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LECTURE OBLIGATOIRE N° 6

Processing capacity vs. representational redescription in cognitive development (U. Goswami)

The development of processing capacity in neo-Piagetien theories

The amount of processing capacity that is available to the child has been seen as a particularly important variable in the development of children's cognition. In fact, a number of recent “neo-Piagetian” theories of cognitive development are based on variations of the processing capacity idea.

For example, Pascual-Leone (1970) has argued that processing space increases with age, and that as processing space ("central computing space") increases, so does the cognitive stage of the child. A similar notion has been advanced by Case (1985), whose model includes a trade-off between "short-term storage space" (a retention component) and "operating space" (a processing component). Overall capacity ("executive processing space") is not thought to change with development, but the amount of available capacity is thought to increase as processing becomes more efficient (e.g. via practice) and consequently takes up less "space". A third neo-Piagetian is Halford (1993), who has proposed a developmental model centred on the capacity of “active" or "primary" memory. Halford defines primary memory as the memory system that holds any information that is currently being processed, and he argues that the capacity of this system increases with development. Finally, a somewhat different neo-Piagetian theorist is Fischer (1980), who has proposed that development is best understood in terms of the control and construction of skills. A skill refers to the ability to carry out a set of actions in a particular context.

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The common element central to the neo-Piagetian theories proposed by Pascual-Leone, Case, and Halford is the notion of processing capacity, which is a form of working memory or attentional capacity. These neo-Piagetian theorists suggest that the size of available processing capacity places an upper limit on cognitive performance, and that specifiable biological factors (as yet unknown) regulate the gradual shift in this upper limit with age. Cognitive development is explained by older children having more processing capacity than younger children, and qualitative improvements in cognitive performance are predicted with increasing age. These qualitative improvements generally arise from the use of more sophisticated information-processing strategies, which become available once increased processing capacity is present. For example, Halford (1993) has argued that increases in processing capacity enable children to use relational mappings of greater complexity.

As processing capacity imposes a theoretical ceiling on children's performance in particular kinds of cognitive tasks, children who have yet to attain sufficient levels of processing capacity should be unable to reach given levels of performance in such tasks. This theoretical assumption of an "upper limit" provides the most usual means of testing neo-Piagetian theories (see Case, 1992). However, neo-Piagetian models can also account for large individual differences between children, as they postulate that some developmental restructuring is more local ("domain-specific") in nature than the restructuring that follows an increase in processing capacity. All neo-Piagetian theories also allow a role for the storage components of memory in cognitive development, as they recognise the quality of the knowledge base as an additional factor in explaining individual differences in cognition.

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Representational redescription as a theory of cognitive development

Finally, I will consider a theoretical account of how insight into the contents of one's memory could affect cognitive development. Such an account has been proposed by Karmiloff-Smith (1992), as part of her theory of representational redescription. Karmiloff-Smith's model makes a critical distinction between information being *in* memory and being available as *explicit* information *to* the cognitive system. Her aim is to explain how children's representations become more manipulable and flexible as development proceeds. An important insight is that the *same* behaviour may arise from *different* representations at different points in developmental time, so that the same performance can be generated at different ages by very different representations. Karmiloff- Smith suggests that there are at least three levels at which knowledge is represented and re-represented with development. The levels are called implicit representations, explicit level 1 representations, and explicit level 2 representations. As the child progresses through these three levels, knowledge representation becomes progressively more explicit. Although the process of representational redescription is domain-general, it depends on the level of explicitness of the representations supporting particular domain-specific knowledge at any given time, and therefore will occur in different domains at different times.

The first phase in the representational redescription process is "data-driven" learning. During this phase, the child takes in relevant and salient information from the external environment until consistently successful performance in a given domain is achieved - "behavioural mastery" .Behavioural mastery depends on implicit representations, and, at this level knowledge, is wholly inaccessible to consciousness. It is "in the mind", and therefore entirely “procedural”. Procedures are activated purely as a response to external stimuli, and so children who are operating on the basis of implicit representations show behaviour that is determined by the particular stimuli that are present in a given task (“bottom-up” behaviour). As the child has no way of halting a procedure in mid-flow, once started she has to "run Off" the entire procedure. For example, if the child sets out to draw a picture of a man, she cannot amend her usual “draw-a-man” procedure in order to draw "a man that doesn't exist", even if she had been planning to do so (see Karmiloff-Smith, 1992, for a fuller account of these data).

