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Imitation

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Imitation is when an observer copies a model's body movement, and as such, it is a type of social interaction. Imitation is crucial for learning culture-specific gestures, such as facial expressions and dance movements, and it may also help us learn technical skills. In the 20th century, imitation was seen as a marker of cognitive sophistication in human infants and nonhuman animals and as an important but mysterious component of the distinctively human capacity for culture, one of the innate cognitive capacities that make us human. Since 2000, cognitive scientists have made progress in understanding the cognitive and neural bases of imitation and learned more about the development of imitation by reexamining claims that human newborns can imitate gestures. These advances suggest that the capacity to imitate is learned through social interaction and that the resulting competence plays an important role in the acquisition of social but not technical skills.

History

The term *imitation* has been used since antiquity in both academic and everyday life. At the turn of the 20th century, the French sociologist, Gabriel Tarde, and American developmental psychologist, James Mark Baldwin, used the notion of *imitation* very broadly to refer to any influence of one mind on another. This included social influences on thought, behavior, or emotion. Complaints about this broader definition appeared as early as 1900 from British ethologist Conwy Lloyd Morgan and led to alternative definitions that attempted to be clear, specific, and scientific. In a storm of neologisms, systematists distinguished *true imitation* from *emulation*, *mimicry*, *response facilitation*, and *observational conditioning*, among other terms (see [Heyes, 1994](#), for a fuller treatment).

Some psychologists and biologists continue to use imitation in the broad everyday sense as a synonym for *social learning*, encompassing all the ways that the behavior of an agent comes to resemble another's through social interaction [see [Social Learning](#)]. Today most researchers use imitation in a narrower sense to refer to social learning where observation of an agent (a *model*) causes the observer to behave like the model, specifically so that their behavior is alike in form. So imitation is when, after an observer views a model, parts of the observer's body move in a similar way to the parts of the model's body. We learn, for example, by imitation to narrow our eyes to express skepticism and to straighten our backs and expand our chests to express confidence.

Three developmental psychologists were highly influential in research on imitation (narrowly defined) in the 20th century: Jean Piaget, Andrew Meltzoff, and Michael Tomasello. Drawing on observations of his own children, [Piaget \(1962\)](#) argued that the capacity to imitate *invisible actions* such as facial expressions—actions that cannot be seen by the actor without a mirror—is learned through the infant's interaction with the world and does not appear until the end of the first year of life. Starting in the 1970s, Meltzoff published striking, contrary evidence that newborn human babies as young as 42 minutes old can imitate facial gestures ([Meltzoff & Moore, 1977](#)). From this they concluded that imitation is an innate, uniquely human cognitive capacity, involving *active intermodal matching*, representation of the look of an action

and the feel of an action in a *supramodal* psychological code ([Meltzoff & Moore, 1997](#)). Tomasello's view was more Piagetian. He argued that the development of human imitation is based on a genetically inherited propensity to see others as intentional beings but emphasized the importance of social interaction in the developmental process. This was supported by evidence that *enculturated* chimpanzees, raised by humans, are superior to chimpanzees reared by their biological mothers and as good as 18–30-month-old human children in imitating actions on objects ([Tomasello et al., 1993b](#)).

Piaget, Meltzoff, and Tomasello disagreed about the evolutionary-developmental origins of imitation, but there was a consensus among them and others working in the field that imitation is an important driver of social and technical development. On the social side, it was seen as an engine of socialization, intersubjectivity, and language acquisition [see [Language Acquisition](#)]; through imitation, children learn to act in conformity with the norms of their society, to appreciate that others have mental states like their own, and to communicate using spoken language. On the technical side, researchers in the 20th century saw imitation as a path to instrumental skills, a way of learning how to make and use tools and to operate machines. In the work of Tomasello and his collaborators, this became a theory of *cultural learning* in which imitation makes a major contribution to the uniquely human capacity to accumulate knowledge and skills over generations—not genetically, but via social learning ([Tomasello et al., 1993a](#)).

Although rich and lively in many ways, 20th century research did not yield a mechanistic psychological theory of imitation. It did not explain how a cognitive system can convert the sight of an action into performance of the same action, a visual representation derived from action observation into a proprioceptive or motoric representation of the kind required for action execution. Piaget said that solving this *correspondence problem* ([Brass & Heyes, 2005](#)) depends on *symbolic thought* and *self-consciousness*, and Meltzoff said that it involves supramodal representation, but they did not define these terms. For example, the Active Intermodal Mapping model of imitation characterized the supramodal code in a negative way, as neither visual nor proprioceptive. It did not give a positive account of the code's features or their mode of operation.

