

CHAPTER 8

Mimicry, emotion, and social context: insights from typical and atypical humans, robots, and androids

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A key task for the field of psychology (and related disciplines) is to identify mechanisms that allow individuals to perceive, understand, influence, and coordinate with others. Within the last decade, *imitation* has been the focus of many empirical and theoretical discussions, since it is thought to be one such social mechanism. Much of this discussion surrounds *intentional imitation* – a phenomenon where an individual deliberately replicates similar movements or performs an action with a similar goal (i.e., *emulation*). Intentional imitation is essential to sociality, given that it constitutes an important source of *social learning*, which involves the transmission of skills, norms, traditions, and rituals. These imitative behaviours are also important in *social communication*, such as signalling group membership (e.g., dressing alike), admiration (e.g., adopting “superior” accents) but also derision (e.g., parodying and parrot). Critically though, intentional imitative behaviours are often exquisitely complex, revealing sophisticated considerations about the rationality and usefulness of the copied behaviours (see the following for excellent reviews on this topic – Csibra & Gergely, 2009; Mesoudi, 2009; Tomasello, Kruger, & Ratner, 1993). We will not focus on intentional imitation here, though we should note at the outset that some of our insights into spontaneous imitation were inspired by the just-mentioned literatures.

Here, our focus is on a more basic (and perhaps simpler) form of imitation: *spontaneous mimicry*. This is a phenomenon where merely observing another individual’s behaviour elicits a corresponding action in the observer, without instruction to initiate such a response. Many have argued that mimicry appears to have phylogenetic roots, since these behaviours can appear in non-human primates (e.g., contagious yawning and smiling; Anderson, Myowa-Yamakoshi, & Matsuzawa, 2004). Such uninstructed mimicry occurs across a variety of modalities and effectors

(e.g., face, voice, body, etc.), and it can arise anywhere from fractions of a second (e.g., finger mimicry; Leighton, Bird, Orsini, & Heyes, 2010), around a half-second (e.g., facial mimicry; Dimberg, 1982), to several seconds (e.g., yawning, pronunciation, and postural mimicry; Tiedens & Fragale, 2003) after the stimulus onset. Spontaneous mimicry clearly occurs in many different real-world social situations and can be used by both producers and perceivers in a non-conscious, dynamic, and adaptive fashion (as we discuss later). In turn, research on mimicry may help to elucidate some basic mechanisms of the mind, informing questions about the way perception and action are connected, the nature of action- and emotion-recognition, and so forth. While many results are based within social and cognitive psychology, they easily extend to more broad and applied domains with clinical relevance (e.g., we will later discuss mimicry’s involvement in emotion-recognition within typical and atypical populations). Moreover, as we also elaborate on later, spontaneous imitation also influences some core social judgements and behaviours, including feelings associated with rapport, trust, competence, and interpersonal similarity. In short, spontaneous mimicry is of interest to a wide variety of researchers from all areas of psychology, cognitive science, and neuroscience.

In this chapter, we hope to advance the understanding of spontaneous mimicry by focusing on three central questions. The first question concerns the role of spontaneous mimicry in the debates about the embodied nature of the mind: More concretely, what does spontaneous mimicry tell us about the relation between perception and action, along with the role of somatosensory processes in higher-order conceptual information? The second question concerns the “simple” versus “complex” – or to say it more dramatically, “dumb” versus “smart” – nature of spontaneous mimicry. Specifically, when is mimicry driven by direct-matching processes, which ensure that perceivers motorically reproduce what they observe? And when does it reflect goals, intentions, and social-emotional context, which results in more complex input–output relations? Finally, the third (and most practically important) question addresses the implications of these debates for understanding atypical individuals. Specifically, what can research on spontaneous mimicry tell us, for example, about autism, and can such research offer any insights into practical interventions?

With these questions in mind, the structure of this chapter is as follows: We begin by introducing the framework of embodiment, as it helps to focus both ours and related research on spontaneous mimicry within the larger intellectual environment. Next, we evaluate the occurrence of motor reaction during stimulus perception, outline the role of sensorimotor feedback in recognition of emotional expressions, and consider how

higher-order concepts contribute to mimicry phenomena. Following this, we move to the discussion of "smart" versus "dumb" processes of mimicry – to do this, we highlight spontaneous imitation in the context of higher-order social variables, including a transformational role of social power, and also within the context of robotics, which demonstrates both its reflexive and reflective aspects. We then extend these findings to the larger context of real-life social interactions. And finally, we discuss the implications of all this work for investigations of developmental disorders (such as autism) by showing the basic atypicality of mimicry, possibilities for some mimicry-based interventions, and highlighting recent research on contextual and affective modulation of mimicry.

Embodiment vs. traditional theories

Research on spontaneous mimicry is often situated within broader debates about the relation between perception and action. As such, before we go into specifics of mimicry, it is worth highlighting a few points about the larger contextual framework of embodiment, which guides much of recent research (including our own) and serves as a major conceptual model for understanding the mind (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005; Schubert & Semin, 2009; Winkielman, Niedenthal, Wielgosz, Eelen, & Kavanagh, 2015).

