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Do actions speak louder than words? A comparative perspective on implicit versus explicit meta-cognition and theory of mind

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Research in non-human animal (hereafter, animal) cognition has found strong evidence that some animal species are capable of meta-cognitively monitoring their mental states. They know when they know and when they do not know. In contrast, animals have generally not shown robust theory of mind (ToM) capabilities. Comparative research uses methods that are non-verbal, and thus might easily be labelled 'implicit' using the terminology of traditional human cognition. However, comparative psychology has developed several non-verbal methods that are designed to test for aspects of meta-cognition that – while perhaps not fully explicit – go beyond the merely implicit or associative. We believe similar methods might be useful to developmental researchers who work with young children, and may provide a sound empirical alternative to verbal reports. Comparative psychology has moved away from all-or-none categorical labels (e.g., 'implicit' vs. 'explicit') towards a theoretical framework that contains a spectrum of mental abilities ranging from implicit to explicit, and from associative to cognitive to fully conscious. We discuss how this same framework might be applied to developmental psychology when it comes to implicit versus explicit processing and ToM.

Early developmental psychology and comparative psychology have similar goals: to discover the psychological capabilities of participants who cannot easily tell us what (or how) they are thinking. In some ways this limitation handicaps researchers by denying us many of the logistical advantages that researchers of adult human cognition take for

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granted – experience, verbal instructions, lengthy or uninteresting tasks, verbal reports, etc. We thus often rely on indirect measures such as looking time, optional responses, or other observations.

When we do create an experiment that works for our participants, we are then faced with the difficult task of interpreting the results. Adults can explain their thought processes in a convincing – though often off-line, *post hoc*, and even unreliable – way. Young children and animals are less capable of explaining their mental processes, and thus are less capable of defending themselves against alternative explanations for their behaviour.

Without verbal instructions or reports, our tasks must still be able to show evidence for sophisticated mental abilities while ruling out low-level explanations. We will describe how the literature pertaining to meta-cognition in animals has overcome several obstacles to provide positive evidence for meta-cognition. Although this research is ongoing, there is now accumulating evidence to suggest that some species have demonstrated meta-cognitive but not theory of mind (ToM) capabilities (Beran, Smith, Redford, & Washburn, 2006; Couchman, Coutinho, Beran, & Smith, 2010; Hampton, 2001; Kornell, Son, & Terrace, 2007; Shields, Smith, & Washburn, 1997; Smith, Beran, Redford, & Washburn, 2006; Smith *et al.*, 1995; Smith, Shields, Allendoerfer, & Washburn, 1998; Smith, Shields, Schull, & Washburn, 1997; Smith, Shields, & Washburn, 2003; Washburn, Smith, & Shields, 2006; Washburn, Gulledge, Beran, & Smith, 2009). We believe the best evolutionary explanation for these results is that meta-cognitive processing predates and perhaps underlies abilities such as human self-awareness (Gallup, 1982) and ToM (see Couchman, Coutinho, Beran, & Smith, 2009). This hypothesis presents several interesting opportunities for developmental and comparative psychologists to test for meta-cognition in children and animals and some of the methodology described could be adapted to ToM paradigms. After presenting the evidence for animal meta-cognition and discussing the relationship between meta-cognition and ToM, we will argue that an all-or-none distinction between implicit and explicit cognition (or implicit ToM vs. explicit ToM) results in unnecessary labels and distinctions that only limit the field. The real richness of both developmental and comparative inquiry is in the middle ground, where we can observe the emergence of these sophisticated mental abilities.

Evidence for animal meta-cognition

Human college students taking an exam often know that they do not know the answer to a particular question. They might respond to this feeling of uncertainty by reflecting on the problem, by trying to think about it differently, by moving on to another question, or by seeking additional information from the exams of nearby students. These types of reflective and hint-seeking behaviours form the basis for the study of human meta-cognition (Benjamin, Bjork, & Schwartz, 1998; Flavell, 1979; Koriat, 1993; Nelson, 1992; Schwartz, 1994). This capacity to think about our own thinking and change our behaviour to adaptively correspond to our feelings of uncertainty is important because it allows us to understand our own mental states (Koriat, 2007; Nelson, 1996). It also forms a certain mental hierarchy: we have knowledge, and then we have knowledge about that knowledge – how reliable we believe it is, how much we are willing to stake on its being correct, etc. This higher level knowledge works as an extra layer of information that we use to make better decisions. Meta-cognition is therefore closely related to human self-awareness (Gallup, 1982) because it involves becoming aware of our personal thoughts and beliefs. It is also closely related to ToM, because understanding our own thoughts may be the first step towards understanding the thoughts of others (Couchman *et al.*, 2009).