Core concepts

Testing for imitation

Imagine a father and his young daughter playing with some blocks. The father, or model, picks up a block using a power grip; he puts the block on the flat of his hand and lifts it by curling his fingers around the block. The daughter, or observer, appears to watch her father and then she too picks up a block. Is this imitation by the daughter of the father? The answer is not simply based on whether the daughter grabbed a block, but instead, what matters is *how* she did it. If she used a precision grip, for example, using only the tips of her fingers and thumb, it is less likely that she was imitating because the form of the actions is different, i.e., her fingers moved differently than her father's. If, on the other hand, she used a power grip—like her father—she may indeed be imitating. To be certain, researchers would need to establish whether a causal relationship exists between the daughter's observation of the father's grip and her own

use of that grip and whether the same grip was not produced by chance or because it is the only practical way of grasping these blocks. The gold standard way of checking for this in the laboratory is known as a *two-action test* or *cross-target procedure*. For example, the little girl would see her father use a power grip in some trials and a precision grip in others. If she was more likely to use the power grip in the first kind of trial than in the second, it would indicate that she was imitating her father. The *ghost control* is another method, although not as effective. Here, a control group sees the outcome of an action but not the actual body movements that produced them (e.g., a block rises in the air with no visible agent), whereas another group sees a model perform the action on the object (e.g., a block rises in the air held in a hand with a power grip). If individuals produce a power grip after observing a power grip, but not in the ghost condition, then perhaps the model's presence or action made the observers more interested in the block—an effect known as *stimulus enhancement*.

Imitation in nonhuman animals

Two-action and ghost control experiments have produced compelling reports of imitation in enculturated chimpanzees (reared from birth by humans). Another approach, *do-as-I-do training*, also appears to reveal imitation, where chimpanzees are rewarded for reproducing successive approximations to actions performed by a human model ([Custance et al., 1995](#)). On the other hand, in mother-reared chimpanzees, and other nonhuman primates, reports of imitation are controversial. For example, dating from the 1950s, claims that Japanese macaques imitate potato-washing and wheat-cleaning are considered misleading today because they use the broad, not narrow, sense of imitation ([Galef, 1976](#)). There are reports of imitation in domesticated dogs, budgerigars, pigeons, African Grey parrots, and Japanese quail ([Zentall, 2022](#)). However, the dogs and parrots had close relationships with their owners and the scientists who studied them. Like the chimpanzees who show imitation, they were enculturated [see [Animal Cognition](#); [Animal Culture](#)]. In contrast to other animals, adult humans are unparalleled imitators. In this sense, we are *Homo imitans* ([Meltzoff, 1988](#)). Nevertheless, quantification of human imitative skill remains a challenge, as does documentation of how humans vary across individuals and across cultures.

The correspondence problem

It is easy enough to imagine how someone could copy finger movements. When I look at you making an okay sign (connecting thumb and index finger in a circle while keeping the other fingers extended), I see something similar to what I would see if I watched myself make an okay sign. Consequently, my cognitive system could learn by trial and error how to make an okay sign. I could generate a variety of finger movements, compare the look of these with a visual memory of your action, and select for reproduction the variants that most closely resemble your okay action. But this trial-and-error process would not work for *perceptually opaque* actions, such as facial expressions and whole-body movements like bowing or shimmying ([Heyes & Ray, 2000](#)). These are actions that I cannot see when I am doing them or that look very different when I am watching you and when I am performing the action myself. So, how can a cognitive system imitate perceptually opaque actions? How can it map the “seen but unfelt” movements

of a model onto the “felt but unseen” movements of the self ([Meltzoff & Moore, 1997](#), p. 179)? This is the correspondence problem.

Researchers distinguish *motor imitation* from *vocal imitation* largely because motor imitation typically poses a more challenging correspondence problem. Imitation usually refers to motor imitation, i.e., the copying of body movement forms, whereas the more specific vocal imitation refers to copying of sequences or elements of sounds (e.g., speech, song) that occurs in humans, birds, and marine mammals (e.g., whales, dolphins). A sound can in principle be made by trial and error, by approximating the target sounds over time. Similarly, there is no correspondence problem for *emulation* (i.e., reproduction of the effects of actions on objects). If I see you moving a potato across a plate with your fork, I could reproduce the movements of the potato and fork in relation to the plate by moving things around until the objects on my plate look like the objects on yours. I do not need to copy how you hold the fork.