One way to appreciate the importance of embodied theories is to contrast them with the traditional, amodal view of processing according to which cognitive processes operate on abstract, non-perceptual symbols. According to those theories, in order to become subjects of "thought," information initially encoded in the perceptual system (e.g., vision and audition) must be re-described and stored in a way that is amodal – that is modality-free, or at least modality independent (Fodor, 1975; Pylyshyn, 1984). This traditional view proposes that when perceiving a stimulus (such as a face or a body), information is initially encoded in the brain's modality systems (such as the visual, auditory, and probably affective systems) and then is extracted into an abstract language-like symbol (a "proposition") and stored as a *node* of a larger propositional network. In the associative network view (e.g., Anderson, 1983; Collins & Loftus, 1975), the node might be the word "SMILE" or the concept of "MIDDLE FINGER." This symbol or node is stored in some relation to other information that represents features such as "FUNNY" or "RUDE." Later, when thinking about FUNNY or RUDE, what is extracted from memory and used to make inferences are (at least) these pieces of information in their language-like form, which serve as a label for the concept and a list of its features. Thus, in *associative network models*, nodes arbitrarily stand for units of information, and those units provide

the primary vehicle for processes such as inference, categorization, memory, and other cognitive operations. Any involvement of somatosensory processes in perception and cognition is therefore perceived as primarily incidental.

In contrast, the basic idea of embodiment theories is that higher-level processing is grounded in the organism's sensory and motor experiences – such frameworks are often called *grounded cognition theories* (Barsalou, 1999; 2008; Clark, 1999; Wilson, 2002). According to embodiment theories, processing of information about (for example) emotional faces, gestures, tools, flavours, melodies, driving directions, social personality characteristics, and even abstract social, moral, emotional, or motivational concepts, along with many other kinds of information, is influenced, informed, associated with, and sometimes dependent on perceptual, somatosensory, and motor resources. An important assumption of this perspective is that thinking involves partial reproduction or "simulation" of experiential and motor states that occur when the perceiver has actually encountered the object. For example, when thinking about whether a concept (e.g., a lemon) includes the property "sour," the perceiver actually recreates the sensory experience (e.g., tasting the lemon). Similarly, when perceivers try to recognize a facial expression or a bodily gesture, they construct a simulation using their own actions to reproduce the hypothesized face or gesture. Critically, embodiment theories hold that, far from being incidental, such re-enactment can be crucial to recognition and reasoning. Further, this re-enactment – called *embodied simulation* – does not have to be a conscious, full-blown physical episode. It also does not need to have any peripheral or behavioural manifestations, as it presumably can run solely on the brain's modality systems. Instead, simulation involves re-instantiating enough of the original experience to be useful in further processing. As we will see shortly, these assumptions of embodiment theories are reasonably supported by empirical research, including research on spontaneous mimicry, though mimicry may not always represent an embodied simulation (e.g., when mimicry is simple reflexive process) and that not all embodied simulation will lead to mimicry (e.g., when simulation is run purely centrally, or on modalities that do not manifest externally).

Spontaneous mimicry and the processing of facial emotions

Empirical studies in the field of emotional facial expressions serve as central demonstrations that somatosensory processes are involved in perception, cognition, and emotion. This point goes back to the original interest in motor processes in cognition and emotion and facial feedback mechanisms (Buck, 1980; Zajonc & Markus, 1984). In fact, a lively debate

went on for years about the relative importance of such processes for emotional perception, experience, and behaviour and about the mechanisms by which such resources work (for a sampling of different views, see McIntosh, 1996).

Critically, note that according to traditional amodal models, expression recognition is primarily a matter of detecting features (e.g., curves at the corners of the mouth, lines in the corners of the eyes, etc.) that are probabilistically associated with an expression (e.g., smile). In other words, the recognition of a smile is very much like the recognition of any other stimulus (e.g., recognizing that an analogue clock is showing 2.45). Of course, the processing of the face itself may involve some unique and dedicated circuitry, but the essence of the process is basically described by the feature extraction models (e.g., Kanwisher, McDermott, & Chun, 1997). In contrast, embodied accounts of expression recognition emphasize that we not only see faces, but that we also have our own faces. As a result, we can employ somatosensory and motor representations of our own faces in the recognition process (Barsalou, 1999; Damasio, 1999; Niedenthal et al., 2005). From the embodied perspective, one can think of the act of smiling, for example, as a partial simulation of happiness when one is thinking about such an affective state, which can verify (via facial feedback) a match between one's own state and the mood of the person we are imitating (while in other cases, a "smile" could merely be an expression of an experienced positive emotional state). Note also that while mimicry often refers to the rote reproduction of a *motor* state (i.e., perceived action or behaviour), embodied simulation posits the reenactment of the underlying mental state itself (which then has downstream consequences on motor behaviour). Given this, many have argued that spontaneous imitation can, at least occasionally, play a useful role in this process.

Motor processes and facial processing

Multiple studies offer evidence that perception of emotional expression is accompanied by spontaneous activation of relevant motor processes. Studies using functional magnetic resonance imaging (fMRI) show that merely observing facial expressions enhances activity in the relevant somatosensory areas of brain (e.g., Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Keysers, Kaas, & Gazzola, 2010; Molenberghs, Cunningham, & Mattingley, 2012). Further, the mere observation of a facial expression leads to activation of actual facial movements, which tend to match the perceived stimulus. This match can be driven by physical appearance but often also by valence – suggesting that both imitative and evaluative processes play a role (for more, see Moody,

