New Views on the Young Brain: offerings from developmental psychology to early childhood education

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ABSTRACT This article presents a broad review of recent developments in perspectives and research on early cognition. An overview of methodologies used to explore infant memory and categorisation is provided, with a discussion of the manner in which studies using these procedures have served to overturn Piagetian viewpoints on infant cognitive competence. In addition, research into the way in which the brain grows and responds to early experience is described, with a consideration of how neural networks are established and shaped by early learning. The general conclusion is that there is now available a range of radically new approaches to understanding the growth of the human brain and mind that is potentially of immense value to early childhood educators.

In the past decade there has been an apparent parting of the ways between developmental psychology and early childhood education. This seems especially regrettable in view of the fact that there have been profoundly important advances in psychological study of children’s earliest cognitive development during this period of separation and many of these changes may well be of immense interest to early childhood educators.

At the heart of the apparent disjunction between developmental psychology and early education have been issues based on attempts to ‘deconstruct’ developmental research in respect to the conceptual assumptions and premises on which it is founded. In particular, there have been objections that research on children’s cognitive development rests on narrow perspectives portraying cognition as an inherent attribute of the individual in isolation from the socio-cultural context, being limited to ‘masculine, and western forms of reasoning’ (Burman, 1994). It is undoubtedly the case that early research was focused on specific aspects or types of children’s cognition and did indeed fail to account for the impact of context and content on cognitive development (Catherwood, 1995). However, care must be taken that in redressing this balance, one set of
limited assumptions is not simply replaced by another that overlooks what is of value in developmental research. For example, it may be equally unsafe to propose that children’s learning necessarily involves or evolves within a social or interpersonal context. It may well be that sometimes children’s learning and cognition is embedded in and given ‘meaning’ by such contexts but sometimes it is motivated and advanced by nothing more nor less than the sheer epistemological challenge of pitting the self against the universe.

Perhaps there is also a need to deconstruct any deconstruction of past developmental research to ensure that old biases are not inadvertently replaced by new ones. For example, it is debatable whether it is appropriate to characterise Piagetian research as reflecting gender inequities by a preoccupation with ‘masculine’ ‘forms of reasoning’ (Burman, 1994), when it is highly contentious whether Piagetian reasoning can be classified along gender lines (e.g. boys typically do better than girls on spatial reasoning tasks but girls often outclass boys on verbal reasoning tasks: Kimura (1992) and Piaget’s tasks may be a complex mixture of both such skills). Indeed one could even claim that Piaget’s predilection for using materials such as clay and beads and his insistence on verbal explanations in children’s responses was biased against boys!

In any case, the field of developmental research has itself already outgrown many of these concerns, moving on to broader conceptions of cognition and providing for the first time clear insights into how the biological apparatus of the human brain and the content and context of human experience are intimately and mutually connected in early development. Many of the old tensions about the relative salience of nature and nurture, biology and culture, self and others have to a large degree evaporated with this new appreciation of the essential unity of brain biology and environmental experience. The present paper offers a brief overview of recent developmental research that has led to this point in our understanding. Firstly however it may be of value to reflect on some general issues about developmental theory and research.

The Evolution of Developmental ‘Theories’:

some general considerations

Psychological perspectives on early cognitive development have undergone a radical change over the last two decades, moving firmly away from a strict ‘stage’ account of the growth of children’s abilities and competence and incorporating the factors of children’s knowledge, interest or learning context in most accounts of early cognition (Catherwood, 1995). It is generally the case that no one theory or model predominates and Piagetian perspectives are now taken to be just one mirror on the multi-faceted world of children’s cognition.

Many of these changes have already been echoed in early childhood practice (e.g. Bredekamp, 1993), but nonetheless early childhood educators seeking a ‘correct’ model of cognitive development may be predisposed to abandon developmental research in its entirety. It is the case that such
research by its very nature will never be likely to settle on one absolute and unchanging model of cognitive development, since such formulations must always be open to amendment or rejection in the face of new data or approaches. However, such research provides the medium for this necessary evolution and as such is still highly relevant in the corresponding development of ideas and perspectives on early education.

