging that will eventually pay off some time in the future. This view is put for example by David Geary (2008), who claims that because of this, evolutionary psychology supports the phonics approach to teaching reading. In a response to his article, one of us has argued (Ellis 2008a) that this is not the case: there are no inbuilt language modules, and written language is learnt by the same processes as spoken language.

There is not space to go into this further here: our fundamental point is that, irrespective of what view you may support in this interchange, the viewpoint put in Witherington's paper has important developmental consequences, with major implications in particular for teaching methods. Similar issues arise e.g. in health care and medicine, where one runs into the tension between neurology, psychiatry, cognitive-behavioural therapy, analytical psychology, and psychoanalysis: this also is in effect a clash between bottom-up and top-down views of causation, with very important consequences. So following up the implications of Witherington's paper is a very significant enterprise.

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Level 2	***Atomic Physics***
Level 1	***Particle physics***

Figure 1*: The hierarchy of structure and causation.* *This figure gives a simplified representation of this hierarchy of levels of reality (as characterised by corresponding academic subjects) in living beings .Each lower level underlies what happens at each higher level, in terms of causation. For a more detailed description of this hierarchical structure, see http://www.mth.uct.ac.za/~ellis/cos0.html.*

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