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Imitation, Emotion, and Embodiment

1. Introduction

What mechanisms allow humans to understand and influence one other? What lets us learn, follow, and adapt to different social norms and customs? This chapter discusses one such mechanism – *imitation*. Recent and growing scientific interest in imitation comes from the recognition of its broadly important role in sociality. First, imitation facilitates *social learning* – the transmission of affective and cognitive skills, norms, traditions, and rituals. Second, imitation aids *social communication* – not only when it helps an individual to understand emotions and gestures but also when it signals the individual's group preferences to outside observers. Third, the capacity for imitation is a form of a *social skill* – reflecting cognitive, emotional, and motivational properties of an individual. Excellent research work has been done on all these aspects of imitation and emulation (where the observer mostly focuses on the demonstrator's goals and environmental effects, rather than specific actions). There are several recent and comprehensive reviews available that focus not only on the basic mechanisms but also on larger implications of imitation for building cultures, societies, norms, rules, and even laws.[1]

[1] B. Brożek, *Rule-Following. From Imitation to the Normative Mind*, Copernicus Center Press, Kraków 2013; G. Csibra, G. Gergely, "Natural pedagogy", *Trends in Cognitive Sciences* 13, 2009, 148–153; A. Mesoudi, "How cultural evolutionary theory can inform social psychology and vice versa", *Psychological Review* 116, 2009, 929–952; M. Tomasello, *A Natural History of Human Thinking*, Harvard University Press, Cambridge (MA) 2014.

Much research on imitation focuses on intentional behaviors – or cases where individuals engage in explicit (and sometimes strategic) considerations before deciding to imitate, or, equally importantly, *not* to imitate. These decisions may consider who specifically will be imitated, what specific behaviors observers will be copied, and what exact form the individual's action will take. Instead, we will focus on *spontaneous imitation*, which we will also refer to as *spontaneous mimicry*. Both of these terms refer to a phenomenon where simply observing another individual's behavior elicits a corresponding action in the observer, without any direct intention or requirement to imitate. We propose that this phenomenon illuminates the functioning of the mind and the brain, but also sheds light on the basic nature of human sociality.

More specifically, our chapter focuses on two central questions. First, what does spontaneous mimicry reveal about the links between perception and action and the role of somatosensory processes in higher-order conceptual information? Second, when is spontaneous mimicry driven by simpler processes (e.g., stimulus matching), and when is it driven by more complex interpretations and goals, especially in the social context. We start our argument with a brief discussion for the framework of embodied cognition, as it helps locate the description of empirical research in larger theoretical debates. Next, we discuss how motor reactions emerge during processing of an emotional stimulus, along with both their associative and causal roles in perception and cognition. After that, we consider spontaneous imitation in the context of higher-order social variables, where we discuss the interplay of the reflexive (associative) and reflective (rational) aspects of mimicry in interactions (which include dealing with robots, individuals varying in social power, and third-party observation of mimicry). Finally, we offer some implications of this work for understanding the general nature of social cognition.

2. Embodiment as a framework to understand spontaneous imitation

Much, though not all, research on spontaneous imitation uses the theoretical framework of *embodiment* – or grounded cognition.[2] This framework proposes that higher-level processing is grounded in the organism's sensory and motor experience.[3] According to embodiment theories, processing of objects, people, and even abstract concepts is tied to somatosensory and motor resources. On this perspective, perception and cognition involve generation or reproduction ("simulation") of relevant actions, sensations, and experiences. For example, consider a simple object – a watermelon. When merely viewing a watermelon, the perceiver may spontaneously generate gustatory sensations, like "sweet."[4] When merely thinking about a watermelon, the perceiver may recreate the sensory experience of smoothness, green skin, or sugary flavor. Similarly, individuals may generate and recreate such somatosensory and motor reactions when perceiving or thinking about facial expressions, bodily gestures, or even abstract concepts.

One central question for embodiment theories is the functional role of somatosensory reenactments in perception and cognition. Clearly, some reenactments can be incidental and perhaps best described as "stimulations," rather than "simulations" (e.g., reflexively salivating when seeing, or even merely thinking about a watermelon). Other reenactments can be top-down driven, and perhaps best compared to con-

[2] P. M. Niedenthal, L. W. Barsalou, P. Winkielman, S. Krauth-Gruber, F. Ric, "Embodiment in attitudes. Social perception, and emotion", *Personality and Social Psychology Review* 9, 2005, 184–211; T. W. Schubert, G. R. Semin, "Embodiment as a unifying perspective for psychology", *European Journal of Social Psychology* 39 (7), 2009, 1135–1141.

[3] L. W. Barsalou, "Perceptual symbol system", *Behavioral and Brain Sciences* 22, 1999, 577–660; L.W. Barsalou, "Grounded cognition", *Annual Review of Psychology* 59, 2008, 617–645; A. Clark, "An embodied cognitive science?", *Trends in Cognitive Sciences* 3, 1999, 345–351, M. Wilson, "Six views of embodied cognition", *Psychonomic Bulletin and Review* 9, 2002, 625–636.