However, it may be that educators have begun to reject the entire concept or approach of developmental psychology, especially in regard to the use of so-called ‘quantitative’ or experimental methodology. Developmental research in fact relies on a multitude of approaches. Some are experimental, but this does not necessarily mean invasive or even laboratory-based procedures. It simply means that they involve comparisons or observations of children’s behaviour or abilities under different ‘conditions’. Such conditions can involve intervention by the researcher (which could be as minimally invasive as measuring children’s visual attention during two different story-telling sessions), but this is not necessarily the case (e.g. simply comparing two different age groups constitutes an ‘experimental’ approach). Moreover, experimental studies may or may not involve ‘quantitative’ measures. For example, children’s problem-solving could be investigated experimentally with two different sets of materials (say, pictures vs. verbal items), but the measures used could be either quantitative (e.g. a count of how many problems the child solved with each set of materials) or qualitative (e.g. a narrative report on the child’s questions or responses during the task).

Moreover, apart from the range of such experimental approaches, there is a long tradition in developmental psychology of more naturalistic investigations of early development (using both quantitative and qualitative measures) such as diary studies of early language (which could for example, involve quantitative measures of different types of word categories, or alternately, qualitative narratives of the child’s use of language with other children). In short, developmental psychology offers a wealth of approaches to explore early development and useful understanding has emerged from all of these. It would be unfortunate to limit our scholarship to one method or another without a deeply-considered estimation of the appropriateness of a chosen methodology for the particular question to be researched. Some questions may well require more naturalistic or ‘qualitative’ approaches but others may never be answered satisfactorily without a systematic and experimental form of investigation.

Nonetheless, it would be an unfortunate stereotype to construe experimental approaches as necessarily confining and limiting and more naturalistic approaches as necessarily more rich and informative. It may well prove to be the converse for some questions. For example, early Piagetian research relied on relatively non-experimental approaches, in the sense that little attempt was made to vary the materials, contexts or language used to test children. Piaget’s observations of children’s responses frequently involved particular sets of materials in highly specific contexts (Piaget, 1953). The conclusions drawn about children’s early abilities may have been
entirely valid for those conditions, but can evaporate under different sets of conditions. It is only through careful and systematic variation of the conditions (i.e., a more experimental approach) that a more balanced or general picture of children’s competence may be obtained. The classic ‘Three Mountains’ task (in which children must identify another person’s point of view of models of mountains) is a case in point. Children younger than 5 or 6 experience considerable difficulty in performing this task but on the other hand are capable of performing comparable tasks with more ‘user-friendly’ (familiar) materials and contexts (e.g. Borke, 1975; Donaldson, 1978). In short, experimental approaches may be less likely to lead to limited conclusions, provided that the full potential of such approaches is employed in respect to exploring a wide spectrum of factors that may impact on early learning and development. With this proviso in mind, it may be of interest to early childhood educators to consider the advances in understanding of early cognitive development that have emerged out of experimental innovations in the post-Piagetian era.

**Recent Experimental Developments in the Study of Early Cognition**

There have been several broad developments that have contributed to a major overhaul in understanding and perspectives on early cognition. In general, these have involved the development of new methodologies for studying cognitive responses in infancy, as well as procedures for observing the activity of the brain itself during cognitive activity and growth, along with new computer-assisted models for speculating about the ways in which the brain develops ‘networks’ of information during early learning and thinking.

These new procedures are profoundly important, not because of their wizardry (Burman, 1994), but because they provide a means for addressing questions about human development and in particular about the relative primacy of conceptualisation and verbalisation in cognitive development, that have been virtually intractable since the time of the earliest philosophers.