Human meta-cognitive awareness might sometimes be implicit. That is, humans might simply monitor their confidence levels and adjust behaviour accordingly, without conceptualizing the process as 'thought monitoring', without representing their thoughts as 'thoughts', and indeed without using the concept 'thought' or 'mental state' at all. Other times it may be explicit – that is, they may say 'I do not know' with the full understanding that they are reporting on their mental states. It may sometimes be second order and meta-representational because the meta-cognitive thoughts represent first-order thoughts (as 'thoughts' that they understand are a category of things). Or, it may fall somewhere in between.

Because meta-cognition is such an important component of humans' reflective mind and cognitive functioning, it is important to ask how and why the ability emerged evolutionarily, and whether any other species have anything like human meta-cognition (see Terrace & Metcalfe, 2005). However, the traditional approach to the study of human meta-cognition involved gathering (usually verbal) feelings of knowing and judgments of learning, or observing tip-of-the-tongue experiences. These explicit reports are useful for understanding human meta-cognition, but they are not easily applied to other species. Thus, it fell to comparative researchers to search for evidence of animal meta-cognition using tasks that did not involve explicit reports. Smith and colleagues (Shields *et al.*, 1997; Smith *et al.*, 1995; Smith *et al.*, 1998; Smith *et al.* 1997; Smith *et al.*, 2003) began this search by giving a dolphin and rhesus monkeys perceptual discrimination tasks that, in addition to primary task responses, included an opt-out response – often called the uncertainty response – that allowed them to decline some trials.

In the first study using this paradigm (Smith *et al.*, 1995), researchers gave a tone discrimination task to a dolphin. On each trial, the dolphin heard one tone and could make one of three possible responses: (1) the high response, which was correct only if the tone was exactly 2,100 Hz; (2) the low response, which was correct whenever the tone was 2,099 Hz or lower; (3) the uncertainty response, which was never correct but allowed the dolphin to decline the trial. At the beginning of each experimental session, the trials were relatively easy – the dolphin was presented with either the high tone or a much lower tone (beginning at 1,200 Hz). Not surprisingly, the dolphin made very accurate primary responses and essentially never responded uncertain. As the dolphin progressed, the lower tones increased in pitch so that they became more difficult to distinguish from the high tone. Uncertainty responding increased as the task became more difficult, and was highest on trials that were close to the animal's perceptual threshold for the primary discrimination. In addition, indirect measures of uncertainty such as hesitating and wavering before making a response also peaked on the most difficult trials.

The dolphin results were replicated in monkeys and humans using a pixel discrimination task (Smith *et al.*, 1997). On each trial, participants saw a pixilated box and could make one of three possible responses: (1) dense, which was correct only if the box contained exactly 2,950 pixels; (2) sparse, which was correct whenever the box contained 2,949 pixels or less; (3) the uncertainty response, which was never correct but allowed the subject to decline the trial and bring about a guaranteed-win trial. Monkeys and humans made very accurate primary discriminations to the relatively easy trials, and made adaptive uncertainty responses to decline the most difficult trials. For humans and monkeys (as well as the dolphin in Smith *et al.*, 1995) uncertainty responding peaked on trials close to their perceptual limen, where primary responses were most inaccurate. In addition, verbal reports taken from humans attributed uncertainty responses to conscious awareness of their own uncertainty. Uncertainty monitoring has also been demonstrated by 3-year-olds (Balcomb & Gerken, 2008), but we are not aware of any studies in pre-linguistic children.

These initial studies raised several methodological and theoretical concerns (Carruthers, 2008, 2009; Crystal & Foote, 2009; Jozefowiez, Staddon, & Cerutti, 2009; Metcalfe, 2008; Smith, Beran, Couchman, & Coutinho, 2008; Smith, Beran, Couchman, Coutinho, & Boomer, 2009a; Staddon, Jozefowiez, & Cerutti, 2007, 2009). Were these results due to monitoring and responding to mental states, or were they due to more simple processes such as stimulus-response associations? Were animals simply motivated by a state of uncertainty, or were they really aware that they were in that state? And if they were aware, did this awareness manifest explicitly – e.g., 'I am in mental state X' or some non-linguistic equivalent – or were animals processing uncertainty in some implicit fashion? These problems and the corresponding solutions have been discussed extensively in other places (see Smith, 2009), but we outline some solutions below that may prove relevant to developmental paradigms.