The role of imitation in cultural evolution

Humans are unlike other animals because our lives depend so heavily on cumulative culture; that is on knowledge and skills that have expanded and improved over generations via an inheritance process based on social learning rather than DNA [see [Cultural Evolution](#)]. This is obvious in contemporary Western societies that use complex technology, such as chatbots, but it is also true of small-scale societies. For example, with little insight into how they work, the people of many cultures in Africa and South America use a complex sequence of cutting, soaking, and drying procedures to make cassava, a plant containing cyanide, safe for human consumption.

Many cognitive scientists and biologists have seen imitation as a crucial psychological ingredient of cumulative culture, as a means by which humans dominate environments using technology. On this view, the cognitive ability to imitate arises through genetic evolution and supports cultural evolution. This means behavior can be passed down with accuracy and refined over generations. Prominent exponents of this view argue that *form copying* is distinctively human ([Tennie et al., 2017](#)) and other apes are not able to do form copying in the same way, even in places where it might seem possible (e.g., ape tool use, such as cracking nuts). Accordingly, nonhuman ape technology is claimed to have limited room for improvement. More broadly, this implies that imitation is critical for the cumulative cultural evolution of technology.

Questions, controversies, and new developments

Can newborns imitate?

The possibility of human neonatal imitation has caused controversy from its first report ([Meltzoff & Moore, 1977](#)). Using the gold standard cross-target procedure for imitation of various gestures (including tongue protrusion and mouth opening, as well as sad and happy faces), a study of 100 human newborns at four time points after birth found no evidence of imitation ([Oostenbroek et al., 2016](#)). In response, concerns have been raised about the methods of this study, for example, about the number of action

targets and duration over which infant responses were recorded ([Meltzoff et al., 2018](#)). Similar concerns have also been raised in other failures to find neonatal imitation regarding the model, response intervals, and statistical procedures. A meta-analysis addressing these concerns concluded that methodological factors cannot explain the replication failure, although researcher affiliation did matter, with a few laboratories being more likely to find large positive effects while most did not ([Davis et al., 2021](#)). In addition, there was evidence of publication bias, with positive findings more likely to be published.

There have also been reports of neonatal imitation in monkeys (e.g., [Wooddell et al., 2019](#)). Critically, these studies do not use the gold standard two-action or cross-target procedures. Instead of using tongue protrusion and lip-smacking as controls for one another, they used a rotating disk as a control. So, they measured whether there was more tongue protrusion after observing tongue protrusion than after observing a rotating disk, instead of the more stringent control of observing lip-smacking. This leaves open the possibility that true imitation of tongue protrusion is not occurring; instead, the results could be explained by the fact that biological, social stimuli elicit more reaction than nonbiological, asocial stimuli. Using the more stringent cross-target procedure, there was no evidence of imitation in newborn monkeys ([Redshaw, 2019](#)). It is of course difficult to provide evidence of absence—in this case, absence of an inborn capacity to imitate gestures; however, these recent studies have cast serious doubt on neonatal imitation for human and nonhuman primates.

Mirror neurons

Mirror neurons are brain cells that fire when an action is performed and when a similar action is passively observed (e.g., when a monkey picks up a grape with a precision grip and when that monkey observes a human pick up a grape with a precision grip, but not when the human uses a power grip). First discovered in monkeys in the 1990s ([Gallese et al., 1996](#)), evidence of mirror neurons—and brain areas with mirror properties—has been reported in humans and some birds. The function of mirror neurons is controversial. It has been claimed and vehemently denied that they contribute to language, action understanding, and, when they are atypical, the development of autism ([Gallese et al., 2011](#)). Not surprisingly, there is evidence that mirror neurons are involved in imitation. For example, disruptive magnetic stimulation of a mirror-neuron brain area, the human inferior frontal gyrus, interferes with imitation behavior ([Heyes & Catmur, 2022](#)).

It is unclear how important mirror neurons are in supporting imitation. They could be one of many neural mechanisms playing specific roles. But even if mirror neurons are crucial, their existence would relocate rather than resolve the correspondence problem. Cognitive scientists would need to explain how mirror neurons match observed with executed actions: how a mirror neuron knows that you opening your mouth is equivalent to me opening my mouth, rather than to me opening my eyes or sticking out my tongue.

