Chapter 8
Anticipated Imitation

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Experimental research in psychology and related fields has traditionally followed a straightforward agenda that we will call the stimulus-response paradigm here. The stimulus-response paradigm involves creating certain situations and measuring the behavior of humans and other animals in these situations. This paradigm offers an elegant blueprint for empirical studies on cognition and behavior, as it follows directly from attempts to introduce experimental methodology into the discipline of psychology (Ueberwasser, 1787; see also Schwarz & Pfister, 2016).

Against the background of the stimulus-response paradigm, it seems intuitive to manipulate clearly perceivable stimulus characteristics and measure behavior (i.e., responses) as a function of these characteristics. This approach already developed in the early days of psychological inquiry, when initial experimental studies approached human perception from the perspective of psychophysics (Fechner, 1877; Weber, 1851, cf. Kingdom & Prins, 2016). Other lines of inquiry quickly adopted similar methods such as early studies with response time measurements (Donders 1869), and this paradigm continues to be a major component of the methodological toolkit of contemporary psychological research.

Applying the stimulus-response agenda to the scientific study of imitation entails a straightforward roadmap for devising experimental setups. Imitation involves at least two agents, a model and an imitator. Because the model action has to precede the imitator action, it is natural to assign the model's behavior to the stimulus side of the experimental design (often using pictures or videos of the model action), and to assign the imitator's behavior to the response side. This assignment has enabled a series of relevant discoveries. One example concerns research on automatic

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imitation (Heyes, 2011) as studied experimentally via motor priming effects (Brass et al., 2000, 2001; Cracco et al., 2018). In studies on motor priming, participants are shown a stimulus on every trial, and this stimulus includes an action of an imitation model, e.g., lifting the index finger of the left hand. They are asked to respond to each stimulus with clearly defined responses, e.g., also lifting the left index finger. These setups reliably produce compatibility effects in the sense that response times and error rates of the imitator are lower if the model action matches the required response (compatible or imitation trials) as compared to mismatches between model action and imitator response (incompatible or counter-imitation trials). This occurs even if participants do not have to attend to the model action, e.g., when responding to a stimulus shape that is superimposed on the model action. Research on motor priming therefore suggests that perceiving the movement of another agent primes similar responses in the observer (Fadiga et al., 1995, but see Hemed et al., 2022).

An elegant way to explain motor priming effects is in terms of the ideomotor principle of action control (Brass & Heyes, 2005). The ideomotor principle assumes that agents represent and access their behavioral repertoire by means of the perceivable changes to be produced by the movement, i.e., in terms of its action effects (Harleß, 1861; Herbart, 1824; James, 1890 Washburn, 1908; for historical perspectives, see Stock & Stock, 2004; Pfister & Janczyk, 2012). Re-encountering any of these effects can therefore prime the associated movements by means of bidirectional associations between actions and their ensuing effects. For a simple finger movement, these effects include the proprioceptive and tactile changes triggered by the moving body, as well as the visual image of the moving finger (e.g., Pfister, 2019). This is precisely the kind of stimulus that triggers imitative tendencies in a typical experiment on motor priming. In this view, therefore, motor priming is a social manifestation of a general and basic property of action representations. The mechanisms proposed by ideomotor theorizing also extend seamlessly to other modalities so that they can account for automatic imitation of complex behaviors such as gestures (Bernieri, 1988; Cracco et al., 2018) and facial expressions (Dimberg, 1982; Seibt et al., 2015). It further accounts for a number of classic findings in the field. For instance, motor priming is affected by how similar model and imitator are (Brass et al., 2001; Liepelt & Brass, 2010; Longo & Bertenthal, 2009; Genschow et al., 2013, 2021; Vogt et al., 2003; see also Schütz-Bosbach & Prinz, 2007). It also captures changes of action priming through novel motor-effect contingencies (Gillmeister et al., 2008; Wiggett et al., 2011). In an ideomotor view, perceiving a model action can re-activate of existing action–effect associations to the extent that there are shared features between model and imitator action. As increased similarity implies increasingly many shared features, ideomotor accounts imply that imitative tendencies should vary with model-imitator similarity.