To answer these questions, similar results have been obtained for monkeys in more abstract situations that often used an uncertainty response that was not rewarded in any way, including Same–Different tasks (Shields *et al.*, 1997) and numerosity tasks (Beran *et al.*, 2006). Uncertainty responding has also been observed on the first trial of novel tasks (Washburn *et al.*, 2006), during delayed matching-to-sample meta-memory judgments (Hampton, 2001), during meta-memory judgments when transcranial magnetic stimulation disrupts memory traces (Washburn *et al.*, 2009), during serial-position meta-memory performance (Smith *et al.*, 1998), and during token-economy meta-memory performance (Kornell *et al.*, 2007). In all of these tasks, monkeys were able to monitor their uncertainty and respond adaptively even when the reward contingencies were not tied to specific concrete stimuli. Note that these tasks contain both judgments of uncertainty states and, in meta-memory paradigms, judgments of mental contents. Thus, the meta-cognitive capacity seems to be flexible with regard to the types of mental phenomenon that it can monitor, and dissociable from stimulus-response associations. These results suggest that meta-cognition is not tied to any specific implicit or first-order system; instead it seems that, like executive or explicit cognition, it is a general ability that can be applied to different situations.

Converging results have also been obtained in tasks that dissociated uncertainty responding from reward contingencies by not allowing animals to know which trials they were answering correctly or incorrectly. Smith *et al.* (2006) taught rhesus monkeys to complete four Sparse–Dense trials before receiving summary feedback (food rewards for correct answers, timeouts for incorrect answers). Uncertainty responses simply escaped the current trial and brought about the next – and that next trial could be harder or easier than the present one. Feedback was also rearranged – all rewards were presented first, followed by all penalties – so that it was impossible to associate a particular response with a particular outcome. Even without direct feedback, one monkey was able to adaptively decline difficult trials. The monkey consistently declined trials that corresponded to his subjective construal of task difficulty. Couchman *et al.* (2010) extended this paradigm to include three monkeys, more humans, and several novel tasks (e.g., the size of a circle, the steepness of a line segment, etc.). Despite lacking any useful information about which stimuli were being rewarded, and despite receiving no reward for uncertainty-response use, both humans and monkeys adaptively declined the trials in new tasks that corresponded to their perceptual threshold. Interestingly, each monkey on each task had a different perceptual threshold and uncertainty responding corresponded to the threshold for that task rather than to associative-learning factors such as session time or factors associated with previous experience. Because implicit cognition usually relies on feedback, and explicit cognition does not (Maddox & Ashby, 2004), this again suggests that despite their lack of language monkeys' meta-cognitive abilities may be explicit (though see below for a discussion of these labels).

In addition to a dolphin and rhesus monkeys, evidence for meta-cognition has been found in apes. Call and Carpenter (2001) asked chimpanzees, orangutans, and human children to choose a tube with a possible food reward inside. Participants either saw or did not see the food reward being placed into one of two or three tubes. Call and Carpenter used an indirect measure of uncertainty – seeking additional information by looking into the tube – to determine whether the participants knew that they had or had not seen the food placement. When participants saw the food being placed into a tube, they immediately chose that tube. But when they did not see the food placement, they sought additional information before making a decision. In a similar experiment, Suda-King (2008) found that orangutans immediately chose a tube they had seen baited with two grapes, but chose to take one guaranteed grape when they had not seen which tube the two grapes had been placed into. These results suggest that apes know and can seek additional information when they do not know the answer to a problem.

Failures of some species, and of some alternative explanations

The cognitive sophistication of dolphins', monkeys', and apes' meta-cognitive capacity is underscored by the failure of other species to show this capacity. Inman and Shettleworth (1999) and Sutton and Shettleworth (2008) found that pigeons did not significantly increase their use of the uncertainty response in the face of increased difficulty in a meta-memory experiment, even when the response not only escaped the current trial but also brought about a small reward. Similarly, Roberts, Feeney, McMillan, MacPherson, & Musolino (2009) found that pigeons would not use a response to ask for information even when that information was needed to complete a match-to-sample task.

Capuchin monkeys, a species less closely related to humans than rhesus monkeys, have also generally failed to show meta-cognitive ability. Beran, Smith, Couchman, & Coutinho (2009) gave capuchins a Sparse–Dense discrimination task that had elicited adaptive uncertainty responding in rhesus monkeys and humans. Capuchins essentially did not use the uncertainty response at all in this task, despite performing similarly to rhesus monkeys and humans on the primary discrimination. When the uncertainty response was replaced with a 'middle' response that was rewarded when used on trials that often elicited uncertainty responses in rhesus monkeys and humans, the capuchins used it readily and easily. This suggests that capuchins were capable of every first-order aspect of the task but were not capable of monitoring their uncertainty (Smith *et al.*, 2009a,b). Basile, Hampton, Suomi, & Murray (2009) gave capuchins Call and Carpenter's (2001) information-seeking paradigm and found that only one of five capuchins visually inspected the tubes more often when they did not see the food being placed inside. Although three were eventually trained to search when they did not see the placement, the possibly meta-cognitive effects went away when effort to search was increased. Paukner, Anderson, and Fujita (2006) found that although some capuchins did search more extensively when food was hidden, they also performed many unnecessary search behaviours (e.g., searching inside transparent tubes) that contrasted sharply with humans and apes. Here too, capuchins clearly understood the behavioural rules and first-order aspects of the task, but failed to adaptively monitor their uncertainty.