[4] W. K. Simmons, A. Martin, L. W. Barsalou, "Pictures of appetizing foods activate gustatory cortices for taste and reward", *Cerebral Cortex* 15, 2005, 1602–1608.

ceptually-guided somatosensory imagery. For instance, when asked to consider "half a watermelon" (as opposed to just "watermelon"), people spontaneously generate visual property of "red," rather than "green."[5]

Critically, in both cases, these reenactments can potentially causally contribute to perception and cognition, as we will discuss shortly. Note also that some reenactments can be full-blown conscious experiences that manifest both centrally and peripherally (e.g., a simulation elicited by a vivid image of vomit involves disgust feelings and bodily cringes). However, this is not necessary. Instead, simulations can involve only the brain's central modality system (without any peripheral instantiation) and recreate enough of the original experience to be useful in further processing.[6] Having said this, it is also important to remember that somatosensory effects may not occur in context in which their generation is irrelevant for processing.[7] As we will see shortly, all these assumptions of embodiment theories are reasonably supported by empirical research, including research on spontaneous mimicry. For a more comprehensive review of this and related literature in the emotion domain.[8]

3. Emotional facial expressions

Among some of the most important social stimuli are facial expressions. They not only communicate and express emotion but also key signals of approval and disapproval.[9] According to traditional models

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[5] L. L. Wu, L. W. Barsalou, "Perceptual simulation in conceptual combination: Evidence from property generation", *Acta Psychologica* 132, 2009, 173–189.

[6] A. R. Damasio, *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*, Harcourt, New York 1999.

[7] E.g. L. A. M. Lebois, C. D. Wilson-Mendenhall, L. W. Barsalou, "Are automatic conceptual cores the gold standard of semantic processing? The context-dependence of spatial meaning in grounded congruency effects", *Cognitive Science* 2014, doi: 10.1111/cogs.12174.

[8] See P. Winkielman, P. Niedenthal, J. Wielgosz, J. Eelen, L. C. Kavanagh, "Embodiment of cognition and emotion", in *APA Handbook of Personality and Social Psychology, Vol. 1. Attitudes and social cognition*, M. Mikulincer, P. R. Shaver, E. Borgida, J. A. Bargh (eds.), APA, Washington, DC 2015, pp. 151–175.

[9] D. Keltner, J. Haidt, "Social functions of emotions at four levels of analysis", *Cognition and Emotion* 13, 1999, 505–521.

of cognition, expression recognition is primarily a matter of detecting relevant features (e.g., curves at the corners of the mouth, lines in the corners of the eyes, etc.). Thus, expression recognition is just like recognition for any other object. For example, recognizing a smile is roughly like recognizing that an analogue clock is showing 2:45. Of course, face processing may involve some unique circuitry specialized in managing holistic information, but the essence of this process is captured by feature extraction models.[10]

In contrast, the embodied cognition framework highlights an important difference between clocks and faces – we not only see faces but we also *have* them ourselves. As a result, we can employ our own somatosensory and motor representations in the recognition process. Why should this matter? First, it simply extends the available perceptual resources to compatible motor resources involved in facial action.[11] Second, the embodied resources help the perceiver to verify (via facial feedback) a match between one's own state and the affective state of the person they are perceiving.[12] Given this, many have argued that spontaneous imitation can play a useful role in the face recognition process, at least occasionally.[13] Historically, these points go back to the original interest in the motor links between emotion and cognition and the mechanisms of facial feedback.[14]

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[10] E.g. N. Kanwisher, J. McDermott, M. M. Chun, "The fusiform face area: A module in human extrastriate cortex specialized for face perception", *The Journal of Neuroscience* 17, 1997, 4302–4311.

[11] R. Adolphs, H. Damasio, D. Tranel, G. Cooper, A. Damasio, "A role for the somatosensory cortices in the visual recognition of emotion as revealed by three dimensional lesion mapping", *Journal of Neuroscience* 20, 2000, 2683–2690.

[12] D. N. McIntosh, "Facial feedback hypotheses: Evidence, implications, and directions", *Motivation and Emotion* 20, 1996, 121–147.

[13] P. M. Niedenthal, *et al.*, "Embodiment in attitudes...", *op. cit.*

[14] R. Buck, "Nonverbal behavior and the theory of emotion: The facial feedback hypothesis", *Journal of Personality and Social Psychology* 38, 1980, 811–824; J. D. Laird, "Self-attribution of emotion: The effects of expressive behavior on the quality of emotional experience", *Journal of Personality and Social Psychology* 29, 1974, 475–486; R. B. Zajonc, H. Markus, "Affect and cognition: The hard interface", in *Emotions, Cognition, and Behavior*, C. E., Izard, J. Kagan, & R.B., Zajonc (eds), Cambridge University Press, New York 1984, pp. 73–102.

4. Spontaneous mimicry of facial expressions

There is much evidence that processing of emotional expressions involves somatosensory and motor resources. For example, merely observing facial expressions enhances brain activity in somatosensory areas.[15] Importantly, such mere observation leads to actual facial movements in the perceiver. Simply put, when people see smiles, they spontaneously produce incipient smiles, and when they see frowns, they spontaneously produce incipient frowns. This process is driven by both motor match and valence.[16] It also seems to be relatively automatic: it is quick,[17] difficult to control,[18] and can be triggered with minimal and even subliminal input.[19]

5. Causal role of motor processes

A popular view sees motor activations as an incidental byproduct of frequent associative pairings between perception and action.[20] As an

[15] E.g. C. Keysers, J. H. Kaas, V. Gazzola, "Somatosensation in social perception", *Nature Reviews Neuroscience* 11, 2010, 417–428; L. Carr, M. Iacoboni, M. C. Dubeau, J. C. Mazziotta, G. L. Lenzi, "Neural mechanisms of empathy in humans: A relay from neural systems for imitation to limbic areas", *Proceedings of the National Academy of Science USA* 100, 2003, 5497–5502; P. Molenberghs, R. Cunnington, J. B. Mattingley, "Brain regions with mirror properties: A metaanalysis of 125 human fMRI studies", *Neuroscience and Biobehavioral Reviews* 36, 2012, 341–349.