Is imitation difficult?

The correspondence problem is greatest for facial gesture imitation and also poses a problem for whole-body movements. This is because an observer cannot see their own facial actions (without a mirror) or their whole-body movement when, for example, bowing with hands joined behind the back. The similarity would only be apparent from a third-party perspective, but it is unclear how an imitator can take that perspective. The imitator would have to transform a sensory representation into a motor representation. This process of transformation has been described in various ways, as *self-conscious*, *symbolic*, and *supramodal*, but not explicated. The correspondence problem poses two challenges then. It is a challenge for cognitive scientists who want to explain how cognitive systems can imitate and a challenge for cognitive systems that do the imitating. Finding it difficult to meet the first challenge, cognitive scientists have assumed that solving the correspondence problem is also difficult for cognitive systems. They have assumed that imitation depends on complex, dedicated processes. But this does not follow. In principle, like the flight of bumblebees, imitation could be difficult to explain but easy to do.

The Associative Sequence Learning model suggests that simple, general-purpose cognitive mechanisms are sufficient for imitation ([Catmur et al., 2009](#); [Heyes & Ray, 2000](#)). It does not accept that imitators need to know their action is similar to the action of a model from a third-party perspective; instead, it proposes that agents learn binary associations between observed and executed action components through temporal contingency. This simple mechanism can explain how an agent can imitate familiar actions that they have performed in the past (also known as *mimicry*) and how an agent imitates others by learning a repertoire of associations and using this to produce new actions (*true imitation* or *imitation learning*). This type of learning requires only the mechanisms of associative learning that underlie Pavlovian conditioning. However, to learn associations that will support imitation, the cognitive system must develop in a complex, sociocultural environment that provides a rich array of correlated sensorimotor experience—experience in which actors see and do the same action at the same time (e.g., ritual practices that scaffold synchronous actions, child-rearing practices where adults imitate children).

Where does imitation come from?

Is imitation a cognitive instinct ([Pinker, 1995](#))—a genetically inherited component of the human mind—or a cognitive gadget ([Heyes, 2020](#))—a capacity that is built from “old parts,” cognitive processes we have in common with other animals, through social interaction in childhood? The Active Intermodal Matching model (see the History section) suggests imitation is an instinct, a view that is supported by evidence of imitation in newborn humans and monkeys and weakened by failures to replicate these results. In contrast, the Associative Sequence Learning model suggests imitation is a gadget, a piece of mental technology fashioned by the cultures in which we grow up. This is a radical theory, but it has support from research with nonhuman animals, children, adults, and artificial cognitive systems ([Catmur et al., 2009](#); [Cook et al., 2014](#); [de Klerk et al., 2019](#)).

In support of the gadget theory, experiments with adults show that the propensity to imitate can be modified with novel sensorimotor experience, and this has consequences for mirror neuron brain areas too. For example, when passively viewing an index finger move, the index finger muscles in the observer's hand normally become activated. But this can be changed. If people are trained to move their little finger when an agent's index finger moves, then viewing an index finger move causes more activation of their own little finger than index finger. Sensorimotor learning converts an automatic tendency to imitate into an automatic tendency to do the opposite of what was observed. Also, robots and other artificial cognitive systems have been successfully trained to imitate via the associative processes that, according to the gadget theory, power the development of imitation in humans ([Bhoopchand et al., 2023](#); [Breazeal et al., 2005](#)).

What does imitation contribute to culture?

The idea that imitation is closely linked to human culture was endorsed in various guises across the 20th century, but it has recently lost favor. There are several reasons to question whether imitation underpins the emergence of human technology. First, learning to make Acheulian hand axes (i.e., teardrop shaped stone tools taken as evidence of emerging cumulative culture in hominins) requires hundreds of hours of practice. Cognitive archaeologists have shown that knapping requires keen perceptual and attentional capacities (in order to make effective strikes) and patience (because learning is slow; [Stout & Hecht, 2017](#)), suggesting a smaller role of imitation, if any. Second, transmission chain experiments suggest that observing the outcome of other people's actions can be as effective as seeing the actions directly. For example, when tasked with building a raw spaghetti tower as high as possible, successive groups improve the strength and height of towers to the same extent when imitation is not possible (i.e., only able to see the final tower produced by the previous group) as when imitation is possible (i.e., seeing the actions of the previous group making a tower; [Caldwell & Millen, 2009](#)). Accordingly, some cultural evolution researchers have concluded that imitation is just one of many precursors of cumulative culture, leaving its particular role unspecified.