The first of this repertoire of new approaches is a set of simple yet powerful procedures for exploring cognition in the first year of life, even before the production of language. Through the techniques of *habituation* and *familiarisation*, it has been possible to open a window on the earliest foundations of cognitive processing and abilities and to obtain insights into how such preliminary capacities evolve into more complex forms of cognition with the added ingredient of experience and knowledge (Oates & Sheldon, 1987; Slater & Bremner, 1989). There are many variations of these procedures, but all depend on the simple observation that if infants are repeatedly shown or presented with something, then they will subsequently prefer to fixate or orient to a novel item rather than this familiar one. This tendency is evident from the moment of birth (Slater et al, 1983) and has
been used as the basis of procedures to explore the origins of principal
cognitive capacities such as memory and categorisation.

There have been criticisms of these procedures on the grounds that
they focus on the infant in isolation from the social context of development
or other potentially ‘motivating’ contextual factors (Burman, 1994). This
criticism would be particularly sobering if these procedures had indicated an
absence of infant capacities (as was the case in Piagetian accounts of the
first year of life) since it may well be that infants will only display or
develop certain responses if motivated to do so by circumstances outside the
experimental context (and indeed no researcher can legitimately draw any
conclusions from null results). However, the opposite is in fact generally the
case. Infants have demonstrated such robust cognitive abilities with such
minimal invitation or stimulation to do so, that there has been little need to
explore conditions that might encourage the exercise of these capacities.
This is not to say that the abilities of infants are not influenced, modified
and extended by the social-physical environment (as indeed they must be: see
comments in next section), but in the first instance it has been confirmed
that infants display such abilities under their own steam. This does not
negate the role of the wider context of development but rather simply offers
a baseline for further exploration of how that context interacts with such
early capacities.

In respect to exploring early memory, the procedure involves
habituating or familiarising the infant to the item-to-be-remembered and then
showing this item along with a new one (either at the same time or one after
the other). Even from birth, infants will typically orient more to the novel
item than the familiarised one, indicating that the latter has been
‘recognised’ or processed into memory and is indeed now ‘familiar’ (and
presumably now ‘boring’ or at least less deserving of visual interest than the
new one). The procedure allows for the systematic variation of a whole
range of factors that could conceivably affect this response and many of
these have been explored to date. For example, there is evidence of infant
memory for colour (Catherwood et al, 1987; Teller & Bornstein, 1987) and
shape (Bomba & Siqueland, 1983), including facial patterns (Fagan, 1971)
and for the other senses, the procedure has been modified to give evidence
of tactile memory for texture and shape (Catherwood, 1993; Streri &
Pecheux, 1986) and auditory memory for musical or speech sounds
(Dowling & Harwood, 1986).

The procedure has also been adapted to explore the origins of
categories and concepts. Infants are generally familiarised or habituated to a
set of items from the same category (e.g. a number of different birds) and
then are shown two new items, one from the familiar category and the other
from a new category (e.g. a new bird vs. a cat). Even in the first few months
of life, infants show more interest to new-category items (irrespective of
what they are), suggesting that the process of detecting categorical
similarities among objects (and people) begins very early in life. This basic
procedure has confirmed that in the first three to four months of life, infants
are able to see categorical similarities among different animal groups such as
cats (Eimas & Quinn, 1994) and may even be beginning to detect broader categories such as that of furniture (Behl-Chahda, 1996).

In general then, these experimental methodologies for exploring infant capacities have revolutionised our understanding of the first year or so of life, indicating that Piagetian characterisations of this early period of development vastly underestimate infant cognitive competence. Alongside these developments, there has also been another major outpouring of research involving new methodologies and approaches that have further contributed to this revised picture of early capacities. Major new technologies have been developed that allow observation of the human brain during active processing and cognition and these have begun to be applied to the study of the developing brain in early childhood. Again, it is not the technological feat that is so revolutionary here, but the opportunity for the first time in human history to observe our own brains in action.

Prominent among these methods are versions of:

1. the electro-encephalogram (EEG) which measures overall patterns of activity in areas of the brain;
2. positron emission tomography (PET) which allows the brain’s activity to be mapped in coloured images reflecting the use of energy in certain areas and occasionally;
3. computerised axial tomography (CAT or CT scans) which use minute X-rays to study brain structures; and
4. magnetic resonance images (MRI) of brain structures revealed by echoes from magnetic waves.