These species certainly encounter situations of uncertainty, they certainly encounter situations where they are often making errors, and they probably *feel* uncertain, but they may lack more sophisticated monitor-and-control abilities. And, given that capuchins can make adaptive 'middle' responses, their failures cannot be attributed to a deficit in first-order cognition. Similarly, if the uncertainty-monitoring performances of rhesus monkeys, a dolphin, and apes were attributable to the low-level dynamics of conditioning, response strength, and reinforcement history or maximization, then pigeons and capuchins – who are superb performers in many first-order cognitive tasks – would likely show the uncertainty-monitoring data pattern. That they do not supports the theoretical conclusion that uncertainty monitoring is a more sophisticated cognitive faculty and may possibly be explicit, second order, or even conscious.

The evidence outlined above and continuing research has led many researchers from independent laboratories to conclude that some animals have shown meta-cognitive capabilities. 'Metamemory ... is clearly established in rhesus macaques (*Macaca mulatta*) by converging evidence from several paradigms' (Sutton & Shettleworth, 2008, p. 266). 'Whereas evidence for metacognition by nonhuman primates has been obtained in great apes and old world monkeys, it is weaker in new world monkeys' (Fujita, 2009, p. 575). 'Substantial evidence from several laboratories converges on the conclusion that rhesus monkeys show metacognition' (Roberts *et al.*, 2009, p. 130). Of course, the exact content of their meta-cognitive thoughts and the nature of their meta-cognitive awareness remains an open area of investigation.

The relationship between meta-cognition and theory of mind

Of the animal species that show strong evidence for meta-cognition, only one, chimpanzees, have shown even a limited ability to understand the knowledge of others. Chimpanzees are able to choose a food reward that cannot be seen by a dominant conspecific over one that is in the dominant chimpanzee's line of sight (Hare, Call, & Tomasello, 2001), though they do not seem to differentiate between human food givers that can or cannot see them (Povinelli & Eddy, 1996; Povinelli & Vonk, 2003, 2004). They do seem to know something about what another chimpanzee knows or sees, but they fail false-belief tasks (Call & Tomasello, 1999; Kaminski, Call, & Tomasello, 2008).

It would seem, given the evidence from the non-human species that have been test thus far, that several exhibit meta-cognition but few, if any, exhibit ToM. To date, no non-human species has been shown to exhibit ToM in the absence of meta-cognition. Only chimpanzees have shown evidence of both, and even they appear to have more robust meta-cognitive than ToM capabilities. Couchman *et al.* (2009) noted that this is a remarkable phylogenetic fact that supports the hypothesis that meta-cognition emerged evolutionarily prior to ToM. Because the two are so closely related, this also supports the hypothesis that meta-cognition may serve as an underlying basis for ToM. How does this impact the relationship between implicit, explicit, and meta-representational meta-cognition and ToM? We discuss this issue below and argue that it is more useful to move past these labels than attempt to reconcile these largely semantic issues.

We recognize that this hypothesis poses several problems for both developmental and comparative psychologists, not the least of which is: how is meta-cognition possible without the meta-representational framework that seems to be needed to succeed in false-belief tasks? Doesn't an animal (or human) need to fully represent its belief states, as well as mentally represent itself and others, before being able to apply belief states to itself or others (Carruthers, 2008)? This meta-representation may not need to be explicit, and certainly need not be linguistic, but isn't it required?

The general standard for false-belief tasks is that humans pass them precisely when they have the mental ability to meta-represent belief states and attribute them to agents. For example, in a standard deceptive appearance task (Bialystok & Senman, 2004; Gopnik & Astington, 1988), participants are shown a box that would usually contain one thing (e.g., crayons) but actually contains another (e.g., rocks). They must represent a belief state 'crayons are in the box' that contradicts their knowledge of the box's contents. They must attribute the belief to an agent – 'Sally will believe crayons are in the box' – in order to give the correct verbal answer, 'crayons', when asked what Sally will think is in the box. Passing the false-belief task in this way is certainly a strong indication that the subject understands something about the mental states of others. However, the explicit and linguistic nature of the task is such that one might fail for a variety of factors that, although the test requires them, may not be required for ToM. False-belief tasks have been linked in this way to various aspects of language ability (de Villiers, 2000; Perner, Stummer, Sprung, & Doherty, 2002; Milligan, Astington, & Dack, 2007). Some have argued that this link exists because ToM itself is dependent on language mastery (de Villiers, 2005).