In the following, we argue that the ideomotor account offers even more than providing an elegant and parsimonious explanation of motor priming effects. Moreover, experimental paradigms that play a central role in studying ideomotor mechanisms of human action control allow to expand the field of study beyond simple reactions to external events. That is: Applying similar experimental approaches to the study of imitation shifts the focus away from the imitator and towards the psychological processes operating in the action model, thus opening a new look at a classic phenomenon. To motivate this claim, we will first discuss several key aspects of studying ideomotor action control outside the field of imitation, and we then show how this line of thinking has stimulated so-called “sociomotor” research on imitation and social actions in general (Kunde et al., 2017; Neszmélyi et al., 2022).

Ideomotor Action Control: The Role of Sensory Anticipations

Ideomotor action presupposes that agents can acquire bidirectional associations between the neural activity that generates overt movements and incoming sensory effects that are triggered by this movement (Harleß, 1861; Herbart, 1824). Once established, these bidirectional associations allow for goal-directed actions because mentally recollecting, i.e., anticipating, the effects will then spread activation across the available associations and thus initiate a movement. It is this anticipative component that renders the ideomotor mechanism particularly relevant for understanding how the human mind represents and produces actions (Kunde, 2006; Kunde et al., 2004).

Empirically studying effect anticipations poses a profound challenge to common experimental designs that follow the general stimulus-response agenda, however. It requires measuring how a stimulus that occurs only after action execution affects the very action that is going to produce the effect in the first place. Instead of varying perceivable characteristics of the current situation, experiments thus need to manipulate future but predictable events and probe for their impact on behavior.

One way to implement a structured manipulation of to-be-produced action effects is the response-effect compatibility paradigm (Kunde, 2001). In this paradigm, participants perform simple responses such as keypresses and each response produces a particular, foreseeable effect such as a visual event on the computer screen. If the experimental design implements responses and effects that vary on a shared dimension, e.g., left versus right, this setup can include compatible trials such that a left keypress triggers an effect on the left-hand side, and incompatible trials such that a left keypress triggers an effect on the right-hand side. Crucially, compatibility here relates to how action features map onto features of later action effects, i.e., events that are not yet present during action execution. Still, responses are usually observed to be faster in compatible trials than in incompatible trials (Pfister & Kunde, 2013; Pfister et al. 2014a; Wirth et al., 2016; Shin & Proctor, 2012). Similarly, the way actions are produced changes with the features of upcoming stimulation so that an action will be less forceful if it triggers a high-intensity effect as compared to a low-intensity effect or no effect at all (Horváth et al., 2018; Kunde et al., 2004; Neszmélyi & Horváth, 2017; Thébault et al., 2020). These findings clearly suggest that participants anticipate upcoming action effects, and that such effect anticipations are functionally relevant for action planning and control.

Even though technically still a stimulus-response paradigm (for the fact of implementing a controlled experimental design), research on response-effect compatibility offers an elegant perspective on imitation by highlighting the model's side of the process as the first part of an action–effect sequence (with the "action" in "action–effect" being the model's action and "effect" being the imitator's response). Understanding whether and how action models are affected by imitation requires a shift in focus towards measuring rather than manipulating the behavior of action models. What needs to be manipulated instead is the later response by the imitator, which also needs to be sufficiently predictable to allow the model to form meaningful anticipations. The following section covers this type of research.

Focusing on the Imitation Model

Imitation can affect the action model in two ways. First, experiencing another person imitate one's own actions may change later cognition and behavior of the model. This is true especially for affective consequences of imitation such as liking of the imitator (Chartrand & Bargh, 1999; De Coster et al., 2013; Dignath et al., 2018; van Baaren et al., 2004; for an overview see Chaps. 13 and 14; this volume). Second, expecting another agent to imitate one's own actions may even affect how models represent, plan, and control their actions in the first place. In this sense, imitative behavior of another person can be seen as an action effect of the model action. Ideomotor theorizing therefore suggests that predictable imitation should facilitate action control as compared to predictably mismatching responses (counter-imitation), and also compared to situations with unpredictable responses of a social interaction partner. Figure 8.1 shows a summary of the assumed processes underlying anticipated and reactive imitation.