[16] E. J. Moody, D. N. McIntosh, L. J, Mann, K. R. Weisser, "More than mere mimicry? The influence of emotion on rapid facial reactions to faces", *Emotion* 7, 2007, 447–457; R. Neumann, S. Schulz, L. Lozo, G. Alpers, "Automatic facial responses to near-threshold presented facial displays of emotion: Imitation or evaluation", *Biological Psychology* 96, 2014, 144–149.

[17] U. Dimberg, "Facial reactions to facial expressions", *Psychophysiology* 18, 1982, 643–647.

[18] U. Dimberg, M. Thunberg, S. Grunedal, "Facial reactions to emotional stimuli: Automatically controlled emotional responses", *Cognition and Emotion* 16, 2002, 449–471.

[19] B. Bornemann, P. Winkielman, E. van der Meer, "Can you feel what you don't see? Using internal feedback to detect briefly presented emotional stimuli", *International Journal of Psychophysiology* 85, 2012, 116–124; U. Dimberg, M. Thunberg, K. Elmehed, "Unconscious facial reactions to emotional facial expressions", *Psychological Science* 11, 2000, 86–89.

[20] R. Cook, G. Bird, C. Catmur, C. Press, C. Heyes, "Mirror neurons: From origin to function", *Behavioral and Brain Sciences* 37, 2014, 177–241.

example, when we make a smile, we typically see a smile. Thus, motor processes could accompany perception without *causally* contributing to it. This may be true in some (or even many) cases, but there is also evidence for the causal role of mimicry in emotion recognition. For instance, blocking a specific facial muscle sometimes impairs the ability to detect facial expressions that involve that specific muscle.[21] One should note, however, that this evidence is much stronger for smiles (compared to other emotions) and for expressions that are relatively weak, ambiguous, brief, or complex. For example, inhibition of smiles results in poorer differentiation between "true" and "false" smiles – a task that relies on processing of very subtle facial distinctions.[22] It is also interesting that peripheral blocking and facilitation effects have also been shown for detection of more complex emotional states and personality traits (such as those implied in the mind-in-the-eyes task) – thus suggesting the possible role of somatosensory facial feedback in higher order social cognition.[23]

Further support for the causal role of motor processes in face processing comes from natural and experimental (temporary) lesion studies showing emotion recognition impairments as a result of (*i*) damage to sensory-motor areas and (*ii*) transitional inactivation of the fusiform face area (FFA) with repetitive transcranial magnetic stim-

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[21] L. M. Oberman, P. Winkielman, V. S. Ramachandran, "Face to face: Blocking facial mimicry can selectively impair recognition of emotional expressions", *Social Neuroscience* 2 (3-4), 2007, 167–178; M. Stel, A. van Knippenberg, "The role of facial mimicry in the recognition of affect", *Psychological Science* 19 (10), 2008, 984–985; P. M. Niedenthal, M. Brauer, J. B. Halberstadt, Å Innes-Ker, "When did her smile drop? Facial mimicry and the influences of emotional state on the detection of change in emotional expression", *Cognition and Emotion* 15, 2001, 853–864.

[22] M. Maringer, E. G. Krumhuber, A. H. Fischer, P. M. Niedenthal, "Beyond smile dynamics: Mimicry and beliefs in judgments of smiles", *Emotion* 11, 2011, 181; M. Rychlowska, E. Cañadas, A. Wood, E. G. Krumhuber, A. Fischer, P. M. Niedenthal, "Blocking mimicry makes true and false smiles look the same", *PLoS One* 9(3), 2014, e90876.

[23] D. Neal, T. Chartrand, "Embodied emotion perception: Amplifying and dampening facial feedback modulates emotion perception accuracy", *Social Psychological and Personality Science* 2, 2011, 673–678.

ulation (TMS).[24] Finally, there is some evidence for the opposite influence – better emotion recognition after facilitation of motor processes.[25] Specifically, this study used an imitation training paradigm in which participants (i) matched expressions of virtual characters (strengthening the perception-action link), and (ii) drove the expressions of the virtual characters by moving their own faces (strengthening the action-perception link). The results suggest that participants who performed correctly in the facial imitation training improved their emotion recognition skills.

Clearly, more work is needed to understand how sensory and motor process contribute to emotion recognition. One puzzle involves knowing when they are *causally* necessary. For instance, in some studies, the degree of mimicry was not correlated with decoding accuracy.[26] Further, individuals with *Moebius Syndrome* (a congenital condition that causes facial paralysis, thus preventing mimicry) do not differ from control participants in accuracy for identifying clear facial expressions.[27] One possible solution to this puzzle is that somatosensory activations play a causal role only when recognition cannot be achieved via a simple, highly automated, fast pattern-recognition strategy (instead requiring more complex construction of somatosensory simulation).

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[24] R. Adolphs, *et al.*, "A role for the somatosensory...", *op. cit.*; D. Pitcher, L. Garrido, V. Walsh, B. Duchaine, "TMS disrupts the perception and embodiment of facial expressions", *Journal of Neuroscience* 28(36), 2008, 8929–8933.

[25] D. Deriso, J. Susskind, J. Tanaka, P. Winkielman, J. Herrington, R. Schultz, M. Bartlett, "Exploring the facial expression perception-production link using real-time automated facial expression recognition", in *Computer Vision – ECCV 2012. Workshops and Demonstrations*, A. Fusiello, V. Murino, R. Cucchiara (eds.), vol. 7584, Springer, Berlin – Heidelberg 2012, pp. 270–279.