However, it is possible that imitation is critical in the cultural learning of gestures if not technology. Gesture production depends critically on how parts of the body move relative to one another. For example, lowering eyebrows indicates doubt, whereas raising eyebrows indicates surprise in Western cultures, and the okay sign only works when the tips of the forefinger and thumb are in contact. This does not hold for making a hand axe, which depends on properties of the stone and the direction, location, and force of the hammer strike on the core rather than the exact reproduction of hand actions. So imitation may play a more important role in communicative and ritualistic behaviors that impact cooperation within groups ([Legare, 2017](#)). These behaviors could have indirectly contributed to the cumulative cultural evolution of technology by enabling risky types of cooperation, such as teaching over longer time periods and the division of labor across individuals.

Broader connections

Studies of *overimitation* show that children are more likely than nonhuman apes to copy unnecessary or irrelevant actions to the achievement of a goal ([Clay & Tennie, 2018](#))—for example, to wave a stick before using it to open a box. This suggests that, whatever the origins and character of the mechanisms that make imitation possible, children are highly motivated to copy the actions of others. It is not yet clear whether this heightened motivation is due to a genetically inherited drive to copy or due to early experience of being rewarded with social approval for copying the actions of others ([Over, 2020](#)).

Social psychologists have shown that adults often unconsciously imitate the facial expressions and gestures of people with whom they are conversing and that this promotes liking and trust. It is not yet clear to what extent this *chameleon effect* ([Chartrand & Bargh, 1999](#)) is due to spatial similarity rather than temporal contingency between the actions of conversation partners ([Catmur & Heyes, 2013](#)).

It is claimed that autistic people have impaired imitation abilities, but this has been questioned by studies showing that when attentional factors are controlled, autistic individuals are as likely or more likely than neurotypical individuals to imitate facial gestures and hand movements ([Press et al., 2010](#)). Consistent with this, there is little evidence supporting the *broken mirror* theory of autism, the idea that people with autism have atypical mirror neuron systems ([Hamilton, 2013](#)).

Further reading

- Bhoopchand, A., Brownfield, B., Collister, A., Dal Lago, A., Edwards, A., Everett, R., Fréchette, A., Oliveira, Y. G., Hughes, E., Mathewson, K. W., Mendolicchio, P., Pawar, J., Pîslar, M., Platonov, A., Senter, E., Singh, S., Zacherl, A., & Zhang, L. M. (2023). Learning few-shot imitation as cultural transmission. *Nature Communications*, 14, 7536. <https://doi.org/10.1038/s41467-023-42875-2>
- Heyes, C. (2023). Imitation and culture: What gives? *Mind & Language*, 38(1), 42–63. <https://doi.org/10.1111/mila.12388>
- Slaughter, V. (2021). Do newborns have the ability to imitate? *Trends in Cognitive Sciences*, 25(5), 377–387. <https://doi.org/10.1016/j.tics.2021.02.006>
- Stout, D., & Hecht, E. E. (2017). Evolutionary neuroscience of cumulative culture. *Proceedings of the National Academy of Sciences*, 114(30), 7861–7868. <https://doi.org/10.1073/pnas.1620738114>

References

- Bhoopchand, A., Brownfield, B., Collister, A., Dal Lago, A., Edwards, A., Everett, R., Fréchette, A., Oliveira, Y. G., Hughes, E., Mathewson, K. W., Mendolicchio, P., Pawar, J., Pîslar, M., Platonov, A., Senter, E., Singh, S., Zacherl, A., & Zhang, L. M. (2023). Learning few-shot imitation as cultural transmission. *Nature Communications*, 14, 7536. <https://doi.org/10.1038/s41467-023-42875-2>

- Brass, M., & Heyes, C. (2005). Imitation: Is cognitive neuroscience solving the correspondence problem? *Trends in Cognitive Sciences*, 9(10), 489–495. <https://doi.org/10.1016/j.tics.2005.08.007>

↩

- Breazeal, C., Buchsbaum, D., Gray, J., Gatenby, D., & Blumberg, B. (2005). Learning from and about others: Towards using imitation to bootstrap the social understanding of others by robots. *Artificial Life*, 11(1-2), 31–62. <https://doi.org/10.1162/1064546053278955>