McIntosh, Mann, & Weisser, 2007; Neumann, Schulz, Lozo, & Alpers, 2014). Thus, when people see smiles, they produce incipient smiles, and when they see frowns, they produce incipient frowns. We will describe some complications to this simple matching pattern shortly, but under "default" conditions, such facial reactions appear relatively straightforward and relatively automatic. Thus, they occur very quickly – within a half- to full-second after seeing an expression (e.g., Dimberg, 1982; Lundqvist & Dimberg, 1995). They occur even when participants are asked not to let a facial response occur or when they are asked to respond to the perceived facial stimulus in the opposite way (Dimberg, Thunberg, & Grunedal, 2002). Further, facial reactions can occur after minimal stimulus input, even with sub-threshold presentations for expressions of happiness or anger (Dimberg, Thunberg, & Elmehed, 2000). Finally, the facial reactions themselves may not be available to conscious awareness. For example, in a recent study, participants were briefly flashed happy, neutral, or angry faces and were asked to identify their valence (Bornemann, Winkelman, & van der Meer, 2012). As in earlier studies, we monitored participants' physiological activity using facial electromyography (EMG) and found that angry and happy faces produced different (and congruent) patterns of EMG activity. But were these reactions consciously available? To test this, we asked one group of participants to do the valence detection task while focusing on their feelings, including "subtle twitches in their faces." Another group was instructed to use a visual focus strategy. The last group received no strategy instructions. Our results revealed no benefit of the feeling-focused strategy on valence detection rates, suggesting that responses to facial stimuli were consciously unavailable. Given all the aforementioned evidence that perceivers often simply match what they observe, some theories (but not others) propose that facial reactions to facial expressions are mere byproducts of perception-action links or visuomotor priming, at least under some conditions. However, we will discuss later that these simple modifications can transition to being subtly complex, suggesting that direct-matching theories often cannot fully explain "smart" imitation, particularly when it is socially and contextually grounded (see also Hess & Fischer, 2013).

Nevertheless, this evidence is also perfectly compatible with the idea that motor activations are there "only for the ride" and result from frequent associative pairing of perception and action (e.g., when we see a smile, we usually smile). Note that the same concern holds regarding the evidence showing that seeing a gesture (e.g., finger or hand moment) is correlated with activation of peripheral and central motor processes (Cook, Bird, Catmur, Press, & Heyes, 2014). This, of course, raises an important question of whether these motor processes

et al., 2010), group membership (Bourgeois & Hess, 2008), attitudes (Likowski, Muhlberger, Seibt, Pauli, & Weyers, 2008), and competition (Weyers, Muhlberger, Kund, Hess, & Pauli, 2009). As a result, recent theories of facial mimicry suggest that imitation is substantially dependent on higher-level processes such as goals, appraisals, and meaning-construction (Hess & Fischer, 2013). Importantly, these social theories serve as a contrast to more traditional direct-matching theories – for example, the Associative Sequence-Learning account (ASL; Cook, Johnston, & Heyes, 2013) and Perception-Action Model (PAM; Preston & de Waal, 2002), among others – which, for the most part, predict stimulus-congruent responses (e.g., smile-to-smile).

One stark demonstration of the role of social flexibility comes from research on power (i.e., how much objective or subjective control and authority someone possesses in an interaction; see Keltner, Gruenfeld, & Anderson, 2003). This research has found that spontaneous facial mimicry of emotional expressions dynamically adjusts to cues of social hierarchy and to the relative relationship between the perceiver and target (Carr, Winkielman, & Oveis, 2014). More specifically, in this study, participants were primed with either a high-power, low-power, or neutral writing task (Galinsky, Gruenfeld, & Magee, 2003) to manipulate the perceivers' feelings of subjective power. They were then 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) in order to manipulate the targets' status levels. 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 revealed that perceivers adapted their physiological EMG responses according to their own power level, the status level of the target, and the emotion of the target's expression: With frowning, all perceivers (regardless of their own power state) responded with an increased *Corrugator Supercilii* response to angry high-power targets, compared to low-power targets. With smiling, low-power participants smiled back to all target expressions (happiness and anger). Interestingly though, high-power participants only exhibited standard smile mimicry towards low-power targets but did not mimic the smiles of high-power targets. Instead, high-power participants smiled more when those high-power targets expressed anger. Critically, the experimental paradigm also controlled for more low-level factors that could have confounded the EMG results (i.e., attention, mood, and demand-effects), and no differences between the perceiver power conditions were found.

These findings are interesting because they demonstrate that spontaneous patterns of facial responding (detected by sensitive physiological measures of muscle activation) shift according to contextual cues of social hierarchy. Further, they highlight two important points: First, even when controlling for simple perceptual variables, these higher-level hierarchical factors influenced (and reversed, in some cases) normal patterns of facial mimicry. Although most direct-matching theories would predict a more straightforward correspondence between perceiver and target expression, these results suggest that spontaneous facial mimicry can be socially driven, even at the most basic level, whereby interaction goals, emotional appraisals, and situational constraints all converge in constructing the perceiver's "appropriate" mimicry response (Hess & Fischer, 2013). And second, the way in which perceivers recruit these responses seems to be largely dependent on their relative relationship with the target (along with the emotion being displayed). Even though many power theories assume that high- and low-power perceivers respond differently according to the status level of the target (e.g., Côté et al., 2011; Fiske, 1993; Guinote, 2010), this "interactive" perspective had yet to be shown to be so influential in breaking down the direct-matching patterns of facial mimicry. In sum, the findings by Carr et al. (2014) are most useful in showing that spontaneous facial mimicry responses are fundamentally reliant on relative power relationships between the perceiver and target, along with their mutual perceptions of the shifts and changes in this dynamic (Mast, 2010). Critically though, high-level social variables (such as hierarchy) are able to influence basic psychological and physiological function, particularly in an emotional context.