All of these have enabled a far richer picture of the human brain and provided invaluable insights into how it grows both before birth and in the first few years of life. Moreover, in addition to these new technologies, there is a growing store of information on brain development in other young animals with strong parallels to our own species. Such comparative research has provided radical new understanding of the way in which the physical components of young brains grow and respond to new learning, giving us a whole new appreciation of this issue. It is always debatable as to the extent to which we can generalise from research with other animals to our own species, but nonetheless such research is a starting point for serious speculation on these issues.

Finally, to complete this exciting new spectrum of approaches, there is the burgeoning area of research and scholarship known as cognitive science – a highly successful blend of psychology, neurophysiology, and computing science focusing on computer programmes that can often replicate human behaviour and development, at times with a remarkable degree of accuracy. Such programmes can even ‘learn’ and change their routines with new input or ‘experience’, producing structured and organised patterns out of random input and so offering a basis for interesting speculation about similar patterns of learning in young children (Bates & Elman, 1993).

Of course, technologies per se cannot be of much use unless we are applying them to the right questions, but collectively all of these new developments have allowed major leaps over the past decade in
understanding how the brain develops as a physical organ in response to learning and experience (Dawson & Fischer, 1994; Johnson, 1993). It would seem of utmost importance to share this new picture with early childhood educators, given that they are in the business of supporting the learning and experience that will bring about such physical changes in the brains of children in early life. The following brief summary of the emerging view of early brain development may serve as an appetiser in this regard.

**The Growing Brain: the physical response to learning and experience**

To gain a full appreciation of this new view about brain development, it may be of value to firstly reflect on some basic information about the human brain. It is essentially a collection of over 100 billion nerve cells (neurons) organised into groups and clusters or networks and pathways. All of our ‘humanity’ is bound up in the activity of these cells: our hopes, dreams, thoughts, feelings, memories, plans, problems, our very personality and sense of identity – all are ‘encoded’ or experienced only through interplay among this vast array of tiny cells. Nerve cells are a little like tiny switches or batteries. The movement of chemicals (mostly the sodium in common salt!) in and out of the cell causes the switch to turn on or off. This simple action is the basis for all of our human experience and capacities: particular combinations or patterns of nerve cell activity provide the means for representing everything we do, feel and think. Of course, even the most elementary aspect of this experience or even the simplest action or ability involves massive numbers of neurons, switching on or off in particular patterns or networks across the brain, but the basic mechanism is always the same.

These patterns or networks may be activated in the first place from the outside world but then may assume a life of their own inside the brain. Sensory stimulation (e.g. light from an object or the sound of a person’s voice) makes its way to the brain by activating chains or pathways of nerves from the senses and these in turn pass on this stimulation by activating many groups of nerves in the brain. Once this has happened, the pattern of activation may make a permanent impression on the brain, becoming part of our memory and learning. When it is reactivated by some cue or trigger, we experience recall or recognition, giving evidence that we have ‘learned’ or are thinking about something.

Many functions involve multiple areas of the brain, working in concert. Your memory of your grandmother for example, may involve multiple groups of neurons in the brain, perhaps those in the sensory areas (coding the sound of her voice or images of her appearance) or those in areas that contribute to our emotions (giving us feelings about her, perhaps of joy or sadness) – all switching on at the same time to give us the summary experience of remembering her as a whole person. A ‘thought’ or memory can therefore be seen as the sum or set of neural pathways and networks that are active at or about the same time. Complex thoughts and ideas probably
require many associations and connections among simpler neural networks. So how does this vast and complex system develop in early life?

The brain appears as early as the third week after conception and develops rapidly, so that by the end of the seventh month of pregnancy, all the neurons of the adult brain (and many to spare) are basically formed and in place (Huttenlocher, 1990; Nowakowski, 1987). However it is not just the neurons themselves that we need to consider. We also need to examine the contacts between neurons (since neurons which do not make contacts with other neurons are not really of any use). Neurons grow branches that spread out and make contact with other neurons. This does not involve actually touching one another, but signals are carried from one neuron to another over a tiny gap or ‘synapse’ on a little wave of chemicals. It is now thought that learning or memory is due to a strengthening of these synaptic links along particular neural pathways, making it easier for the nerve impulse to travel along certain routes (like altering the flow of a river across a field). When does the baby’s brain show signs of developing these synaptic links that are the basis for learning?

