

one to four in the mother tongue of the participants. E continued to demonstrate the movement sequence until participants could reproduce it by themselves. Then, E rotated them 180 degrees around their own axis, and positioned himself behind them (Figure 1: Rotation 1). E asked the participants to 'dance again'.

After the participants performed, E rotated them back into their original orientation (Figure 1: Rotation 2). If participants coded a RLRR dance in egocentric coordinates they should produce a RLRR sequence after both Rotations 1 and 2. Alternatively, if participants coded a RLRR dance in allocentric coordinates they should produce a LRLR sequence after Rotation 1 and a RLRR sequence after Rotation 2 (see also Supplemental Movie 1). Any response that did not match one of these two patterns was coded as 'other'. These were either mixed responses (RLRR, LRLR, LRLR) and/or failures to memorize the sequence (RLRR, LRLR, RLRL).

We tested 50 German and 35 Hai||om children between 4 and 12 years of age (German:  $M = 7;3$ ;  $SD = 2;7$ ; Hai||om:  $M = 7;8$ ;  $SD = 2;0$ ). There were 40 boys and 45 girls (German: 25 boys, 25 girls; Hai||om: 15 boys, 20 girls). German children produced 60% egocentric, 6% allocentric and 34% other responses. Hai||om children produced 20% egocentric, 54% allocentric and 26% other responses. This difference in response distribution is statistically significant (Fisher-exact,  $p < 0.0001$ ). Extracting 'other' responses, German children produced 91% egocentric and 9% allocentric responses. Hai||om children produced 27% egocentric and 73% allocentric responses. These distributions were significantly different from each other (Fisher-exact,  $p < 0.0001$ ) and different from chance (50%) in both populations (German:  $p < 0.0001$ , binomial test; Hai||om:  $p < 0.05$ , binomial test). The frequency of egocentric vs. allocentric responses did not correlate with age (German:  $p > 0.05$ , point-biserial; Hai||om:  $p > 0.05$ , point-biserial). The absence of an increase of locally dominant responses with age is surprising given previous research documenting an increase in cross-cultural differences with age [5]. Samples of younger children are needed to document the developmental trajectory of this task.

In summary, we show that the ways in which we memorize movements

of our own body differ in line with culture-specific preferences for how to conceive of spatial relations. These results support the view that, at least in some domains, cultural diversity goes hand in hand with cognitive diversity, and a cross-cultural perspective should play a central part in understanding how variable adult cognition is built from a common cognitive foundation.

#### Supplemental Data

Supplemental data are available at [http://www.cell.com/current-biology/supplemental/S0960-9822\(09\)01898-3](http://www.cell.com/current-biology/supplemental/S0960-9822(09)01898-3).

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#### References

1. Boas, F. (1911). *The Mind of Primitive Man* (New York: Macmillan).
2. Pinker, S. (2002). *The Blank Slate: The Denial of Human Nature in Modern Intellectual Life* (New York: Viking).
3. Segall, M.H., Campbell, D.T., and Herskovits, M.J. (1966). *The Influence of Culture on Visual Perception* (Indianapolis: Bobbs-Merrill).
4. Levinson, S.C. (2003). *Space in Language and Cognition: Explorations in Cognitive Diversity* (Cambridge: Cambridge University Press).
5. Haun, D.B.M., Rapold, C.J., Call, J., Janzen, G., and Levinson, S.C. (2006). Cognitive cladistics and cultural override in Hominid spatial cognition. *Proc. Natl. Acad. Sci. USA* 103, 17568–17573.
6. Majid, A., Bowerman, M., Kita, S., Haun, D.B.M., and Levinson, S.C. (2004). Can language restructure cognition? The case for space. *Trends Cogn. Sci.* 8, 108–114.
7. Li, P., and Gleitman, L. (2002). Turning the tables: language and spatial reasoning. *Cognition* 83, 265–294.
8. Levinson, S.C., Kita, S., Haun, D.B.M., and Rasch, B.H. (2002). Returning the tables: Language affects spatial reasoning. *Cognition* 84, 155–188.
9. Burgess, N. (2006). Spatial memory: how egocentric and allocentric combine. *Trends Cogn. Sci.* 10, 551–557.
10. Graziano, M.S.A., Cooke, D.F., and Taylor, C.S.R. (2000). Coding the location of the arm by sight. *Science* 290, 1782–1786.