Another possibility is that the explicit answers often required in false-belief tasks are only measuring the explicit aspects of ToM (Clements & Perner, 1994) – aspects that may not have yet developed in children (or animals). Indeed, the description of false-belief tasks above hinges entirely on the assumption that a participant ought to be able to explicitly represent (and state) answers that are indicative of its mental abilities. Other measures might find implicit evidence of both meta-cognition and ToM in participants that cannot pass the explicit false-belief task.

And indeed these measures seem to be emerging. Young children have demonstrated the ability to look more often towards a location where a protagonist would search if they had a false belief (Clements & Perner, 1994; Low, 2010; Southgate, Senju, & Csibra, 2007) or to stare more intently when an action violates a false belief that the protagonist ought to have (Onishi & Baillargeon, 2005). These might be termed 'implicit' measures of ToM. Children demonstrating these behaviours are thought to show a nascent sensitivity to the false beliefs of others despite their 'explicit' failures (Low, 2010). Similarly, the animal research outlined above might be said to use 'implicit' measures of meta-cognition (i.e., optional or indirect behaviours). The research could indicate that animals have access to their mental states without necessarily representing them in the explicit or linguistic sense.

These considerations place the phylogenetic and ontogenetic emergence of meta-cognition and ToM in a new light. Both meta-cognition and ToM appear to have primitive forms that precede their explicit counterparts in adult humans. That is, assessments of one's own mental states and the mental states of others do not seem to be inherently dependent on linguistic ability or meta-representation. To the contrary, the empirical state of the comparative literature suggests that one consider the converse: That explicit and/or meta-representational ability might be dependent on the more implicit forms of meta-cognition and ToM.

Similar results may emerge from studies of adult human response strategies in false-belief tasks. Belief-reasoning errors occur in patients with either prefrontal cortical damage or damage to the temporo-parietal junction (Apperly, Samson, Chiavarino, & Humphreys, 2004). Similarly, functional magnetic resonance imaging (fMRI) evidence has associated the prefrontal cortex with action monitoring and stimulus-independent cognitive processing and the temporo-parietal junction with mental representations in false-belief tasks (Sommer *et al.*, 2007). An obvious next step would be to determine if these brain areas are activated during implicit paradigms. Furthermore, implicit ToM tends to interfere and delay verbal reporting (Kovács, Téglás, & Endress, 2010), and while not fully linguistic it may be closely tied to language (Meristo *et al.*, 2010). Although all of these studies make distinctions between implicit and explicit ToM, it is important to realize that these terms are descriptors of the form of the empirical assessment (e.g., looking time vs. predictive pointing vs. verbal explanations). They are not necessarily descriptions of the minds that are carrying out the performance, which in many cases appear to be quite similar.

Conclusion

The aim of the current article is to give readers with a background in developmental research an account of a growing, influential area of comparative research. The two fields share significant common ground, both in the nature of our research participants and the nature of our methods. Most importantly we share a problem: how to describe the mental processes of participants who have the behavioural but not the verbal ability to do something widely believed to require meta-representation. We believe that both empirical strategies and theoretical insights can help solve this problem within comparative and developmental domains.

To date, a dolphin, rhesus monkeys, and several ape species have shown some understanding of their own mental states (see Smith, 2009 or Smith *et al.*, 2009a,b for a review). Rhesus monkeys in particular have made adaptive use of the uncertainty response – a response that, in humans, would easily bear the label 'I don't know' – in a wide variety of situations. It is thus important to know what kind of mental awareness animals might be experiencing when they make an uncertainty response. Is pressing the uncertainty response equivalent to saying 'I don't know', as it often is in humans, or is it the result of an entirely implicit and reactive process that may involve only avoidance or low-level reward maximization?

This implicit versus explicit distinction is precisely the same problem facing developmental ToM researchers. If the location of a person's toy changes while that person is not looking, a 3-year-old child might incorrectly say that the person will look for it in the new location; but anticipatory gazes might indicate that the child expects the person to look in the old location (Low, 2010). Is the anticipatory gaze equivalent to saying 'The person believes it is there when in fact it has moved', as it might be in adult humans, or are the eyes governed by separate implicit processes that have not yet come into cognitive (or linguistic) awareness?

When one considers these questions, it is apparent that neither the implicit nor the explicit answer is exclusively and completely sufficient or compelling. Behavioural uncertainty responses and anticipatory gazes are implicit measures as operationally defined traditionally within an experimental context. But they might have an emerging explicit mind producing them. Verbalizations and justifications are explicit measures, operationally/traditionally. But rather than evidence of explicit and/or conscious and/or meta-representational processing, these could be, and probably often are, *post hoc* rationalizations and explanations for behaviours that may have occurred much more implicitly within the on-line stream of cognitive processing that produced the decisions. Therefore, in our view, the real issue is the character of the mind performing the operation. And even that question cannot be addressed, and should not be addressed, qualitatively and in some all-or-none fashion. Rather, the issue is where the performing mind falls on the continuum spanning the implicit or explicit extreme.