Most development of synapses or links between neurons occurs after birth. At the time of birth, the brain of a baby has less than half the number of synapses that are found in the adult brain (the precise number varies across brain areas). However, there is remarkably rapid growth thereafter – especially in the two- to four-month age period, with the result that by about six months of age, a baby’s brain in fact has more synapses than an adult brain (Huttenlocher, 1990). Studies of this course of development (Changeux & Dehaene, 1989; Huttenlocher, 1990) have led to the conclusion that there are two main ways in which the human brain develops or grows as the result of experience or input from the environment.

It seems as if in the first year of life, the brain generates a massive number of neural connections (possibly as the result of interaction between innate genetic programmes and the trigger of environmental stimulation via the senses). However, thereafter, only a selection of these connections are maintained possibly because these belong to the most-used neural pathways or networks. In other words, the brain at first over-produces neural connections and then as the result of experience or learning, subsequently trims them back so that only a smaller percentage of the initial connections actually end up surviving and being used throughout life. Only the synapses which are stabilised or consolidated through usage will be maintained (Changeux & Dehaene, 1989; Huttenlocher, 1990).

It is a little like starting out in a new city. At first you might explore many different routes from work to home, but eventually you will end up only using a favoured or preferred route and will not bother with the alternatives. In this sense, learning involves the favouring of some nerve connections over others, with only the preferred ones surviving. This process of competition among synapses seems to begin around 1 year of age for most brain areas and continues up until about 10 years of age (later for the areas involved in the most abstract aspects of thought). It is believed that this pattern accounts for the apparent ‘critical periods’ found for many aspects of
early development. As long as there are ‘spare’ synapses, the brain can readily take on new learning and recover from injury or damage, but when this extra allowance of ready-made synapses disappears, then learning may be less readily established and recovery from brain injury may be more difficult.

Does this mean then that the brain uses up its learning potential in early life? The answer is no, for two reasons. Firstly, even with the trimming process, there is still a very large number of synapses in the adult brain (of the order of $10^{14}$) and these can be used and re-used in many different networks to produce new learning. For example, a network of neurons representing ‘cat’ and one representing ‘dog’ can contribute to a higher-order network for ‘animals’. So the brain can learn something new by re-patterning or sharing among old networks and indeed much of children’s cognitive development would seem to require precisely this kind of process. However, this is not the whole story and there is still some capacity for ongoing production of completely new connections or synapses right across the lifespan.

Most of the support for this suggestion comes from studies of other animals. Adult animals living in ‘enriched’ learning conditions typically show a greater number of synapses in particular brain areas than animals living in less stimulating conditions (Greenough et al, 1987), suggesting that even if the brain reduces its overall number of synapses with age, learning can continue to forge new synapses even after childhood.

In summary then, stimulation from the environment causes ‘learning’ either by stabilising existing networks in the brain or by forging new ones. These appear to be the fundamental physical mechanisms by which cognitive capacities develop. This new understanding of brain growth provides for the first time an appreciation of how biology and the environmental content and context are inextricably linked in the very tissue of the developing brain. Many of the essential characteristics of children’s learning can be more completely described from this frame of reference. For example, the way in which children’s knowledge or interests intrude on new learning can be described in terms of the degree of resonance or overlap between the neural networks aroused by the new information and those representing older knowledge or current interests. A larger degree of overlap would be more likely to allow new information to be incorporated more readily into the span of the previous networks and hence be ‘learned’ more easily.