[26] S. Blairy, P. Herrera, U. Hess, "Mimicry and the judgment of emotional facial expressions", *Journal of Nonverbal Behavior* 23, 1999, 5–41.

[27] K. Rives Bogart, D. Matsumoto, "Facial mimicry is not necessary to recognize emotion: Facial expression recognition by people with Moebius syndrome", *Social Neuroscience* 5 (2), 2010, 241–251.

6. The sensorimotor bridge between faces and concepts

One fascinating role for spontaneous mimicry is to link sensorimotor representations with higher-order concepts. Empirically, this notion was explored in a study testing whether people's own facial reactions to other individuals' faces interact with conceptual information about those faces.[28] In the first part of the study, participants were asked to examine faces of different individuals with ambiguous (mixed) facial expressions and simply consider the possibility that these individuals might feel "happy" or "angry." During this task, EMG responses showed that the same faces paired with the "happy" concept elicited more smiling than faces paired with the "angry" concept. This finding reveals the impact of merely thinking about concepts of "happiness" or "anger" on participants' facial responses.[29] More importantly, in the second part of the experiment, participants were also asked to recall the exact expression presented by each individual in the first part of the study. The results show clear distortion of memory towards the concept (e.g., faces were remembered as angrier when first paired with "angry" label). Finally, when participants merely viewed the faces, the EMG data showed that they spontaneously smiled more to "happy" faces than "angry" faces (as if mimicking real smiles).

Overall, the findings suggest that *concept*-driven motor representations can easily become linked to *perception*-driven motor representations. Indeed, mimicry could be said to represent a bridge between the sensorimotor and cognitive system. One interesting recent interpretation is that the process of linking motor, somatic, and cognitive states, via interoceptive feedback, is an example of a general process where the mind is building a comprehensive model of the self in the world.[30]

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[28] J. Halberstadt, P. Winkielman, P. M. Niedenthal, N. Dalle, "Emotional conception how embodied emotion concepts guide perception and facial action", *Psychological Science* 20, 2009, 1254–1261.

[29] See also P. M. Niedenthal, *et al.*, "Embodiment in attitudes...", *op. cit.*

[30] A. K. Seth, "Interoceptive inference, emotion, and the embodied self", *Trends in Cognitive Sciences* 17 (11), 2013, 656–663.

7. Mimicry in the social world

The aforementioned discussion suggests that spontaneous reactions to faces and gestures consist of simple, direct-matching effects (e.g., yawn-to-yawn, smile-to-smile, finger lift to finger lift, etc.). These matching effects are consistent with a variety of embodied simulation models, as well as more traditional models like the Perception-Action Model (PAM)[31] and the Associative Sequence-Learning account (ASL).[32] However, newer research has challenged the notion that such direct-matching effects are the norm in social life and suggested that individuals' imitative behaviors are fundamentally transformed by social context.[33] For example, several studies have demonstrated that the extent of mimicry depends on interpersonal cues such as prosociality,[34] group membership,[35] attitudes,[36] and competition.[37]

A particularly illustrative evidence for the role of social cues on spontaneous imitation comes from research on power.[38] This research has demonstrated that spontaneous mimicry of emotional expressions dynamically adapts to hierarchical cues, like how much power the perceiver or target has within an interaction. More specifically, in this

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[31] S. D. Preston, F. de Waal, "Empathy: Its ultimate and proximate bases", *Behavioral and Brain Sciences* 25 (1), 2002, 1–20.

[32] R. Cook, A. Johnston, C. Heyes, "Facial self-imitation objective measurement reveals no improvement without visual feedback", *Psychological Science* 24, 2013, 93–98.

[33] U. Hess, A. Fischer, "Emotional mimicry as social regulation", *Personality and Social Psychology Review*, 2013.

[34] J. Leighton, G. Bird, C. Orsini, C. Heyes, "Social attitudes modulate automatic imitation", *Journal of Experimental Social Psychology* 46 (6), 2010, 905–910.

[35] P. Bourgeois, U. Hess, "The impact of social context on mimicry", *Biological Psychology* 77, 2008, 343–352.

[36] K. U. Likowski, A. Mühlberger, B. Seibt, P. Pauli, P. Weyers, "Modulation of facial mimicry by attitudes", *Journal of Experimental Social Psychology* 44 (4), 2008, 1065–1072.

[37] P. Weyers, A. Mühlberger, A. Kund, U. Hess, P. Pauli, "Modulation of facial reactions to avatar emotional faces by nonconscious competition priming", *Psychophysiology* 46, 2009, 328–335.

[38] E. W. Carr, P. Winkielman, C. Oveis, "Transforming the mirror: Power fundamentally changes facial responding to emotional expressions", *Journal of Experimental Psychology: General* 143, 2014, 997–1003.

experiment, subjects were first primed into high-power, low-power, or neutral states (using a well-established writing task[39]). Next, they were exposed to happy and angry videos of four different targets that were paired with either a high-power profession (i.e., physician or CEO) or low-power profession (i.e., fast-food worker or grocery store stocker) – thus manipulating the power level associated with each of the targets. While the participants viewed the videos, facial EMG was recorded over two muscles to gauge mimicry activity – *zygomaticus major* ("smiling muscle" that lifts up the corners of the mouth) and *corrugator supercilii* ("frowning muscle" that furrows the brow). The results showed that subjects' facial EMG reactions depended on their own power state, the power state of the target, and the emotion the target displayed. Frowning responses were the most straightforward, in that all perceivers (regardless of their own power state) responded with increased corrugator responses to angry high-power targets. On the other hand, EMG smiling responses were more complex. Low-power participants spontaneously smiled back to all target expressions (happiness and anger), while high-power participants exhibited standard smile-to-smile mimicry only toward low-power targets. In fact, not only did high-power subjects not mimic other high-power target smiles, but they actually smiled more when those high-power targets expressed *anger*. This pattern of counter-matching (smile-to-anger) was evident even in very early EMG responses, suggesting that it reflects a quick, implicit form of complementarity (rather than a deliberate decision to react with an opposite expression[40]).