Initial evidence for this hypothesis comes from a response-effect compatibility experiment that assessed the impact of anticipated action effects on how facial muscles are controlled (Kunde et al., 2011). Participants were asked to perform facial gestures by either contracting the zygomaticus major muscle (generating a smiling expression) or by contracting the corrugator supercilii muscle (generating a frowning expression). Each response further triggered the image of either a smiling or frowning face on the computer screen. Different blocks of the experiment implemented either a predictably compatible mapping (smiling response triggers smiling face) or a predictably incompatible mapping (smiling response triggers frowning face). Generating a correct facial gesture was indeed faster if predictably followed by a compatible rather than incompatible action effect. These findings are in line with the idea that social effects enter action representations in addition to other (e.g., body-related) effects so that anticipated imitation directly primes corresponding model responses.

In a second, direct test of the anticipated imitation hypothesis, we asked two participants to act in leader–follower, i.e., model–imitator dyads (Pfister et al., 2013). They sat face to face at a table and operated one response key each, with both

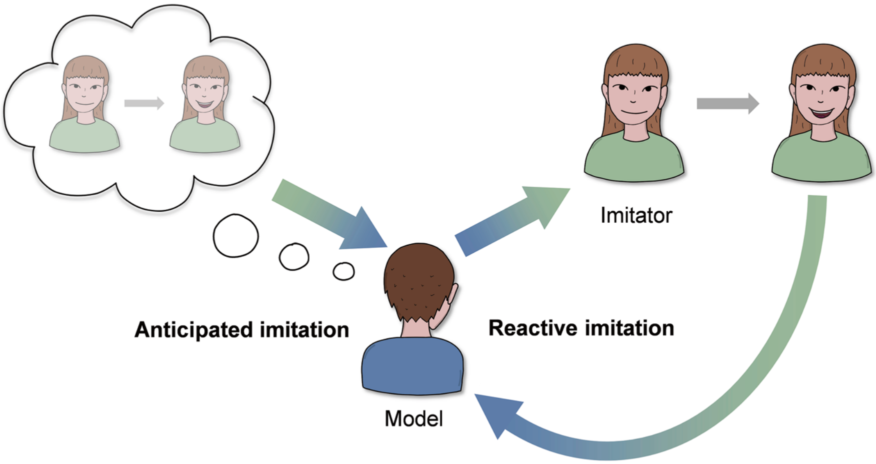

Fig. 8.1 Interplay of anticipated and reactive imitation when a model's smile (depicted from behind) makes the imitator smile back. Even before actually perceiving an imitative response (reactive imitation), models may anticipate likely imitative behavior which, in turn, triggers imitative tendencies on the model's side (anticipated imitation; for a corresponding theoretical framework, see Kunde et al., 2018). Such tendencies can be shown experimentally by having the imitator predictably imitate or counter-imitate a model action (e.g., Pfister et al., 2013; Müller, 2016)

keys placed close to each other on the table. The leader observed a computer screen on each trial and performed either a short or a long keypress in response to the screen background changing from black to either red or green. In different conditions, the follower was asked to consistently imitate or counter-imitate the leader's action. In the imitation condition, the follower would thus perform a short keypress in response to a short keypress of the leader, whereas the counter-imitation condition would call for long keypresses of the follower in response to a short keypress of the leader (see Kunde, 2003, for a blueprint of this setup with physical action effects). The experimental conditions were again manipulated across blocks so that the leader could predict the likely follower response to his or her action on each trial. Crucially, this manipulation did indeed affect the leader's behavior in that their responses were faster in the imitation condition as compared to the counter-imitation condition. These imitation effects on the leader were smaller than the imitation effects of directly perceived stimuli as observed with the follower but, crucially, both were highly reliable across experiments. The same held true when comparing the imitation condition to a control condition with unpredictable follower responses. Further work extended the approach to larger-scale movements such as moving virtual objects on a multi-touch table (Müller, 2016). These findings again suggest that models built up anticipations of upcoming imitator responses, thus boosting performance if these anticipations overlapped with the currently required response.