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## Defensive tool use in a coconut-carrying octopus

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The use of tools has become a benchmark for cognitive sophistication. Originally regarded as a defining feature of our species, tool-use behaviours have subsequently been revealed in other primates and a growing spectrum of mammals and birds [1]. Among invertebrates, however, the acquisition of items that are deployed later has not previously been reported. We repeatedly observed soft-sediment dwelling octopuses carrying around coconut shell halves, assembling them as a shelter only when needed. Whilst being carried, the shells offer no protection and place a requirement on the carrier to use a novel and cumbersome form of locomotion — 'stilt-walking'.

To date, invertebrates have generally been regarded as lacking the cognitive abilities to engage in such sophisticated behaviours. Putative examples of tool use do exist among invertebrates — perhaps most convincingly in the form of the use of leaves or pellets of sand to collect and transport food in various ant species — but these behaviours have been regarded as distinct from tool use in higher animals on the grounds that they only occur in response to very specific stimuli [2]. This highlights a key feature of widely used functional definitions of tool use [3] — simple behaviours, such as the use of an object (or objects) as shelter, are not generally regarded as tool use, because the shelter is effectively in use all the time, whereas a tool provides no benefit until it is used for a specific purpose. This rules out examples such as the use of gastropod shells by hermit crabs, but includes situations where there is an immediate cost, but a deferred benefit, such as dolphins carrying sponges to protect against abrasion during foraging [4] and where an object is carried around in a non-functional form to be deployed when required [5].

The dramatic and complex colour and shape change abilities

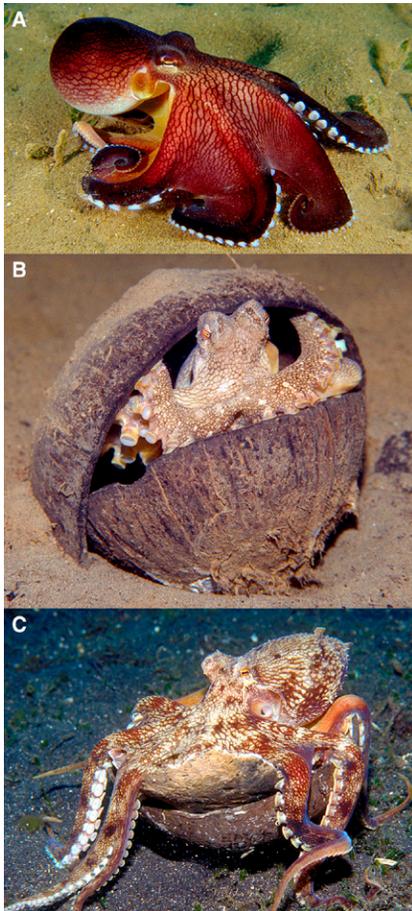


Figure 1. Veined octopus, *Amphioctopus marginatus*.

(A) Emerged on sand. (B) Using coconut shell halves assembled as shelter. (C) 'Stilt-walking' while carrying two stacked coconut shell halves (see Movie S1). Photos: M. Norman (A), R. Steene (B,C).

of cephalopods are well known [6]. However, recent observations of unexpected behavioural flexibility [7,8] and the capacity of these molluscs to physically manipulate their environment — prey manipulation, burying and den excavation [6]; arm dexterity [9]; den barricading with rocks/coral [10] — suggest that member species, particularly octopuses, could have the capacity to wield tools.

Between 1999 and 2008, we undertook more than 500 diver hours (day and night) on subtidal soft-sediment substrates to 18 metres deep off the coasts of Northern Sulawesi and Bali in Indonesia. Over this period, we studied more than 20 individuals of the Veined Octopus, *Amphioctopus marginatus* (Figure 1). Octopuses were encountered in a