Reflexive and context-dependent facial responses in human-robot interaction

The discussion above highlights the sensitivity of the mimicry process to conceptual influences (and to the larger social meaning). This message is reinforced and extended by recent work from our laboratory, using state-of-the-art robots and androids. Note that research with such artificial agents allows systematic testing of agent attributes that are necessary for mimicry. It can also inform theoretical questions of robotics, such as synchronization between robotic and human agents, the role of emotions in human-robot interaction, and the role of androids' physical presence on cognitive and emotional responses. Answering these questions is of practical importance, as there is substantial and growing interest in developing such agents for healthcare, education, and customer service purposes (Coradeschi et al., 2006). Such development is costly, and the

actually contribute to perception. Fortunately, some research provides evidence for the causal, constitutive role of such spontaneous mimicry in emotion recognition. For example, preventing participants from engaging expression-relevant facial muscles sometimes impairs their ability to detect briefly presented or relatively ambiguous facial expressions that involve that specific muscle – though one should note that this evidence is much stronger for smiles than other emotions, and for expressions that are weak, ambiguous, or brief (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001; Oberman, Winkielman, & Ramachandran, 2007; Stel & Knippenberg, 2008). Further support for the causal contribution of motor representations to recognition of facial emotion comes from natural and experimental (temporary) lesion studies that examined the effects of (a) damage to sensory-motor areas and (b) transitional inactivation of the fusiform face area (FFA) with repetitive transcranial magnetic stimulation (TMS) (Adolphs et al., 2000; Pitcher et al., 2008).

Having said that, it is clear that more work needs to be done to fully understand the *boundary conditions* for causal mechanisms of facial mimicry in emotion-recognition. In fact, we are far from proposing that mimicry is always involved in the processing of facial expressions (or that it is always causally necessary). For instance, in some studies, observers mimicked emotional faces, but the degree of mimicry was not correlated with decoding accuracy (Blairy, Herrera, & Hess, 1999). Further, Calder, Keane, Cole, Campbell, & Young (2000) found that three patients with Möbius syndrome (a congenital condition that causes facial paralysis, thus preventing mimicry) were able to appropriately categorize standard emotional faces, with impairments noticeable only at high levels of recognition difficulty. Another study found that individuals with Möbius syndrome do not differ in facial emotion-recognition accuracy compared to controls (Rives-Bogart & Matsumoto, 2010), though such individuals also had a life to learn alternative recognition strategies. Additionally, as discussed below, autistic participants, who show reductions or delays in mimicry, may also develop alternative routes to recognition. Here, the critical point is that typical perceivers may activate the somatosensory networks, when appropriate, in the course of everyday processing. Further, such activations can be useful for recognition, especially when the recognition cannot be achieved via a simple, highly automated pattern-recognition strategy. Just to illustrate this point, motor feedback is probably not important to recognize a huge, simple smile, but could be quite useful in more subtle recognition tasks with weak, ambiguous or brief expressions, as mentioned above. In addition, the inhibition of smiles results in poorer differentiation between “true” and “false” smiles – a task that relies on processing of very subtle facial

distinctions (Maringer, Krumhuber, Fischer, & Niedenthal, 2011; Rychlowska et al., 2014).

Faces and concepts: the sensorimotor bridge

Spontaneous mimicry may not only facilitate online processing but it also links sensorimotor representations with higher-order concepts (Zajonc & Markus, 1984). This notion was explored in a study testing whether people's own facial reactions to other individuals' emotional faces interact with conceptual information about those faces (Halberstadt, Winkielman, Niedenthal, & Dalle, 2009). In these studies, participants were first asked to look at the faces of several different individuals with ambiguous facial expressions. For each face, they were asked to consider the possibility that each of these individuals might feel “happy” or “angry” (i.e., concept label was randomly paired with the ambiguous face). EMG responses were monitored and showed that the faces paired with the “happy” concept label elicited more smiling than faces paired with the “angry” label. This already shows the influence of higher-order concepts of “happiness” or “anger” on participants' own facial responses (see also Niedenthal, et al., 2005). Critically though, in the second phase of the experiment, participants were also asked to recall the exact expression presented by each individual. The data showed that participants' memory of expression was biased in the direction of the earlier concept (e.g., remembering a face as happier when it was earlier associated with a “happy” label). In this second phase, participants were also asked to merely view the faces, and EMG data showed that they spontaneously smiled more to “happy” faces than “angry” faces. Importantly, the memory distortion effect was correlated with spontaneous facial EMG response during mere viewing. One interpretation of this effect suggests that *concept-driven* motor representations get tied to the *perception-driven* motor representations of the face. As a result, later spontaneous “mimicry” reflects a combination of both perceptual and conceptual influences. Indeed, mimicry could be said to represent a bridge between the sensorimotor and cognitive system.

Social variables

As mentioned earlier, spontaneous mimicry can reflect simple, direct-matching effects (e.g., yawn-to-yawn, smile-to-smile, finger-to-finger, etc.). However, it is also clear that individuals' imitative behaviors are profoundly impacted by the social context in which the interaction occurs (see also Hess et al., Chapter 5). This is also true for spontaneous mimicry, which is sensitive to interpersonal cues such as prosociality (Leighton

success of these agents depends on the naturalness of interaction with their human users. In turn, knowing how to elicit natural, spontaneous human mimicry could facilitate meaningful social engagement between human users and androids.