↩

- Caldwell, C. A., & Millen, A. E. (2009). Social learning mechanisms and cumulative cultural evolution: Is imitation necessary? *Psychological Science*, 20(12), 1478–1483. <https://doi.org/10.1111/j.1467-9280.2009.02469.x>

↩

- Catmur, C., & Heyes, C. (2013). Is it what you do, or when you do it? The roles of contingency and similarity in pro-social effects of imitation. *Cognitive Science*, 37(8), 1541–1552. <https://doi.org/10.1111/cogs.12071>

↩

- Catmur, C., Walsh, V., & Heyes, C. (2009). Associative sequence learning: The role of experience in the development of imitation and the mirror system. *Philosophical Transactions of the Royal Society B*, 364(1528), 2369–2380. <https://doi.org/10.1098/rstb.2009.0048>

↩

- Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception–behavior link and social interaction. *Journal of Personality and Social Psychology*, 76(6), 893–910. <https://doi.org/10.1037/0022-3514.76.6.893>

↩

- Clay, Z., & Tennie, C. (2018). Is overimitation a uniquely human phenomenon? Insights from human children as compared to bonobos. *Child Development*, 89(5), 1535–1544. <https://doi.org/10.1111/cdev.12857>

↩

- Cook, R., Bird, G., Catmur, C., Press, C., & Heyes, C. (2014). Mirror neurons: From origin to function. *Behavioral and Brain Sciences*, 37(2), 177–192. <https://doi.org/10.1017/S0140525X13000903>

↩

- Custance, D. M., Whiten, A., & Bard, K. A. (1995). Can young chimpanzees (*Pan troglodytes*) imitate arbitrary actions? Hayes and Hayes (1952) revisited. *Behaviour*, 132(11-12), 837–859. <https://doi.org/10.1163/156853995X00036>

↩

- Davis, J., Redshaw, J., Suddendorf, T., Nielsen, M., Kennedy-Costantini, S., Oostenbroek, J., & Slaughter, V. (2021). Does neonatal imitation exist? Insights from a meta-analysis of 336 effect sizes. *Perspectives on Psychological Science*, 16(6), 1373–1397. <https://doi.org/10.1177/1745691620959834>

↩

- de Klerk, C. C. J. M., Lamy-Yang, I., & Southgate, V. (2019). The role of sensorimotor experience in the development of mimicry in infancy. *Developmental Science*, 22(3), e12771. <https://doi.org/10.1111/desc.12771>

↩

- Galef, B. G., Jr. (1976). Social transmission of acquired behavior: A discussion of tradition and social learning in vertebrates. *Advances in the Study of Behavior*, 6, 77–100. [https://doi.org/10.1016/S0065-3454\(08\)60082-0](https://doi.org/10.1016/S0065-3454(08)60082-0)

↩

- Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, 119(2), 593–609. <https://doi.org/10.1093/brain/119.2.593>

↩

- Gallese, V., Gernsbacher, M. A., Heyes, C., Hickok, G., & Iacoboni, M. (2011). Mirror neuron forum. *Perspectives on Psychological Science*, 6(4), 369–407. <https://doi.org/10.1177/1745691611413392>

↩

- Hamilton, A. F. (2013). Reflecting on the mirror neuron system in autism: A systematic review of current theories. *Developmental Cognitive Neuroscience*, 3, 91–105. <https://doi.org/10.1016/j.dcn.2012.09.008>

↩

- Heyes, C. (2020). Psychological mechanisms forged by cultural evolution. *Current Directions in Psychological Science*, 29(4), 399–404. <https://doi.org/10.1177/0963721420917736>

↩

- Heyes, C. M. (1994). Social learning in animals: Categories and mechanisms. *Biological Reviews*, 69(2), 207–231. <https://doi.org/10.1111/j.1469-185X.1994.tb01506.x>

↩

- Heyes, C. M., & Ray, E. D. (2000). What is the significance of imitation in animals? In P. J. B. Slater, J. S. Rosenblatt, C. T. Snowdon, & T. J. Roper (Eds.), *Advances in the study of behavior* (Vol. 29, pp. 215–245). Academic Press. [https://doi.org/10.1016/S0065-3454\(08\)60106-0](https://doi.org/10.1016/S0065-3454(08)60106-0)

↩

- Heyes, C., & Catmur, C. (2022). What happened to mirror neurons? *Perspectives on Psychological Science*, 17(1), 153–168. <https://doi.org/10.1177/1745691621990638>

↩

- Legare, C. H. (2017). Cumulative cultural learning: Development and diversity. *Proceedings of the National Academy of Sciences*, 114(30), 7877–7883. <https://doi.org/10.1073/pnas.1620743114>

↩

- Meltzoff, A. N. (1988). The human infant as “Homo imitans.” In T. R. Zentall & B. G. Galef, Jr. (Eds.), *Social learning: Psychological and biological perspectives* (pp. 319–341). Psychology Press.