range of behavioral states — emerged and active on the seafloor (Figure 1A); occupying empty gastropod shells, discarded coconut shell halves (Figure 1B) or other human refuse; or buried within the substrate (with or without accompanying shells; see Supplemental Movie S1 in the Supplemental Data available on-line with this issue). When flushed from shells by the observer, individuals quickly reoccupied the shells. On four occasions (three in Northern Sulawesi, one in Gilimanuk, Bali), individuals were observed to travel over considerable distances (up to 20 m) while carrying stacked coconut shell halves below their body (Figure 1C; Movie S1). For all instances of this behaviour, observing divers (JF, MN) remained static for up to 20 minutes at 1–2 metres from stationary octopuses, which emerged from the cover of one or two shells halves, arranged the shell(s) under the arm crown, and departed. Two shell-less octopuses were also observed to extract previously un-encountered coconut shells buried in the substrate, aided by jets of water to flush mud from shells (Movie S1).

To carry one or more shells, this octopus manipulates and arranges the shells so that the concave surfaces are uppermost, then extends its arms around the outside and walks using the arms as rigid limbs. We describe this lumbering octopedal gait as 'stilt walking' (see Movie S1). This unique and previously undescribed form of locomotion is ungainly and clearly less efficient than unencumbered locomotion (i.e. costly in terms of energy and increased predator risk compared with normal walking or the faster jet swimming escape; see Movie S2). While 'stilt-walking' the octopus gains no protective benefits from the shell(s) it is carrying as the head and body are fully exposed to potential predators. The only benefit is the potential future deployment of the shell(s) as a surface shelter (Figure 1B) or as a buried encapsulating lair (Movie S1).

The fact that the shell is carried for future use rather than as part of a specific task differentiates this behaviour from other examples of object manipulation by octopuses, such as rocks being used to barricade lair entrances [10]. Further evidence that this shell-carrying behaviour is an example of tool use

comes from the requirement of the octopus to correctly assemble the separate parts (when transporting two shells) in order to create a single functioning tool.

The behaviour reported here is likely to have evolved using large empty bivalve shells prior to the relatively recent supply of the clean and light coconut shell halves discarded by the coastal human communities adjacent to the marine habitat of this species.

Ultimately, the collection and use of objects by animals is likely to form a continuum stretching from insects to primates, with the definition of tools providing a perpetual opportunity for debate. However the discovery of this octopus tiptoeing across the sea floor with its prized coconut shells suggests that even marine invertebrates engage in behaviours that we once thought the preserve of humans.

#### Supplemental Data

Supplemental data are available at [http://www.cell.com/current-biology/supplemental/S0960-9822\(09\)01914-9](http://www.cell.com/current-biology/supplemental/S0960-9822(09)01914-9).

#### References

1. Hansell, M., and Ruxton, G.D. (2008). Setting tool use within the context of animal construction behaviour. *Trends Ecol. Evol.* 23, 73–78.
2. Baber, C. (2003). *Cognition and Tool Use: Forms of Engagement in Human and Animal Use of Tools* (Boca Raton: CRC Press).
3. Beck, B.B. (1980). *Animal Tool Behavior: The Use and Manufacture of Tools* (New York: Garland STPM Press).
4. Smolker, R.A., Richards, A.F., Connor, R.C., Mann, J., and Berggren, P. (1997). Sponge-carrying by Indian Ocean bottlenose dolphins: Possible tooluse by a delphinid. *Ethology* 103, 454–465.
5. Mulcahy, N.J., and Call, J. (2006). Apes save tools for future use. *Science* 312, 1038–1040.
6. Hanlon, R., and Messenger, J. (1996). *Cephalopod Behaviour* (Cambridge: Cambridge University Press).
7. Norman, M.D., Finn, J., and Tregenza, T. (1999). Female impersonation as an alternative reproductive strategy in giant cuttlefish. *Proc. Roy. Soc. Lond. B* 266, 1347–1349.
8. Norman, M.D., Finn, J., and Tregenza, T. (2001). Dynamic mimicry in an Indo-Malayan octopus. *Proc. Roy. Soc. Lond. B* 268, 1755–1758.
9. Huffard, C.L., Boneka, F., and Full, R.J. (2005). Underwater bipedal locomotion by octopuses in disguise. *Science* 307, 1927.
10. Mather, J. (1994). 'Home' choice and modification by juvenile *Octopus vulgaris* (Mollusca: Cephalopoda): specialized intelligence and tool use? *J. Zool.* 233, 359–368.

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