One question about mimicry that is particularly suitable to exploration with androids 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: (a) visual similarity (Likowski et al., 2008; Nadel et al., 2006; Press, Bird, Flach, & Heyes, 2005; Weyers, Mühlberger, Hefe, & Pauli, 2006), (b) psychological or "intentional" similarity (Goldman & Sripada, 2005), (c) similarity in type or biological nature of motion (Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006; Chaminade, Franklin, Oztop, & Cheng, 2005), and (d) emotional similarity (i.e., relatability, liking and comfort; Bourgeois & Hess, 2008; Likowski et al., 2008). 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, whereas others focused on gesture.

Expressive androids

Two studies examined spontaneous mimicry to android and human emotional expressions of anger and happiness (Hofree, Ruvolo, Bartlett, & Winkielman, 2014). In both studies, we employed a state-of-the-art android (Hanson's Einstein) programmed to perform realistic human facial expressions (more details on the android in Wu, Butko, Ruvolo, Bartlett, & Movellan, 2009). Both experiments followed the same basic paradigm, where participants were first told to simply watch the agent (*spontaneous* mimicry) and, in the second block, were 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* and *Corrugator Supercilii* 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 the IDAQ; Waytz, Cacioppo, & Epley, 2010). The critical difference between Study 1 and Study 2 was the mode of android presentation (i.e., video vs. direct presence).

In Study 1, participants viewed videos of either Einstein or an age-matched human control displaying emotional expressions. As expected, all participants spontaneously mimicked the human control. More 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 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, and to other living creatures, such as reptiles, fish, and mammals. In sum, this study suggests that perceived physical similarity (not emotional or psychological ones) 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 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 it (spontaneous condition) and, after that, to 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 highlights 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 using actual values of electricity supplied to android's motors (i.e., activity generated from the individual servos moving Einstein's face) and EMG activity demonstrated that these spontaneous mimicry reactions shared similar time-flows 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 behaviours. More specifically, for non-human agents such as androids, physical presence can influence attribution of human-likeness, which we found to be associated with a greater likelihood of mimicry reactions. Finally, these studies suggest that although psychological similarity and emotional comfort may play an important role in mimicry and other social behaviours, it is not necessary for spontaneous mimicry.

Androids and gestures

In order to further understand the role of observed agent features on motor simulation, we have recently explored the role of changes in

appearance similarity and motion similarity (Hofree, Urgen, Winkielman, & Saygin, 2015). In this study, we took advantage of humanoid robots 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; for more information on the original stimuli, see Saygin, Chaminade, Ishiguro, Driver, & Frith, 2011). 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 (a) merely observed the three agents produce actions with their right arm, or (b) 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 that 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.

Androids in context

As mentioned, mimicry to emotional expressions also depends on social cues in the perceiver's environment. For example, when playing a game with an opponent, watching that opponent smile might not elicit a smile from you, since the smile signals that he/she is winning, and you might be losing. It is not yet clear how our emotional processes interact with automatic mimicry reactions, yet there is evidence that mimicry is difficult to inhibit (Cook, Bird, Lünser, Huck, & Heyes, 2012) and can slow down non-mimicking responses (Brass, Bekkering, & Prinz, 2001). On the other hand, 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 (Tamir, Robinson, Clore, Martin, & Whitaker, 2004). 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. In order to address these questions, we conducted 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, 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, sad "frowning" when losing). Participants' facial expressions were measured using EMG, as before, over the Zygomaticus Major and Corrugator Supercilii.

Overall, participants responded facially 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 was the case during the competitive block (where android's smile communicated participants' loss, and his frown communicated participants' gain). 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 (e.g., Bourgeois & Hess, 2008; Likowski et al., 2008). Interestingly, the current studies suggest that rather than "suppressing" or overshadowing basic mimicry reaction, the social context can fundamentally reshape them (as in Carr et al., 2014). Specifically, our facial behaviours 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 – frown). Finally, although the android's emotional expression provided a very simple cue (winning/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.

Taking the just-discussed several studies on androids 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 the context of the broader social context, along with the inherent "intelligence" of the underlying process.

Third-party interaction: mimicry and "smart" social cognition

All the studies described so far concerned mimicry within a dyad. However, perhaps the strongest evidence for the role of social context comes from our work on inferences from human gestural mimicry as observed by third parties. This is important because social contexts in which mimicry occurs can also include situations where "outside" people are watching others' interactions, and these observers can then use information about who mimics whom when making basic social judgements. In fact, some previous work has shown that in situations like this, mimicry can serve as a visible and viable social cue to third-party observers who use this information to infer a variety of social traits, including the degree of affiliation within the dyad (Grahe & Bernieri, 1999). Critically, mimicry seems to inform observers' judgements in subtle, complex ways, "mirroring" the intelligence that we have seen in mimicry production, which we will demonstrate with a few illustrative examples.