Carefully inspecting the setup and design of the latter two studies highlights a potential shortcoming, however (Lelonkiewicz & Gambi, 2017). Because the experimental conditions varied across blocks, each imitation trial also follows another imitation trial in the imitation condition, and each counter-imitation trial always follows other counter-imitation trials in the counter-imitation condition. Any systematic effects between conditions may therefore relate to anticipations as hypothesized above, or they might be due to after-effects of just having experienced imitation or counter-imitation in the preceding trial(s). This concern is particularly relevant for designs with direct interactions of actual participants, i.e., if not relegating either the model or the imitator side to picture or video stimuli (e.g., Pfister et al., 2013). In cases of direct interactions, imitators of course also show typical motor priming effects so that the imitator's responses are systematically delayed in the counter-imitation condition as compared to the imitation condition (Brass et al., 2001). One way to assess concerns related to the blocked experimental design is to manipulate imitation conditions on a trial-by-trial level. This design choice only requires an additional cue on every trial to enable the model to predict the imitator's response. The issue of different temporal delays during imitation and counter-imitation, by contrast, is best addressed by using virtual agents as imitator, which allows controlling the interval between the model's and the imitator's movements. Studies that applied such modifications to the original setup still replicated the previously observed impact of anticipated imitation, thus supporting the above reading in terms of actual anticipations (Lelonkiewicz et al., 2020; see also Pfister et al., 2017).

Predictable Imitation

The processes occurring during anticipated imitation are tied to the model actually predicting a social partner to imitate (see Fig. 8.1). But are such predictions actually warranted in the real world? They are warranted in the context of a psychological experiment as discussed above, because the imitator is explicitly asked to produce imitation actions in certain conditions. Imitation can indeed be expected also in many real-world interactions, however. Smiling at another person routinely triggers this person to smile back, greeting another person will also make this person greet back, though not necessarily using the same phrase. Many innocuous movements are also copied readily by others, such as scratching one's noes, crossing one's legs, and the like.

A familiar everyday instance of imitation is the tendency to copy the body posture of other people during a meeting. Imitation also occurs frequently when interacting with children or during interactions among children (Agnetta & Rochat, 2004). Imitative games between caregivers and children can involve extended loops of mutual provoking and performing imitative responses. Deliberately provoking imitation therefore enables early, pre-verbal forms of interaction and communication, thus serving a crucial role in ontogenetic development (Nagy, 2006; Nagy & Molnar, 2004).

Motor priming through anticipated imitation arguably facilitates these crucial interactions. Specifically, imitation is a kind of win-win situation for the imitator and the model alike. The benefits for imitators are pretty obvious (e.g., Heyes, 2013). For example, while it may sometimes be hard to explain a complicated body movement to another person verbally, e.g., performing a certain dance move or eating with cutlery, this is much more easily done by demonstrating the action to another person and asking him or her to do the same. Imitation drives the imitator towards doing the right thing in such demonstration scenarios. Yet, the foreseeable imitation is beneficial for the models as well, namely to generate the to-be-imitated behavior in the first place. Think of it: it is easier to demonstrate a certain movement to another person that most likely will imitate, as compared to demonstrating the same movement to, let us say to a wardrobe, that most likely will not imitate. Only in the former case can the model build reasonable anticipations of upcoming imitative responses. Motor priming by expected imitation from a social partner thus facilitates model behavior directly.

Despite imitation being likely and predictable on many occasions, direct interactions will also include situations in which corresponding expectations are violated. That is, a model might sometimes anticipate their interaction partner to imitate while the partner actually fails to do so. Reasons for such failures may be inattention to the model's action, error commission while actually aiming to imitate, or deliberate omission of an imitative response. Unexpectedly observing a social partner not to mirror one's behavior has been shown to trigger immediate neurophysiological and behavioral responses (Pfister et al., 2020; Weller et al., 2017), suggesting that action models monitor the behavior of their interaction partners closely.