Generally, these findings highlight two important points. First, facial mimicry in social contexts cannot be solely mediated by simple low-level perceptual factors. After all, in our study higher-level hierarchical factors modified (and reversed, in some cases) normal pat-

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[39] A. D. Galinsky, D. H. Gruenfeld, J. C. Magee, "From power to action", *Journal of Personality and Social Psychology* 85, 2003, 453–66.

[40] L. Z. Tiedens, A. R. Fragale, "Power moves: Complementarity in dominant and submissive nonverbal behavior", *Journal of Personality and Social Psychology* 84, 2003, 558–568.

terns of facial mimicry, even when these lower-level variables were controlled (attention, mood, etc). As such, these results indicate that even the most basic and spontaneous level goals and interpretations related to the emotion and social situation at-hand all converge to build a context-appropriate mimicry response.[41] Second, these findings clearly show that perceivers adapt their facial mimicry responses based on their *relative* relationship with the target and the observed emotion. Thus, they represent a novel demonstration of an "interactive" response that clearly breaks down any direct facial mimicry patterns. This interactivity logically follows from many power theories that assume individuals respond differently according to the status level of the target.[42]

8. Simple and complex mimicry in human-robot interaction

Recent research in our lab has explored the sensitivity of spontaneous mimicry to simple and complex cues by using state-of-the-art robots and androids. Such research allows systematic testing of agents' attributes that are necessary for mimicry – a useful approach, given that human minds evolved in the environment without robots. One question about mimicry that is particularly suitable to exploration with androids

[41] E. W. Carr, P. Winkielman, "When mirroring is both simple and 'smart': how mimicry can be embodied, adaptive, and non-representational", *Frontiers in Human Neuroscience* 8, 2014, 505. doi: 10.3389/fnhum.2014.00505; B. Seibt, A. Mühlberger, K. Likowski, P. Weyers, "Facial Mimicry in its Social Setting", *Frontiers in Psychology* 6, 2015, 1122. doi: 10.3389/fpsyg.2015.01122; U. Hess, A. Fischer, "Emotional mimicry as social regulation", *Personality and Social Psychology Review* 17, 2013, 142–157.

[42] E.g. S. Côté, M. W. Kraus, B. H. Cheng, C. Oveis, I. Van der Löwe, H. Lian, D. Keltner, "Social power facilitates the effect of prosocial orientation on empathic accuracy", *Journal of Personality and Social Psychology* 101, 2011, 217; S. T. Fiske, "Controlling other people: The impact of power on stereotyping", *American Psychologist* 48, 1993, 621; A. Guinote, "The situated focus theory of power", in: *The Social Psychology of Power*, A. Guinote, T. Vescio (eds.), Guilford Press, New York 2010; D. Keltner, D. H. Gruenfeld, C. Anderson, "Power, approach, and inhibition", *Psychological Review* 110, 2003, 265–284; M. S. Mast, "Interpersonal behaviour and social perception in a hierarchy: The interpersonal power and behaviour model", *European Review of Social Psychology* 21, 2010, 1–33.

is the role of agent-perceiver similarity. Most mimicry theories assume that spontaneous imitation occurs when the observed agent is "similar" to a human. Yet "human-likeness" is a complex, multifaceted concept, and the relevant dimensions of similarity can dynamically vary – which matters for predicting when such agents elicit mimicry. Specifically, many experiments and theoretical perspectives highlight that mimicry is influenced by visual similarity,[43] psychological or "intentional" similarity,[44] similarity in type or biological nature of motion,[45] and emotional similarity (i.e., relatability, liking, and comfort[46]). In order to examine these different components, we recently conducted a series of studies using human, android, and robot targets. Some of these experiments focused on facial expressions, while others focused on gestures.

9. Imitation of android expressions

We examined spontaneous mimicry to android and human emotional expressions of anger and happiness in two studies.[47] In both studies, we

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[43] K. U. Likowski, *et al.*, 'Modulation of facial mimicry by attitudes", *op. cit.*; J. Nadel, M. Simon, P. Canet, R. Soussignan, P. Blancard, L. Canamero, P. Gaussier, "Human responses to an expressive robot", in *Proceedings of the sixth international workshop on epigenetic robotics*, Vol. 128, Lund University Cognitive Studies, Lund 2006, pp. 79–86; C. Press, G. Bird, R. Flach, C. Heyes, "Robotic movement elicits automatic imitation", *Cognitive Brain Research* 25 (3), 2005, 632–640; P. Weyers, A. Mühlberger, C. Hefele, P. Pauli, "Electromyographic responses to static and dynamic avatar emotional facial expressions", *Psychophysiology* 43, 2006, 450–453.

[44] A. I. Goldman, C. S. Sripada, "Simulationist models of face-based emotion recognition", *Cognition* 94, 2005, 193–213.

[45] B. Calvo-Merino, J. Grèzes, D. E. Glaser, R. E. Passingham, P. Haggard, "Seeing or doing? Influence of visual and motor familiarity in action observation", *Current Biology* 16 (19), 2006, 1905–1910; T. Chaminade, D. W. Franklin, E. Oztop, G. Cheng, "Motor interference between humans and humanoid robots: Effect of biological and artificial motion", in *The 4th International Conference on Development and Learning, 2005. Proceedings*, 2005, pp. 96–101.