In a now-classic study, third-party observers used mimicry to guess whether members of a party are socially related (Bernieri, 1988). Recently, we have shown that observers draw more complex inferences from observed mimicry by taking into account the quality of the interaction (Kavanagh, Suhler, Churchland, & Winkielman, 2011). 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 mimicker as social incompetent, as compared to a target who refrains from spontaneous mimicry. In fact, the mimicker was rated as less competent than the non-mimicker, reversing the usually observed benefit of mimicry. Notably, this occurs even though observers do not explicitly notice the presence of mimicry. This finding neatly contrasts with the general belief that greater mimicry tends to confer benefits (greater liking, greater tipping, greater rapport). 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, a rational observer can take an act of mimicry (or non-mimicry) as a window into the mimicker's assessment of a social situation, given a larger social context. Kavanagh and colleagues (2013) have illustrated this point by showing that observers' judgements reflect not only whether people mimic or not but also the reputation of the model and whether the mimicker is aware of the model's reputation. Specifically, in this study, participants observed a dyadic interaction in which 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. 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 judgements was quite sophisticated and reflected not just the presence of mimicry but also the model's moral reputation. Critically, these judgements were further influenced by observers' knowledge of the target's awareness for the model's reputation. This led observers to rate targets as trustworthy when they mimicked untrustworthy models, but only when the observers knew that the model reputation was unknown to the target.

In conclusion, it appears that third-party observation of mimicry reflects highly sophisticated, context-sensitive, yet still implicit processes. Of course, future research is needed to determine to what extent the actual *interactants* in the dyad share this same level of sophistication as external third-party observers, when making social inferences from the observation of mimicry (or lack thereof). However, in the context of previously discussed studies using manipulations of social power, group membership, and competitive versus cooperative contexts, we should expect as much (if not more) "intelligence" in the mimicry production and interpretation within the interacting dyad. This question of intelligence becomes crucial, as we move on to the discussion of atypical mimicry processes.

Spontaneous mimicry and atypical social behaviour: the case of autism

So far, we have surveyed a variety of ways in which spontaneous mimicry functions in everyday social cognition. We have argued that a full analysis of this phenomenon requires consideration of isolated sensorimotor and emotional processes, as well as conceptual influences that

occur within the larger social context. In this section, we will argue that our analysis can also be usefully applied to understanding apparent deficits or atypical forms of social processing. Here, we will consider the specific case of autism – a significant clinical condition, whereby impairments in social and emotional functioning play a fundamental role.

Let us first offer a short reminder and some qualifications: Recall that Autism Spectrum Disorders (ASD) represent a set of complex and multifaceted conditions characterized by a mosaic of deficits in three general areas: (a) *social interaction*, such as lack of social interest, social skills, or theory-of-mind, (b) *communicative skills*, including pragmatic language, and (c) *behavioural abnormalities*, as with the presence of restricted, repetitive, and stereotyped patterns of behaviours, interests, and activities (American Psychiatric Association, 1994). Critically, autism is a very complex disorder. In fact, there is no identified biological cause of autism, and there is no single causal explanation, at any level, that is able to explain all aspects of the syndrome. Further, the behavioural manifestations of this disorder vary in severity (low- and high-functioning ASDs) and heterogeneity of cognitive profile (e.g., language, intelligence, emotion, etc.). Unfortunately, different profiles of ASDs are often lumped together when reporting findings, sometimes obscuring the information about the level of functioning for which the findings are relevant. This matters because high-functioning individuals represent around 25 per cent of the total ASD population, yet they make up the majority of the participants in published studies. As such, any generalizations must be made with extreme caution. Yet, there are some reasonably consistent data emerging in the domain of spontaneous mimicry (but see Southgate & Hamilton, 2008), but it is worth noting that they may not generalize to intentional mimicry (Rogers & Williams, 2006).

Atypical spontaneous mimicry of non-emotional stimuli

Some early evidence about atypicalities in spontaneous mimicry comes from studies using gestures. As an example, in one study, ASD individuals and matched controls were asked to simply view videos of a person executing simple actions, or to perform the same actions (Oberman et al., 2005). During these tasks, the experimenters recorded mu wave suppression, an electroencephalography (EEG) index of activity in the primary motor cortex, which has been proposed to be indicative of activity in the premotor “mirror neuron area” during the observation of action. Typically developing individuals showed mu wave suppression to both the execution and observation of action; however, individuals with ASD only showed mu wave suppression when performing their own actual

movement, but not when observing movement (see also Nishitani, Avikainen, & Hari, 2004, for similar results with MEG).

Consistent with the social psychological literature on the role of self–other overlap in mimicry phenomena, ASD impairments might relate to a deficit in mapping the representation of the observed action to the self. Théoret et al. (2005) asked typical and ASD groups to view videos of index-finger and thumb movements that were directed either towards or away from the participants. During these tasks, the experimenters recorded motor-evoked potentials (MEP) induced by single-pulse TMS. In the typical group, both participant-directed and other-directed actions increased MEPs recorded from the participant's muscles, suggesting spontaneous mirroring. However, the ASD group showed increased MEPs only when viewing actions directed towards the participant, but not when viewing actions directed away from the participant. This suggests that ASD participants' mirroring failures might be due to a reduction in self–other mapping. Consistent with these results, ASD children show a typical degree of mu suppression (EEG index of “mirroring” activity) in response to an action performed by a family member, or the participant himself, but not to the same action performed by a stranger (Oberman, Ramachandran, & Pineda, 2008). Interestingly, more recent studies have argued that ASD subjects often show less mimicry modulations after social manipulations, suggesting perhaps that in their case, mimicry is less related to representation of the self (e.g., Cook & Bird, 2012). There have also been reports where ASD participants demonstrate intact imitation of both hand actions (Bird, Leighton, Press, and Heyes, 2007) and facial expressions (Press, Richardson, & Bird, 2010; also see Cook, Brewer, Shah, & Bird, 2014). Therefore, while much evidence suggests that mirroring deficits in ASD subjects might be due (at least in part) to decrements in self–other mappings, further work should be done to explore the relationship between these “mirroring” and “mentalizing” processes, especially when they become dissociated (e.g., ASD subjects can show hyperimitation along with less brain activation in mental state attribution areas, like mPFC and TPJ; Spengler, Bird, & Brass, 2010).