One of the directions for developmental research at present is to examine the links between specific aspects of cognitive growth and underlying patterns of neural change in the child’s brain. For example, a number of research projects have considered whether the increase in neural growth and activity in the frontal area of the brain (usually considered to be involved in ‘higher order’ functions such as planning or decision-making) after 6 months or so of age may be tied to apparent advances in infant ability to perform tasks such as the search for hidden objects (Bell & Fox, 1994; Chugani & Phelps, 1986; Diamond, 1994). Such studies are still highly
controversial and subject to ongoing review but represent an attempt to bring about some convergence between the more recent understanding about the growth of the brain and other evidence regarding specific patterns or timetables of early development.

Conclusions for Early Childhood Educators

The aim of this brief passage through recent developmental research on early cognition was to offer a bridge for early childhood educators to a profoundly important body of information and debate on the growth of the human brain during early learning. It may well be that this narrow window on such a large and growing domain of research cannot directly inform or support early childhood teachers in the immediate demands of providing rich and appropriate contexts for early education. Indeed it is necessary to caution that there is a considerable distance yet to be travelled in specifying in any detail the links between general patterns of brain growth and particular aspects of early learning. Even the simplest learning tasks obviously engage vast networks of neurons across diverse brain areas. However it would seem that there are at least some gross parallels between the findings of recent developmental research and the concerns and practices of effective early childhood teachers that are worthy of further consideration.

For example, the research on infant cognition indicates clearly that the infant is able to respond coherently to the sensory world and to retain highly faithful records of experience in that world. It is evident that these findings have implications for the professional care of very young children. It is critical in the design of early care environments both in regard to interpersonal and physical dimensions that the young child be offered a context that supports these early capacities but yet does so in a way that allows their optimal use. It is relatively simple to predict the kinds of sensory stimuli that will elicit the attention of an alert infant – for example, babies prefer symmetrical shapes, saturated colours (blue and red in particular) or strong contrast black and white patterns, facial stimuli, and so on (Haith, 1990). It would thus be reprehensible to install an infant in a nursery area that was devoid of any such features (e.g. with blank white surfaces). However, on the other hand, the opposite extreme of overwhelming the baby to the extent that it was difficult to sustain attention for any prolonged period without distraction from another source, should equally be avoided. It is long-established that moderation is the best choice in offering stimulation to the infant (White & Held, 1966) and if an environment is overwhelming for an adult then it almost certainly will be for an infant. Moreover, the aim should be to provide the baby with an opportunity to direct her/his own sensory exploration of the environment according to individual preference and competence. Finally, and just as importantly, the sensory-cognitive networks in the infant brain (like those in the adult brain) are not wholly separate from the affective, interpersonal or motivational networks and hence a child who is discomforted or insecure emotionally will be unlikely to engage perceptual-cognitive capacities.
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(Ainsworth & Wittig, 1969), so that the care environment must account for the multiple dimensions of early learning.

It is difficult to spell out detailed implications of current research on early cognition for the development of education programmes for older children without stretching the current level of developmental understanding into the realms of fantasy. The aim of the present review was to provide a conceptual bridge or scaffold for early years educators to work from in their own professional appraisals of children’s needs, rather than to offer ill-founded formulae for designing early education strategies or curriculum. Nonetheless, the current body of developmental research has helped to make it clear that by the time the child is three or four years of age, there has already developed an enormously complex and interlinked knowledge base about the world. The tasks for early years educators may thus be seen in the light of facilitating the further articulation and application of that web of understanding. Initially this may involve engaging the child in an effort to gain a more explicit and articulated awareness and control over that knowledge base and subsequently to facilitate links between this knowledge and verbal expression. It is not possible to be more precise without delving into the realms of sheer speculation, but nonetheless in a general sense it can be said that experiences that support the child in making connections amongst domains of knowledge (e.g. as in ‘event-based’ programmes in which children develop activities around conceptual themes) are likely to impact on and enhance the richness of neural networks in the child’s brain.

From this perspective, teaching and learning are an odyssey into the neural architecture of the human brain. Of course, we are a long way off making any such direct mapping of learning activities and neural changes, but the challenge now exists for collaboration among scholars from early education and developmental psychology to at least frame relevant questions about these issues.

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References


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