[46] P. Bourgeois, U. Hess, "The impact of social context on mimicry", *op. cit.*; K. U. Likowski, *et al.*, 'Modulation of facial mimicry by attitudes", *op. cit.*

[47] G. Hofree, P. Ruvolo, M. S. Bartlett, P. Winkielman, "Bridging the mechanical and the human mind: Spontaneous mimicry of a physically present android", *PLoS ONE* 9 (7), 2014, e99934.

employed a state-of-the-art android (Hanson's Einstein) programmed to perform realistic human facial expressions.[48] Both experiments followed the same basic paradigm, where participants were first told to simply watch the agent (*spontaneous* mimicry), and in the second block, they were then instructed to mimic the agent (*deliberate* mimicry). In each block, participants viewed randomized presentations of both happy and angry expressions, and facial mimicry was measured using EMG over the *zygomaticus major* (used in smiling) and *corrugator supercilii* (used in frowning) muscles. In addition, we collected ratings on comfort and human-likeness for the agent, as well as psychological human attributes, such as intentionality, mental states, and emotions (using IDAQ[49]). The critical difference between Study 1 and Study 2 was the mode of android presentation (i.e., video vs. direct presence).

Study 1 had participants viewing videos of either Einstein or an aged-matched human control displaying emotional expressions. As expected, all participants spontaneously mimicked the human control. Interestingly, this study found evidence of spontaneous mimicry of Einstein, but this was observed only amongst participants who rated the android high on human-likeness, in terms of *physical similarity*. Importantly, ratings of comfort with the android did not influence mimicry reactions, suggesting that at least in this case, emotional relatability was not the critical factor. Further, ratings of *psychological similarity* to humans were very low for the android, as compared to the human control (along with other living creatures, such as reptiles, fish, and mammals). In sum, this study suggests that perceived physical similarity (not emotional or psychological similarity) plays an important role in spontaneous mimicry reactions.

To further investigate this, we conducted Study 2, where participants saw the same android, but now Einstein was physically present

[48] More details on the android can be found in T. Wu, N. J. Butko, P. Ruvulo, M. S. Bartlett, J. R. Movellan, "Learning to make facial expressions", in *Proceedings of the 2009 IEEE 8th International Conference on Development and Learning*, IEEE, 2009, pp. 1–6.
[49] A. Waytz, J. Cacioppo, N. Epley, "Who sees human? The stability and importance of individual differences in anthropomorphism", *Perspectives on Psychological Science* 5, 2010, 219–232.

in the room with them. Participants sat facing the actual android while it randomly produced both happy and angry expressions. Once again, participants were first told to just watch Einstein (spontaneous condition), and after that, deliberately mimic the android (voluntary condition). Participants rated the android on similar measures as used in Study 1. A comparison of ratings across Studies 1 and 2 highlight that physical presence makes the android appear significantly more humanlike than its video counterpart, yet more emotionally discomforting and less psychologically humanlike. Nonetheless, participants reliably mimicked the android. Specifically, amplitude and synchronization analyses comparing EMG activity to actual values of electricity supplied to android's motors (i.e., activity generated from the individual servos moving Einstein's face) demonstrated that these spontaneous mimicry reactions shared similar time-courses to those of the android's expression. That is, while they lagged shortly after the android initialized an expression (as expected), they had similar onset, offset, and duration features.

Together, these studies demonstrate the power of physical presence on mimicry (and other social behaviors). More specifically, for non-human agents such as androids, it can influence attribution of human-likeness, which we found to be associated with a greater likelihood of mimicry reactions. Finally, these studies suggest that while psychological similarity and emotional comfort may play an important role in mimicry and other social behaviors, it is not necessary for spontaneous mimicry.

10. Imitation of android gestures

Our recent studies further explored how features of observed agents influence motor simulation by varying similarity in appearance and similarity in motion.[50] In this study, we took advantage of humanoid robots

[50] G. Hofree, B. A. Urgen, P. Winkielman, A. P. Saygin, "Observation and imitation of actions performed by humans, androids, and robots: An EMG study", *Frontiers in Human Neuroscience* 9, 2015, 364.

with different degrees of human-likeness in appearance and movement that were performing simple arm movements (e.g., waving, cleaning, etc.). The agents were a human adult (biological appearance and biological motion), a robot (mechanical appearance and mechanical motion) and an android (biological appearance, but mechanical motion). The android was Repliee Q2. The human was the woman whose appearance Repliee Q2 was modelled after. The robot was the same Repliee Q2 stripped of surface human-like features (such as skin, hair, and clothes–any of these features that could not be removed were covered).[51] Moreover, the robot and android displayed identical motion kinematics, since they were in fact the same robot with different perceptual features. Muscle activity in both participants' arms was measured with EMG while they either merely observed the three agents produce actions with their right arm, or when they were explicitly told to imitate these same actions.

The results showed that participants faithfully imitated all agents with their dominant (right) arm when explicitly told to do so. More interestingly, participants also mirrored these agents with their left arm, even when passively observing the actions. Furthermore, muscle activity was sensitive to differences in motion dynamics. Participants mimicked the human with greater intensity than both the identical looking android and the non-human appearing robot. These results suggest that motor simulation is not limited to observation and imitation of agents with a biological appearance, but this phenomenon is also present in response to robotic agents. On the other hand, the viewed agent's motion may play an important role, especially for action observation.