Reduction and delay in spontaneous mimicry of emotional stimuli

A similar picture of impairments emerges from the literature on facial expressions. In contrast to typical participants, autistic individuals do not spontaneously reproduce (mimic) facial expressions when they “just watch” them, without any prompts to recognize the expressions or to react to them (Beall, Moody, McIntosh, Hepburn, & Reed, 2008; McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006; Stel, van den

Heuvel, & Smeets, 2008). But again, this deficit is somewhat conditional – for instance, when autistic individuals are explicitly asked to focus on recognizing expressions, their mimicry is present, albeit significantly delayed (Oberman, Winkielman, & Ramachandran, 2009). These and related findings fuel a debate whether any emotional mimicry deficits are primary, or result from attentional and motivational factors (Wang & Hamilton, 2012).

But, whatever their origin, why do ASD mimicry impairments matter? First, as discussed previously, others respond to the presence of mimicry, both as members of the interacting dyad and as third-party observers. Comparatively, ASD individuals could suffer direct and indirect social consequences from not having these tendencies. Second, as also discussed above, spontaneous mimicry may facilitate emotion-recognition. If so, mimicry deficits may hinder recognition of facial expressions, at least under some conditions. One clue to this comes from a study where the performance of ASD individuals was compared on easy and difficult emotion-recognition tasks (Clark, Winkielman, & McIntosh, 2008). More specifically, in the difficult condition, participants were shown images for durations in the range of micro-expressions (15 and 30 milliseconds). Participants detected (a) if emotional faces were happy or angry, (b) if neutral faces were male or female, and (c) if neutral images were animals or objects. ASD individuals performed selectively worse on emotion extraction from faces (60 per cent vs. approximately 75 per cent for control groups). There were no group differences on gender or animal-object tasks, with groups all performing around 65–70 per cent. Importantly, there were no group differences in accuracy, which was perfect (100 per cent) on any type of stimuli when pictures were presented for a longer duration (3 seconds). Crucially however, note that the good performance of ASD participants may come from using different, non-embodied strategies. This conclusion is suggested by Rutherford and McIntosh (2007), since they showed that individuals with ASD use facial features for a rule-based strategy, accepting expressions as “valid” even when such expressions had extremely exaggerated features (e.g., sadness with lips curled down to a biologically unrealistic degree). A recent study reached a similar conclusion from an observation that ASD participants show reduced emotional reactivity to very briefly presented expressions, suggesting processing using more descriptive routes (Nuske et al., 2014). In short, it appears that ASD individuals use a disembodied approach to emotion-perception, rather than one that employs embodied simulation of real-life, biologically constrained expressions (for a fuller review of theory and evidence in this area, see Winkielman, McIntosh, & Oberman, 2009).

Training mimicry

If it is indeed true that embodiment is contributing to recognition, it should be possible to improve individuals’ real-life emotional communication skills by training their sensorimotor responses. Success in such a programme would also provide a powerful example of how theories of social cognition can inform and facilitate actual interpersonal behaviour. One domain where this can be easily achieved is facial mimicry, where quick motor reactions to faces are developed by frequent pairing of a specific stimulus and motor response (e.g., smile-to-smile, frown-to-frown, etc.). In fact, we recently tested this idea in our laboratory by using a training paradigm in which typical participants produce facial expressions in response to schematic facial stimuli (Deriso et al., 2012). The initial results are encouraging and suggest that facial imitation training may indeed improve facial recognition. Future studies in our laboratory (and related laboratories) will extend these interventions to participants with autism. One reason to expect that this may be beneficial are earlier findings suggesting that ASD participants show improvement in face perception after playing face-related video games (Tanaka et al., 2010). We are also planning an intervention programme with the earlier-described humanoid robot that makes realistic facial expressions (Wu et al., 2009). We hypothesize that these perception–action pairings will enhance the ability of ASD participants to quickly mirror facial expressions, which in turn may facilitate their recognition of emotional faces. Of course, the hope here is that being able to mimic will make others judge ASD individuals as more socially skilled. However, as we have argued throughout the chapter, the question of “social intelligence” of mimicry is critical, since direct “mirroring” is often inappropriate in many contexts. Thus, before making any practical recommendations, we need to more fully understand the underlying social and emotional dynamics of mimicry. One promising cue comes from research on the connection between mimicry and reward, which we discuss next.

The role of reward processes in mimicry, and a clue to studying initiation deficits in autism

As mentioned, in many contexts, ASD individuals’ spontaneous mimicry of emotional facial expressions is reduced. Interestingly, ASD is also characterized by a largely atypical response to social rewards (Chevallier, Kohls, Troiani, Brodtkin, & Schultz, 2012; Dawson et al., 2002; Dichter, Richey, Rittenberg, Sabatino, & Bodfish, 2012; Kohls et al., 2012; Scott-Van Zeeland, Dapretto, Chahremani, Poldrack, & Bookheimer, 2010). The set of studies discussed next provide a theoretical framework to

