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Interaction between comparative psychology and cognitive development

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Comparative psychologists and cognitive developmentalists often share methods and topics of research. Here we review three domains in which there has been particularly fruitful interaction between the fields and reflect on the theoretical positions behind these interactions. Overall, we conclude that there is much to be gained, as cognitive and behavioural scientists, for drawing together work from human children and non-human species.

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An increasingly popular strategy is for comparative psychologists and cognitive developmentalists to collaborate and exchange findings [1••]. Cognitive development continues throughout the lifespan but it is the early years of childhood that have most to share with comparative psychology and will be the focus here. First, we review some (and certainly not all) of the domains in which there has been interesting interaction, followed by reflection on the theoretical positions behind these interactions.

Theory of mind

Theory of mind (attributing mental states to oneself and others) was first described by researchers working with chimpanzees [2] and raised many questions concerning how to assess theory of mind. This challenge was taken up by cognitive developmentalists who devised the unexpected transfer false belief task [3]: participants are asked where someone thinks an object is when they have not seen it moved. Three-year-olds typically answer incorrectly: he will look for the object where it is, but 4-year-olds are more likely to say he will look where he left it. Attempts have been made by both cognitive developmentalists [4] and comparative psychologists [5] to reduce the task demands (especially verbal) to see if success could be identified earlier in humans or in non-human species. Onishi and Baillargeon [6] used looking time measures with infants, aged only 15 months, who discriminated between situations where an actor held a true or false belief. Subsequently, researchers have claimed that even 6-month-olds are sensitive to others' false beliefs [7,8].

Originally cognitive development borrowed this topic from comparative psychology. Now the wheel has come full circle and, very recently, a looking-time study showed that bonobos, chimpanzees, and orangutans correctly anticipate how an individual will act based on a false belief [9•]. Krupenye et al. based their task on Southgate's [10] "seminal anticipatory looking false-belief study with human infants" p111. The remarkable success of non-human apes and very young human infants are forcing researchers to think carefully about interpretation (e.g. [11–13]). Furthermore, it will be interesting to see whether this new observation of non-human species' performance will dissuade those who have argued that theory of mind is uniquely human from seeing implicit success on the false belief task as gold-standard evidence for theory of mind.

Tool use

A second domain with fruitful exchange between cognitive development and comparative psychology is that of tool use and innovation. In the trap tube task individuals use a stick to push or rake a reward from a horizontal transparent tube. If the reward is pushed or pulled over a trap in the tube, it is lost. In the original study [14], capuchin monkeys failed to retrieve the reward. Chimpanzees perform better, even succeeding in a control trial with the tube rotated making the trap non-functional (e.g. [15]). Interestingly, rooks showed mixed performance in a version where they pulled a string to move the reward: while most birds seemed to learn a set of associative rules, one bird solved the task, even when associative rules would result in the wrong behaviour [16].

Meanwhile, cognitive development has focussed on social aspects of tool use, recognising that the diversity of human tool use must rely on transfer between generations of individuals (cumulative culture, see e.g. [17]). However, researchers often overlooked individual tool-use abilities. Indeed, the first study of human children's performance on the trap tube was concerned with adult demonstrations not children's independent problem solving [18]. Two- and three-year-olds rarely retrieved the reward consistently without adult input. Subsequently, Horner and Whiten [19•] found that 5- and 6-year-olds could master the trap tube, but were unaffected by social demonstrations.

In another task, a New Caledonian crow bent a piece of wire into a hook to retrieve a reward from a tall vertical tube [20]. Despite the finding being heralded as evidence for innovation in corvids (see Bird and Emery [21] for an extension to rooks), it was a decade before this tool-innovation task was conducted with human children. These studies produced the surprising finding that 3- and 4-year-olds failed to make a novel tool to obtain a reward and it was not until around 8 years that the majority of children succeeded [22•]. Similar results were observed in children from different cultures [23] and tested in different environments (although when tested in an informal museum setting, while 3- and 4-year-olds struggled, success was seen earlier than 8 years [24]). In a similar vein, Reindl et al. [25] tested children on 12 tool-using behaviours based on those observed in wild great apes and identified as potentially cultural e.g. [26]. For example, a) chimpanzees use sticks to making probing holes in termite nests; children were required to use a stick perforate a barrier in a box to retrieve a sticker, b) chimpanzees use sticks to fish for honey or water; children were required to use a stick to dip for paint in a tube. Two-year-olds were able to reinvent these novel tool-use behaviours and at least some of them successfully completed the task (e.g. (a) retrieved the sticker, (b) transferred the paint to a new container). One change made in adapting these behaviours for children was that participants were directed by an adult to try to solve a task (but not told how they should do this), whereas the wild great apes were solving tasks that they had identified.

Mental time travel

Research on what it is to think about the future and the past (mental time travel) has generated much interaction between cognitive development and comparative psychology.

It often benefits an individual to reject a current reward and wait for a better one. In the 1970s Mischel and colleagues (reviewed in [27]) developed delay of gratification tasks in which children had to choose between a small reward delivered immediately or a larger reward later. Preschoolers improve in their ability to wait for the larger reward with age. This research question was adopted by comparative researchers, often explicitly, e.g. Beran [28] asks "whether chimpanzees can delay gratification in a manner similar to that of human children" p121. Chimpanzees [28,29] and orangutans [30] delay on tasks that measure either delay choice (where one chooses explicitly between 2 rewards with different wait times) or delay maintenance (waiting for the larger reward while one can accept at any point the small one). Furthermore, a language-trained grey parrot, waited up to 15 min for a larger reward [31] and corvids will wait for qualitatively (but not quantitively) different rewards [32].