[51] For more information on the original stimuli, see A. P. Saygin, T. Chaminade, H. Ishiguro, J. Driver, C. Frith, "The thing that should not be: Predictive coding and the uncanny valley in perceiving human and humanoid robot actions", *Social Cognitive and Affective Neuroscience*, 2011, nsr025.

11. Imitation of androids in social context

Our earlier discussion highlighted that mimicry of emotional expressions depends on social cues. One such cue is the nature of a social relation – competitive or cooperative. For example, imagine you are playing a dice game with a spontaneously expressive and honest opponent. Seeing that opponent smile might not elicit a smile from you, since it signals that he/she is winning, and you might be losing. Empirically, it is not yet clear how our emotional processes interact with automatic mimicry reactions, yet there is evidence that this type of mimicry is difficult to inhibit[52] and can slow down non-mimicking responses.[53] Conversely, research suggests that we are very attentive to our environment and that our responses to even unconscious cues can be influenced by the current context.[54] Although it appears that humanlike androids elicit automatic mimicry reactions, it is not clear whether these more complex emotional responses would occur when faced with an android.

To address these questions, we ran another study with the same android (Einstein). In this study, participants played repeated dice games with the android. In one block, participants were told that Einstein was their teammate (cooperative block), and in the second block, they were told that he was their opponent (competitive block). Each game depended purely on chance, and the outcome was displayed either on the computer screen or through Einstein's facial expressions (i.e., happy "smiling" when winning and sad "frowning" when losing). As before, participants' facial expressions were measured using EMG, over the zygomaticus major and corrugator supercilii muscles.

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[52] R. Cook, G. Bird, G. Lünser, S. Huck, C. Heyes, "Automatic imitation in a strategic context: Players of rock–paper–scissors imitate opponents' gestures", *Proceedings of the Royal Society B: Biological Sciences* 279 (1729), 2012, 780–786.
[53] M. Brass, H. Bekkering, W. Prinz, "Movement observation affects movement execution in a simple response task", *Acta Psychologica* 106 (1–2),2001, 3–22.
[54] M. Tamir, M. D. Robinson, G. L. Clore, L. L. Martin, D. J. Whitaker, "Are we puppets on a string? The contextual meaning of unconscious expressive cues", *Personality and Social Psychology Bulletin* 30, 2004, 237–249.

Overall, participants responded to the "expressions" of the android, and they did so in a way that expressed their own emotional reactions to the valence of the outcome. That is, participants smiled more when they themselves won, and frowned more when they themselves lost. Critically though, participants displayed these expressions even when the android's expressions communicating the outcome were *incongruent* with their own, such as in the case during the competitive block (where android's smile communicated participants' losses, and his frown communicated participants' gains). Interestingly, these facial reactions did not differ in timing or magnitude from those in the cooperative block. Furthermore, these reactions were weaker when the same outcome information was displayed on the screen, suggesting that participants are more expressive when viewing the android's actual facial movements communicating the outcome.

In conclusion, this study suggests that basic, direct mimicry reactions can be overridden or transformed in certain situations. This has been previously discussed in the context of work on reduction of basic mimicry to out-groups.[55] Interestingly, the current studies suggest that rather than "suppressing" or overshadowing basic mimicry reaction, the social context can fundamentally reshape them.[56] Specifically, our facial behaviors can reflect the *meaning* behind the observed expression, not just the perceptual features of the expression itself (e.g., we not only fail to mimic a smile if that expression carries implicit negative consequences, but we actively do the opposite – we frown). Finally, although the android's emotional expression provided a very simple cue (winning vs. losing) that was identical to the information conveyed on the screen, it elicited greater expressivity. This suggests that our emotional reaction to information is strengthened when that information is conveyed through a face, rather than on a screen.

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55 E.g. P. Bourgeois, U. Hess, "The impact of social context on mimicry", *op. cit.*; K. U. Likowski, *et al.*, 'Modulation of facial mimicry by attitudes", *op. cit.*

56 As in E. W. Carr, P. Winkielman, C. Oveis, "Transforming the mirror", *op. cit.*

Considering all of the just-discussed android studies together, they suggest that artificial agents can elicit varied reactions, depending on the attributes of the androids and the context of the interaction. It appears that low-level mimicry reactions are mostly sensitive to how physically humanlike the android appears, how present it is, and basic biological properties of its movement. However, it is *also* clear that broader context can fundamentally reshape even the most basic and rapid reactions to android targets. This once again highlights the role of considering mimicry in broader social contexts, along with the inherent "intelligence" of the underlying process.

12. Third-party interaction: Smart social cognition in observation of mimicry.

One core message of our chapter is that spontaneous mimicry can occasionally be simple and almost reflexive. However, in the richer social context, mimicry often functions in a nuanced manner, reflecting sensitivity to subtle contextual cues. Some of the strongest evidence for this point comes not from studies using the standard paradigm of dyadic mimicry but also from studies using a paradigm where mimicry is observed by third parties. This is important because in real social contexts, dyadic interactions are often watched by others who use information about who mimics whom when making social judgments. Some earlier work has shown that in such situations, mimicry allows third-party observers to accurately infer the degree of affiliation within the dyad.[57] Recent work suggests that mimicry also informs observers' judgments in more complex ways, "mirroring" the intelligence that we have seen in mimicry production, which we will demonstrate with a few illustrative examples.

[57] F. Bernieri, "Coordinated movement and rapport in teacher-student interactions", *Journal of Nonverbal Behavior* 12, 1988, 120–138; J. E. Grahe, F. J. Bernieri, "The importance of nonverbal cues in judging rapport", *Journal of Nonverbal Behavior* 23, 1999, 253–269.