consider how these two deficits may be related to each other. Before we do so, let us again remind, we have done throughout the chapter, that mimicry can be influenced by context both when it operates in a more direct, automatic, fashion (e.g., when imitation is easily modifiable in a "dumb" fashion, based off lower-level stimulus cues) or more rational, indirect fashion (e.g., when imitation flexibly adapts in a "flexible" way to the specific social demands of the situation at hand). Some example moderators of these "dumb" and "smart" imitative patterns include social variables such as liking (Likowski et al., 2008; Stel et al., 2010), social competition (Carr et al., 2014; Lanzetta & Englis, 1989; Weyers et al., 2009), and group membership (Yabar, Johnston, Miles, & Peace, 2006). Now note that all of these processes effectively alter the reward value attached to the stimulus – that is, liking is related to how rewarding a person is, and being part of the same group/team can make the in-group member more rewarding than the out-group member, suggesting that reward may influence the degree of spontaneous mimicry. This idea was directly tested in a psychophysiological study, which found that spontaneous facial mimicry (measured using facial EMG) was modulated by the reward value of different stimuli (Sims, van Reekum, Johnstone, & Chakrabarti, 2012). In this experiment, neutral faces were conditioned with high and low rewards using an implicit conditioning task, instantiated through a card game. In the test phase, participants saw happy and angry expressions made by these same faces, while facial EMG was recorded from congruent muscles to measure spontaneous facial mimicry. This study found that more rewarding faces were associated with greater spontaneous mimicry, compared to less rewarding faces. This observation was true only for mimicry of happy faces, and not for angry faces, similar to observations made by Hofree and colleagues (Hofree et al., 2014). Crucially, this reward-dependent modulation of spontaneous mimicry of happy faces was inversely related to autistic traits (i.e., individuals high in autistic traits showed little difference in the extent of spontaneous mimicry for high vs. low rewarding faces, while this difference was pronounced in those with low autistic traits). In a separate sample of individuals who underwent an identical conditioning phase, brain activity was measured using fMRI during the testing phase. This study found that the functional connectivity between the nucleus accumbens (coordinates identified using a meta-analysis of studies of reward processing; Liu, Hairston, Schrier, & Fan, 2011) and the inferior frontal gyrus (coordinates identified using a meta-analysis of studies on mimicry; Caspers, Zilles, Laird, & Eickhoff, 2010) was inversely proportional to autistic traits, in response to happy faces conditioned with high reward compared to those conditioned with low reward. Thus, both of these studies

found that autistic traits modulated the impact of reward on spontaneous facial mimicry.

This relationship between autistic traits and the reward-dependent modulation of mimicry was further tested using hand stimuli in a task developed by Heyes and colleagues (e.g., Press et al., 2005). In this task, two human hand silhouettes were conditioned with high and low rewards using an implicit conditioning task as described above. In the test phase, participants were asked to make a pre-specified movement ("close" or "open"), while a hand stimulus was presented simultaneously on screen, which was making a congruent or incongruent movement. The difference in reaction time to congruent vs. incongruent stimuli was measured as a proxy metric of automatic imitation. Autistic traits were found to be inversely related to the reward-dependent modulation of automatic mimicry of human hands (Haffey, Press, O'Connell, & Chakrabarti, 2013). Interestingly, this result was true only for human hands and not for robot hands, which were used as a control condition to test whether the reward-dependent modulation of automatic mimicry extended to non-human stimuli.

Generally, these studies suggest that autistic traits modulate the link between reward processing and spontaneous mimicry of social stimuli. This suggestion provides a potential theoretical bridge between studies that suggest a mirror system deficit in autism (Beall et al., 2008; Dapretto et al., 2006; McIntosh et al., 2006), and those that do not (Bird et al., 2007; Dinstein et al., 2010). Here, the idea is that the autistic phenotype is not characterized by a circumscribed deficit of the mirror system, but one of atypical modulation between the mirror system and the reward response to social stimuli. This view is in agreement with a recently suggested framework, which suggests atypical top-down modulation of mimicry in autism (Wang & Hamilton, 2012).

Summary and conclusion

Successful social interaction hinges on a number of psychological mechanisms. One of them appears to be the ability of people to spontaneously mimic others. In this chapter, we argued that this ability reveals how our perceptual and conceptual mind is grounded in embodied, somatosensory processes. Further, we have argued that mimicry, as a form of embodiment, is not just a byproduct of perception-action links, but instead, can sometimes play a constitutive role in information processing. Moreover, we have posited that spontaneous mimicry can (under some conditions) manifest features of an automatic and associative process (i.e., "dumb" mimicry), but still can be helpful in basic recognition tasks and influence memory performance and judgements.

Concurrently, we have highlighted many "smart" features of spontaneous mimicry, whereby its production is sensitive to a variety of social and emotional variables, when dealing with people but also artificial entities, such as androids. Further, we have demonstrated that the perception of mimicry is also attuned to these contextual cues and that they can be used to draw complex inferences. Finally, we discussed the implications of this work for developmental disorders, such as autism. We highlighted that part of the atypicality here may reflect differences at the level of basic perception-action links (and suitable to relevant interventions at that level), but also that ASD participants reveal a complex pattern of modulation by social and affective variables.

In conclusion, the picture of spontaneous mimicry that emerges from our chapter may seem rather complex – a conclusion that is surprising to us, given that our own work started as a fascination with mimicry as a seemingly simple and tractable, yet widespread and important process. But the mind is a complex entity, which consistently reveals itself to science in new ways. Further, the complexity here gives a testimony to the sophistication of the social mind even at its most spontaneous, fast, and implicit manifestation. Going forward, we hope that the insights highlighted here both enlighten and encourage further explorations of this fascinating process, in both typical and atypical individuals.

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