↩

- Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science*, 198(4312), 75–78. <https://doi.org/10.1126/science.198.4312.75>

↩

- Meltzoff, A. N., & Moore, M. K. (1997). Explaining facial imitation: A theoretical model. *Early Development and Parenting*, 6(3-4), 179–192. [https://doi.org/10.1002/\(SICI\)1099-0917\(199709/12\)6:3/4<179::AID-EDP157>3.0.CO;2-R](https://doi.org/10.1002/(SICI)1099-0917(199709/12)6:3/4<179::AID-EDP157>3.0.CO;2-R)

↩

- Meltzoff, A. N., Murray, L., Simpson, E., Heimann, M., Nagy, E., Nadel, J., Pedersen, E. J., Brooks, R., Messinger, D. S., Pascalis, L., Subiaul, F., Paukner, A., & Ferrari, P. F. (2018). Re-examination of Oostenbroek et al. (2016): Evidence for neonatal imitation of tongue protrusion. *Developmental Science*, 21(4), e12609. <https://doi.org/10.1111/desc.12609>

↩

- Oostenbroek, J., Suddendorf, T., Nielsen, M., Redshaw, J., Kennedy-Costantini, S., Davis, J., Clark, S., & Slaughter, V. (2016). Comprehensive longitudinal study challenges the existence of neonatal imitation in humans. *Current Biology*, 26(10), 1334–1338. <https://doi.org/10.1016/j.cub.2016.03.047>

↩

- Over, H. (2020). The social function of imitation in development. *Annual Review of Developmental Psychology*, 2, 93–109. <https://doi.org/10.1146/annurev-devpsych-033020-024051>

↩

- Piaget, J. (1962). *Play, dreams and imitation in childhood* (C. Gattegno & F. H. Hodgson, Trans.). WW Norton.

↩

- Pinker, S. (1995). *The language instinct: The new science of language and mind* (Vol. 7529). Penguin.

↩

- Press, C., Richardson, D., & Bird, G. (2010). Intact imitation of emotional facial actions in autism spectrum conditions. *Neuropsychologia*, 48(11), 3291–3297.
<https://doi.org/10.1016/j.neuropsychologia.2010.07.012>

↩

- Redshaw, J. (2019). Re-analysis of data reveals no evidence for neonatal imitation in rhesus macaques. *Biology Letters*, 15(7), 20190342. <https://doi.org/10.1098/rsbl.2019.0342>

↩

- Stout, D., & Hecht, E. E. (2017). Evolutionary neuroscience of cumulative culture. *Proceedings of the National Academy of Sciences*, 114(30), 7861–7868. <https://doi.org/10.1073/pnas.1620738114>

↩

- Tennie, C., Premo, L. S., Braun, D. R., & McPherron, S. P. (2017). Early stone tools and cultural transmission: Resetting the Null Hypothesis. *Current Anthropology*, 58(5), 652–672.
<https://doi.org/10.1086/693846>

↩

- Tomasello, M., Kruger, A. C., & Ratner, H. H. (1993a). Cultural learning. *Behavioral and Brain Sciences*, 16(3), 495–511. <https://doi.org/10.1017/S0140525X0003123X>

↩

- Tomasello, M., Savage-Rumbaugh, S., & Kruger, A. C. (1993b). Imitative learning of actions on objects by children, chimpanzees, and enculturated chimpanzees. *Child Development*, 64(6), 1688–1705.
<https://doi.org/10.2307/1131463>

↩

- Wooddell, L. J., Simpson, E. A., Murphy, A. M., Dettmer, A. M., & Paukner, A. (2019). Interindividual differences in neonatal sociality and emotionality predict juvenile social status in rhesus monkeys. *Developmental Science*, 22(2), e12749. <https://doi.org/10.1111/desc.12749>

↩

- Zentall, T. R. (2022). Mechanisms of copying, social learning, and imitation in animals. *Learning and Motivation*, 80, 101844. <https://doi.org/10.1016/j.lmot.2022.101844>

↩