Our strategy for taking on this issue has been to develop tasks that require purely behavioural responses, but nonetheless are designed to elicit various levels of cognitive processing along this continuum. Theory-of-mind tasks, like false-belief tasks, could be adapted in a similar way – and undoubtedly in other ways that the authors have not imagined – to tap into increasingly sophisticated aspects of ToM using only behavioural measures like gaze time and direction. For that matter, our theoretical perspective is probably bidirectional and synergistic—these gaze measures might also be used in alternative approaches to exploring ToM in macaques. This strategy will probably never yield a simple and categorical answer – indeed, from our perspective this kind of answer is neither desired nor even possible. But this strategy will allow for exploring the development of meta-cognition and ToM as it unfolds phylogenetically and ontogenetically.

Just as transitional bird species speak eloquently about the emergence of birdness, even more so than robins do, so transitional forms of meta-cognition and ToM may speak eloquently about the emergence of reflective mind, even more so than college undergraduates do. The exact relationship between the meta-cognition of animals, the ToM of young children, and their corresponding forms in adult humans is an exciting area of exploration that raises many provocative questions. We believe that illuminating answers will come not from marking and defending the primitive and ultimate endpoints of meta-cognition or ToM, but rather from mapping the wilderness in between.

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References

Apperly, I. A., Samson, D., Chiavarino, C., & Humphreys, G. W. (2004). Frontal and temporo-parietal lobe contributions to theory of mind: Neuropsychological evidence from a false-belief task with reduced language and executive demands. *Journal of Cognitive Neuroscience*, *16*(10), 1773–1784.

Balcomb, F. K., & Gerken, L. (2008). Three-year-old children can access their own memory to guide responses on a visual matching task. *Developmental Science*, *11*, 750–760.

Basile, B. M., Hampton, R. R., Suomi, S. J., & Murray, E. A. (2009). An assessment of memory awareness in tufted capuchin monkeys (*Cebus apella*). *Animal Cognition*, *12*, 169–180.

Benjamin, A. S., Bjork, R. A., & Schwartz, B. L. (1998). The mismeasure of memory: When retrieval fluency is misleading as a metacognitive index. *Journal of Experimental Psychology: General*, *127*, 55–68.

Beran, M. J., Smith, J. D., Couchman, J. J., & Coutinho, M. V. C. (2009). The psychological organization of "uncertainty" responses and "middle" responses: A dissociation in capuchin monkeys (*Cebus capucinus*). *Journal of Experimental Psychology: Animal Behavior Processes*, *35*(3), 371–381.

Beran, M. J., Smith, J. D., Redford, J. S., & Washburn, D. A. (2006). Rhesus macaques (*Macaca mulatta*) monitor uncertainty during numerosity judgments. *Journal of Experimental Psychology: Animal Behavior Processes*, *32*, 111–119.

Bialystok, E., & Senman, L. (2004). Executive processes in appearance-reality tasks: The role of inhibition of attention and symbolic representation. *Child Development*, *75*, 562–579.

Call, J., & Carpenter, M. (2001). Do apes and children know what they have seen? *Animal Cognition*, *4*, 207–220.

Call, J., & Tomasello, M. (1999). A nonverbal false belief task: The performance of children and great apes. *Child Development*, *70*, 381–395.

Carruthers, P. (2008). Meta-cognition in animals: A skeptical look. *Mind and Language*, *23*(1), 58–89.

Carruthers, P. (2009). How we know our own minds: The relationship between mindreading and metacognition. *Behavioral and Brain Sciences*, *32*, 121–138.

Clements, W. A., & Perner, J. (1994). Implicit understanding of belief. *Cognitive Development*, *9*, 377–395.

Couchman, J. J., Coutinho, M. V. C., Beran, M. J., & Smith, J. D. (2009). Metacognition is prior. *Behavioral and Brain Sciences*, *32*, 142.

Couchman, J. J., Coutinho, M. V. C., Beran, M. J., & Smith, J. D. (2010). Beyond stimulus cues and reinforcement history: A new approach to animal metacognition. *Journal of Comparative Psychology*, *124*(4), 356–368.

Crystal, J. D., & Foote, A. L. (2009). Metacognition in animals. *Comparative Cognition and Behavior Reviews*, *4*, 1–16.

de Villiers, J. (2000). Language and theory of mind: What are the developmental relationships? In S. Baron-Cohen, H. Tager-Flusberg, & D. J. Cohen (Eds.), *Understanding other minds: Perspectives from developmental cognitive neuroscience* (2nd ed., pp. 83–123). New York: Oxford University Press.

de Villiers, J. G. (2005). Can language acquisition give children a point of view? In J. W. Astington & J. A. Baird (Eds.), *Why language matters for theory of mind* (pp. 186–219). New York: Oxford University Press.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*, *34*, 906–911.