One study from our lab shows that a choice to engage in a dyadic mimicry leads observers to draw inferences about social competence.[58] Specifically, we found that if a target person mimics a model who is rude to the target, third-party observers of this interaction will judge the mimic as socially incompetent, as compared to a target who refrains from mimicry. In fact, the mimic was rated as less competent than the non-mimic. This finding stands in stark contrast with the general belief that greater mimicry tends to confer *benefits* (such as greater liking and rapport). The sophistication of these social inferences becomes all the more apparent when it is considered that these usual benefits are not associated with competence, but rather more with the other major dimension of social judgement, in that of trust or "warmth".[59] Notably, the above results occur even though observers do not explicitly notice the presence of mimicry. However, our phenomenon of "disadvantageous mimicry" makes sense from a theoretical perspective – if a person chooses to mimic (i.e., attempts to affiliate with) a rude model, the person does not know "how to pick his friends," or in other words, he or she may be lacking social competence.

In general, mimicry (or non-mimicry) reflects the mimic's assessment of a social situation and should "rationally" be interpreted in light of the mimic's knowledge about that situation. Kavanagh and colleagues[60] have illustrated this point by showing that observers' judgments about mimics depend on both the reputation of the model and whether the mimic is aware of the model's reputation. Specifically, in this study, participants observed a dyadic interaction in which

[58] L. C. Kavanagh, C. L. Suhler, P. S. Churchland, P. Winkielman, "When it's an error to mirror: The surprising reputational costs of mimicry", *Psychological Science* 22, 2011, 1274–1276.
[59] C. M. Judd, L. James-Hawkins, V. Yzerbyt, Y. Kashima, "Fundamental dimensions of social judgment: Understanding the relations between judgments of competence and warmth" *Journal of Personality and Social Psychology* 89, 2005 899–913.
[60] L. Kavanagh, G. Bakhtiari, C. Suhler, P. Churchland, R. W. Holland, P. Winkielman, "What they don't know might help them: A demonstration of subtle social inference from mimicry", *Proceedings of the 35th Annual Conference of the Cognitive Science Society*, Cognitive Science Society, Berlin 2013.

a target mimicked or did not mimic a model. Prior to observation, the model's honesty was either defamed or praised, in front of some (but not other) targets. Thus, observers always knew the model's reputation *and* which targets were aware of the model's reputation. Results showed that observers' use of mimicry in trust judgments reflected not just the presence of mimicry but also the model's moral reputation. Critically, observers' judgments were also influenced by whether the targets of these judgements (the mimics) were aware of their model's reputation. This led observers to feel increased trust towards those targets that unknowingly mimicked an untrustworthy model (i.e. a model whose reputation had been tarnished by the experimental manipulation). Observers did not extend these same feelings of trust, however, to targets that mimicked their model despite having full knowledge of their model's poor reputation.

To conclude this section, third-party observation of mimicry reflects sophisticated, if still largely implicit processes. One vital question is whether participants in the actual dyad make similar (and similarity sophisticated) inferences from the presence and absence of mimicry. Still, in the context of other research discussed in this chapter, such sophistication is not only expected but also essential for proper social functioning. After all, mimicry in some ways is like any other social manner and social rule – it works best when applied intelligently.

13. Summary, extensions, and conclusions

Toward the start of our chapter we asked about the basic mechanisms that allow humans to perceive, understand and influence each other as well as learn, follow, and adapt to different social norms and customs. We argued that one such mechanism is spontaneous mimicry. It is clear that spontaneous mimicry can sometimes emerge from simple perception-action links. Still, even such an associative process can facilitate emotion recognition and influence judgments. Spontaneous mimicry can also be "smart," by flexibly adjusting to a variety of social and emotional variables, entering complex inferences and judgments. All this gives a testimony to the sophistication of the social mind, even at its most implicit, quick, effortless operations.

One general point we hope our chapter conveys is that the interactions between conceptual and embodied processes we illustrated using spontaneous mimicry extend to other types of mind-body interactions. One such extension is explored in research on the role of embodiment in emotional concepts and emotional language. For example, we showed that people spontaneously activate and use somatosensory and motor resources when processing abstract emotion concepts[61] and abstract emotional sentences.[62] Importantly, such use of embodied signals can be quick, simple and reasonably automatic.[63] But, once again, in the social context, the engagement of embodied resources is flexible, context-dependent, and "smart."[64]

In conclusion, we see future developments in the field investigating the nature of those contextual influences on the mind-body. This is key not only for understanding how the mind works, but also for how this flexibility makes for smart, socially useful, adaptive social cognition.

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[61] P. M. Niedenthal, P. Winkielman, L. Mondillon, N. Vermeulen, "Embodiment of emotional concepts: Evidence from EMG measures", *Journal of Personality and Social Psychology* 96, 2009, 1120–1136.

[62] J. D. Davis, P. Winkielman, S. Coulson, "Facial action and emotional language: ERP evidence that blocking facial feedback selectively impairs sentence comprehension", *Journal of Cognitive Neuroscience*, in press.

[63] F. Pulvermüeller, L. Fadiga, "Active perception: sensorimotor circuits as a cortical basis for language", *Nature Reviews Neuroscience* 11, 2010, 351–360.

[64] S. Oosterwijk, S. Mackey, C. Wilson-Mendenhall, P. Winkielman, M. P. Paulus, "Concepts in context: Processing mental state concepts with internal or external focus involves different neural systems", *Social Neuroscience* 10, 2015, 294–307.