The second phase of representational redescription is internally driven. Instead of the child's representations depending on external data, the currently available internal representations predominate, and these representations become the focus of change via "system-internal dynamics". These explicit level 1 representations are accessible to other parts of the mind, although the child herself has no explicit awareness of this accessibility. This means that the products of interactions between explicit level 1 representations are not available to conscious awareness. In terms of drawing "a man that doesn't exist", the child may be able to change elements in the procedure, such as body shape or leg size, but cannot introduce re-orderings of the sequential constraints (e.g. by drawing his feet sticking out of his head). This requires a further level of redescription, called explicit level 2 representations.

The third phase of representational redescription depends on the reconciliation of internal representations and external data, so that a balance is achieved. This gives children conscious access to their own knowledge. Explicit level 2 representations are stateable verbally, and can be communicated to others. Level 2 children can “draw a man that doesn't exist" by inserting elements from other conceptual categories, such as giving the man a pair of wings. It is only at this final level of redescription that Karmiloff-Smith credits children with insight into their own conceptual processes. This can be thought of as having metaknowledge about your knowledge ("metacognition").

Karmiloff-Smith suggests that a useful analogy for understanding her theoretical ideas is learning to play the piano (Karmiloff-Smith, 1994). The pathway to becoming an-efficient pianist involves a first phase of learning to play a whole piece automatically via paying conscious attention to particular notes and to chunks of several notes which can be played together as blocks. At this point, the sequence has become a "procedure", analogous to an implicit representation. Knowledge is implicit at this stage as the fledgling pianist cannot start playing in the middle of the piece, and cannot play variations on a theme. Instead, his or her "knowledge" of the piece is embedded in the motor commands and actions sustaining its execution. Representational redescription must now take place, so that knowledge of the different notes and chords can become explicit and available as manipulable data. Eventually the learner will become able to generate variations on a theme, to introduce insertions from other pieces of music, and to play creatively. The end result of representational redescription is representational flexibility and control.

Karmiloff-Smith's theory depends on the idea that knowledge can be stored and accessible at *more than one* level. The key idea is that the human mind recursively re-represents its own internal representations, and that this re-representation is the main process that underlies cognitive development. Furthermore, the redescriptions that occur during development remain in the mind. This results in *multiple* representations of similar knowledge at different levels of detail and explicitness. The notion of multiple encoding means that the child's mind as envisaged by Karmiloff-Smith is a storehouse of knowledge and processes, some of which have become redundant. The idea that humans differ from other species because of their unique ability to "appropriate" their own internal representations - to "know about" their knowledge - is a very appealing one. The capacity to enrich knowledge from within, by redescribing knowledge that is already stored in memory, seems to be a specifically human capacity.

Representational redescription theory differs markedly from the "neo-Piagetian" theories based on processing capacity that were described earlier, as it is not a stage theory of cognitive development. This is because the three kinds of representation postulated by Karmiloff-Smith can occur at different times in different domains. However, the neo-Piagetian theories are in some ways easier to test than Karmiloff-Smith' s theory, because they make empirical predictions about upper limits on cognitive performance. Representational redescription theory does not, requiring instead careful and detailed investigation of how representations change progressively over time. As Karmiloff-Smith (1994) has pointed out, connectionist models provide one possible avenue for modelling developmental change that could incorporate a representational redescription format. A research strategy based on connectionist simulations is already being widely used in adult cognition, but to date has not featured strongly in children's cognition. This situation will probably change during the next decade of progress in cognitive science.

Source: Goswami, U. (1998). *Cognition in Children*, pp. 214-218. Hove, UK: Psychology Press Ltd.