Fujita, K. (2009). Metamemory in tufted capuchin monkeys (*Cebus apella*). *Animal Cognition*, *12*, 575–85.

Gallup, G. G. (1982). Self-awareness and the emergence of mind in primates. *American Journal of Primatology*, *2*, 237–248.

Gopnik, A., & Astington, J. W. (1988). Children's understanding of representational change and its relation to the understanding of false-belief and the appearance-reality distinction. *Child Development*, *59*, 26–37.

Hampton, R. R. (2001). Rhesus monkeys know when they remember. *Proceedings of the National Academy of Sciences*, *98*, 5359–5362.

Hare, B., Call, J., & Tomasello, M. (2001). Do chimpanzees know what conspecif1cs know? *Animal Behaviour*, *61*, 139–151.

Inman, A., & Shettleworth, S. J. (1999). Detecting metamemory in nonverbal subjects: A test with pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, *25*, 389–395.

Jozefowiez, J., Staddon, J. E. R., & Cerutti, D. T. (2009). Metacognition in animals: How do we know that they know? *Comparative Cognition & Behavior Reviews*, *4*, 29–39.

Koriat, A. (1993). How do we know that we know? The accessibility model of the feeling of knowing. *Psychological Review*, *100*, 609–639.

Koriat, A. (2007). Metacognition and consciousness. In P. D. Zelazo, M. Moscovitch, & E. Thompson (Eds.), *The Cambridge Handbook of Consciousness* (pp. 289–325). Cambridge, UK: Cambridge University Press.

Kornell, N., Son, L., & Terrace, H. (2007). Transfer of metacognitive skills and hint seeking in monkeys. *Psychological Science*, *18*, 64–71.

Kovács, A. M., Téglás, E., & Endress, A. D. (2010). The social sense: Susceptibility to others' beliefs in human infants and adults. *Science*, *330*, 1830–1834.

Low, J. (2010). Preschoolers' implicit and explicit false-belief understanding: Relations with complex syntactical mastery. *Child Development*, *81*, 597–615.

Maddox, W. T., & Ashby, F. G. (2004). Dissociating explicit and procedural-learning based systems of perceptual category learning. *Behavioural Processes*, *66*, 309–332.

Meristo, M., Geraci, A., Surian, L., Iozzi, L., Morgan, G., Hjelmquist, E., & Siegal, M. (2010, January). Belief-attribution in deaf and hearing infants: Evidence for the importance of conversational input. Poster presented at the Opening Conference of the Cognitive Development Center, Budapest, Hungary.

Metcalfe, J. (2008). Evolution of metacognition. In J. Dunlosky & R. Bjork (Eds.), *Handbook of metamemory and memory* (pp. 29–46). New York: Psychology Press.

Milligan, K., Astington, J. W., & Dack, L. A. (2007). Language and theory of mind: Meta-analysis of the relation between language ability and false-belief understanding. *Child Development*, *78*, 622–646.

Nelson, T. O. (Ed.) (1992). *Metacognition: Core readings*. Toronto: Allyn and Bacon.

Nelson, T. O. (1996). Consciousness and metacognition. *American Psychologist*, *51*, 102–116.

Nelson. T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. *Psychology of Learning and Motivation*, *26*, 125–141.

Nelson, T. O., & Narens, L. (1994). Why investigate metacognition. In J. Metcalfe & A. P. Shimamura (Eds.), *Metacognition: Knowing about knowing*. Cambridge, MA: MIT Press.

Onishi, K. H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science*, *308*, 255–258.

Paukner, A., Anderson, J. R., & Fujita, K. (2006). Redundant food searches by capuchin monkeys (*Cebus apella*): A failure of metacognition? *Animal Cognition*, *9*, 110–117.

Perner, J., Stummer, S., Sprung, M., & Doherty, M. (2002). Theory of mind finds its Piagetian perspective: Why alternative naming comes with understanding belief. *Cognitive Development*, *17*, 1451–1472.

Povinelli, D. J., & Eddy, T. J. (1996). What young chimpanzees know about seeing. *Monographs of the Society for Research in Child Development*, *61*(3), 1–152.

Povinelli, D. J., & Vonk, J. (2003). Chimpanzee minds: Suspiciously human? *Trends in Cognitive Sciences*, *7*(4), 157–160.

Povinelli, D. J., & Vonk, J. (2004). We don't need a microscope to explore the chimpanzee's mind. *Mind and Language*, *19*(1), 1–28.