Clayton and Dickinson [33] used an intriguing study to argue that scrub jays could engage in episodic-like memory, recalling what happened, when, and where: scrub jays cached a preferred food (worms) in location A at time 1 and a less preferred food (nuts) in location B at time 2 (or vice versa). They were able to retrieve food at time 3, 4 h after hiding food at time 2 and 124 h after time 1. Without any further intervention, birds sought food preferentially from the worm location. However, if the birds learnt that worms became inedible after 124 h, they only sought them if they were cached at time 2.

A neat analogue of this study [34] had children explore two rooms each containing an identical set of four locations (bags and boxes), one of which held a toy. The hidden toy was different in each room. At a later time, children returned to one room (the clue to 'when' the event happened) and were asked to find the toy. It was not until five-years-old that children consistently performed well.

Developmental research has highlighted another important element of temporal thinking: the understanding that the future is undetermined. In one study [35], children saw a mouse about to come down an inverted Y-shaped slide. Children were asked to place cotton wool to cushion its landing. 'Ideally' children should ensure that there was cotton wool under both possible exits (both branches of the Y). Five- and six-year-olds did, however, three- and four-year-olds tended to cover only one exit, suggesting that they did not represent the future as holding multiple possibilities.

Redshaw and Suddendorf [36] used the same basic paradigm to test chimpanzees and orangutans. Like younger children, the apes covered just one potential exit. They also tested human children, finding earlier success than in the original study, at 3- rather than 5- years, probably because the target response was simpler for children: putting out their hands, rather than moving cotton wool mats. Thus, here is an example of a methodological change directed at testing non-humans, which also reveals new evidence about human children (note however, that the newer study does not contain control trials included in the original study [35]).

Interaction

As these three domains illustrate there is very fruitful interaction between comparative psychology and cognitive developmentalists in sharing and improving methodologies. Although there are some tasks where very similar methods can be used cross species, it remains the case that there will always be some differences in how we test human children and non-human species (and probably between different populations of non-human species as well). For example, when a nonverbal task has been run with non-human animals and is adapted for human children it is tempting to maintain the lack of any verbal instructions or communication. However, this can risk putting additional social demands on the child, who will expect some interaction from the adult experimenter. Instead, developmental researchers often minimise verbal instructions or adult interaction (e.g. [22•]), but they cannot do this entirely, nor need they, for fruitful exchange between the fields.

When observing these interactions, it is also important to recognise the differing theoretical approaches used by researchers between (and sometimes within) fields. Comparative psychologists often seek 'existence proofs', i.e. whether a species has the capacity to think in a certain way. For psychologists studying humans the existence proof is typically already established: we know that human adults can think about minds, use tools, and mental time travel. Some researchers explore whether elements of these abilities exist innately, see [37], which is to some extent a developmental existence proof. But most of the studies we covered in this review are concerned with older children. The researchers conducting these studies tend ask questions about patterns in development, for example, which abilities are necessary to support others' emergence or the processes by which change occurs e.g. [38]. One important difference, which becomes obvious as one engages with the two fields, is that in the search for existence proofs evidence from a successful individual is sufficient. Whereas for developmental psychologists interested in patterns of change a single success is more likely to be treated as an outlier. Both approaches are valid, but we need to avoid ambiguities when the fields come together to talk about whether a particular participant group 'can' think in a particular way.

Other researchers who focus on the question of human uniqueness e.g. [39,40] (or other species' uniqueness), are also interested in the comparisons between human children and non-human species. Studies of young children are beneficial for these comparisons, because tasks need to be simplified as much as possible, if one is to claim that a particular species does not show a way of thinking. A related approach, but with a complementary goal, is the search for evidence of our evolutionary history. Here the search is for correspondence between human children and non-human species which can be interpreted as evidence that the ability was present in our shared ancestry.

In conclusion, there are many examples of transfer of concepts and methodologies between comparative psychologists and cognitive developmentalists. Theory of mind, tool use, and mental time travel are three particularly interactive domains although there are many others. Interaction can generate new ideas for research studies, which benefits researchers primarily interested in human children or non-human species. It also allows for comparison between species which contributes to questions of species uniqueness and evolution. In sum, the fields have much to offer and gain from each other.

Conflict of interest statement

'Nothing declared.

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This review argues clearly for the need to integrate findings from comparative and developmental psychology, and also for the importance of a cross-cultural perspective. It gives very useful illustrations of where performances from non-human species have been compared to that of young children. The focus is on non-human great apes, and so it is useful to think about how findings from other species might also advance out understanding of the domains of interest.

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The pair of studies described here are an excellent illustration of the exchange of ideas between fields. Although originally discussed in relation to non-human species, the false belief task was developed for use with human children. After several important methodological advances, comparative psychologists borrow the task for studies with non-human great apes. The resulting findings will contribute to the debate on how to interpret this behaviour in humans and non-humans.

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Here the authors make direct comparison between chimpanzees and human children on the trap tube task. They also address developmental questions, by testing children at different ages. The paper shows how careful interpretation of results permits some comparisons between groups, but also highlights the difficulties in making exact comparisons (e.g. in number of trials, time period of testing).

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This paper reports three studies which adapted the hook-making task previously used with corvids. Taking a task from one species to another proved interesting because the new population found the task remarkably difficult. It is worth noting that because of the difference in availability of participants the child paper reports results from over 380 children and additional hypotheses can be tested (e.g. giving practice with the materials). This may be a useful strategy for identifying interesting questions to return to the comparative field. However, it is important to see the differences inherent in testing human children and corvids revealed in this paper (e.g. children were tested with a friendly adult in attendance).

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