Roberts, W. A., Feeney, M. C., McMillan, N., MacPherson, K., & Musolino, E. (2009). Do pigeons (*Columba livia*) study for a test? *Journal of Experimental Psychology: Animal Behavior Processes*, *35*, 129–142.

Schwartz, B. L. (1994). Sources of information in metamemory: Judgments of learning and feelings of knowing. *Psychonomic Bulletin and Review*, *1*, 357–375.

Shields, W. E., Smith, J. D., & Washburn, D. A. (1997). Uncertain responses by humans and rhesus monkeys (*Macaca mulatta*) in a psychophysical same-different task. *Journal of Experimental Psychology: General*, *126*, 147–164.

Sommer, M., Döhnel, K., Sodian, B., Meinhardt, J., Thoermer, C., & Hajak, G. (2007). Neural correlates of true and false belief reasoning. *NeuroImage*, *35*, 1378–1384.

Smith, J. D. (2009). The study of animal metacognition. *Trends in Cognitive Sciences*, *13*, 389–396.

Smith, J. D., Beran, M. J., Couchman, J. J., & Coutinho, M. V. C. (2008). The comparative study of metacognition: Sharper paradigms, safer inferences. *Psychonomic Bulletin and Review*, *15*, 679–691.

Smith, J. D., Beran, M. J., Couchman, J. J., Coutinho, M. V. C., & Boomer, J. B. (2009a). Animal metacognition: Problems and prospects. *Comparative Cognition & Behavior Reviews*, *4*, 33–46.

Smith, J. D., Beran, M. J., Couchman, J. J., Coutinho, M. V. C., & Boomer, J. B. (2009b). The curious incident of the capuchins. *Comparative Cognition & Behavior Reviews*, *4*, 47–50.

Smith, J. D., Beran, M. J., Redford, J. S., & Washburn, D. A. (2006). Dissociating uncertainty states and reinforcement signals in the comparative study of metacognition. *Journal of Experimental Psychology: General*, *135*, 282–297.

Smith, J. D., & Kemler Nelson, D. G. (1988). Is the more impulsive child a more holistic processor? A reconsideration. *Child Development*, *50*, 719–727.

Smith, J. D., Minda, J. P., & Washburn, D. A. (2004). Category learning in rhesus monkeys: A study of the Shepard, Hovland, and Jenkins tasks. *Journal of Experimental Psychology: General*, *133*, 398–414.

Smith, J. D., Schull, J., Strote, J., McGee, K., Egnor, R., & Erb, L. (1995). The uncertain response in the bottlenosed dolphin (*Tursiops truncatus*). *Journal of Experimental Psychology: General*, *124*, 391–408.

Smith, J. D., Shields, W. E., Allendoerfer, K. R., & Washburn, W. A. (1998). Memory monitoring by animals and humans. *Journal of Experimental Psychology: General*, *127*, 227–250.

Smith, J. D., Shields, W. E., Schull, J., & Washburn, D. A. (1997). The uncertain response in humans and animals. *Cognition*, *62*, 75–97.

Smith, J. D., Shields, W. E., & Washburn, D. A. (2003). The comparative psychology of uncertainty monitoring and metacognition. *Behavioral and Brain Sciences*, *26*, 317–373.

Southgate, V., Senju, A., & Csibra, G. (2007). Action anticipation through attribution of false beliefs by two-year-olds. *Psychological Science*, *18*, 587–592.

Staddon, J. E. R., Jozefowiez, J., & Cerutti, D. (2007). Metacognition: A problem not a process. *PsyCrit*, 1–5.

Staddon, J. E. R., Jozefowiez, J., & Cerutti, D. (2009). Metacognition in animals: How do we know that they know? *Comparative Cognition and Behavior Reviews*, *4*, 29–39.

Suda-King, C. (2008). Do orangutans (*Pongo pygmaeus*) know when they do not remember? *Animal Cognition*, *7*, 239–246.

Sutton, J. E., & Shettleworth, S. J. (2008). Memory without awareness: Pigeons do not show metamemory in delayed matching-to-sample. *Journal of Experimental Psychology: Animal Behavior Processes*, *34*, 266–282.

Terrace, H. S., & Metcalfe, J. (Eds.) (2005). *The missing link in cognition: Origins of self-reflective consciousness*. New York: Oxford University Press.

Washburn, D. A., Gulledge, J. P., Beran, M. J., & Smith, J. D. (2009). With his memory magnetically erased, a monkey knows he is uncertain. *Biology Letters*, *6*, 160–162.

Washburn, D. A., Smith, J. D., & Shields, W. E. (2006). Rhesus monkeys (*Macaca mulatta*) immediately generalize the uncertain response. *Journal of Experimental Psychology: Animal Behavior Processes*, *32*, 85–89.

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