Imitating Anticipated Actions

The discussion so far had centered on the model's perspective. Anticipation might also play a crucial role for the observing imitator. More precisely, when observing others, humans tend to predict future behavior of their social partners (Bach et al., 2011; Bach & Schenke, 2017). Following the logic of ideomotor theorizing, such predictions or anticipations might induce similar imitative tendencies as in the case of anticipated imitation. This is indeed the case: If participants can reasonably predict another agent to perform an action, they are biased towards performing precisely this predicted action (Genschow & Brass, 2015; Genschow et al., 2018). Watching someone wrinkle their nose, for instance, is predictive of this event being followed by nose scratching. Participants observing a model performing the first action (nose wrinkling) are indeed likely to perform the predicted follow-up action (nose scratching) themselves even if the model does not execute the second action at all. Moreover, merely drawing attention to a certain body part of others does not induce similar action tendencies (Genschow & Groß-Bölting, 2021). Participants therefore form a prediction of a specific action and likely activate own actions with similar features in much the same way as imitation models are primed by anticipating the imitator's response (Genschow & Brass, 2015; Pfister et al., 2013).

Findings on imitation of anticipated actions (Genschow & Brass, 2015) find a non-social counterpart in ideomotor-inspired research on motor priming by merely intended events (De Maeght & Prinz, 2004, Knuf et al., 2001; Prinz et al., 2005). In these experiments, participants watched the trajectory of a rolling ball that steered towards a target area. Each movement lasted several seconds and the ball appeared to miss the target if participants did not intervene early on in the trajectory. During the later phases of the trajectory, participants knew that they could no longer affect the ball movements. Still, they consistently continued to perform actions that would have steered the ball in the intended direction. This mirrors imitation of anticipated actions in that motor priming only derived from anticipated or intended events. In case these anticipated events are actions of another partner, however, this priming is additionally boosted by the strong resemblance of predicted partner actions and the observer's own motor repertoire (Colton et al., 2018).

Anticipating Imitation Versus Actually Imitating

The findings discussed so far suggest striking similarities between the impact of anticipated imitation and the processes occurring when actually performing an imitative response to a currently perceivable stimulus, i.e., reactive imitation. Both seem to come with a similar behavioral signature and both can be explained by the same ideomotor mechanism. This mirrors the relationship of stimulus–response and response–effect associations in ideomotor theorizing. Both types of associations are assumed to rely on the very same linkage between efferent activity and (re)afferent signals, regardless of the temporal order of the perceptual and motor events. Whenever action models expect or anticipate an imitative response of a social partner, this process effectively blurs who imitates whom: Even though the second person to physically respond is clearly triggered by observing the first action, this first action is already biased by imitative tendencies due to anticipated imitation. Expecting another person to return a smile thus makes us smile back before actually perceiving the imitative smile.

Several notable differences qualify the observed similarities of anticipated and reactive imitation, however. For instance, reactive imitation has been suggested to be moderated by group membership, with stronger imitation effects for in-group members than for outgroup members (Bourgeois & Hess, 2008; McIntosh, 2006; Yabar et al., 2006), specifically when groups were framed as competing with one another (Gleibs et al., 2016). This effect of group membership was further reported to depend on the imitator's motivation to affiliate with social partners, with reliable effects of group membership emerging particularly for participants with a high motivation to affiliate (Genschow & Schindler, 2016). The observation of limited imitation of out-group members resonates with a range of findings outside the imitation literature indicating that the impact of social partners on an agent's performance is relatively small or even absent when construing the other as belonging to an out-group (Aquino et al., 2015; Iani et al., 2011; McClung et al., 2013; Müller et al., 2011). The available evidence for anticipated imitation, by contrast, does not support a role of social group (Weller et al., 2020). Here, four participants were invited to each session and were split into two groups of two participants each. Group membership was consistently reinforced by colored t-shirts to be worn throughout the experiment (red for one group, blue for the other). Participants were further informed that one group would win an additional reward based on the combined performance of the group members to instill a competitive context. Participants then interacted with in-group members and out-group members in an imitation setup with short versus long keypresses of a leader and a follower as sketched above (Pfister et al., 2013). This study showed anticipated and reactive imitation for all participants and groups in two separate experiments, suggesting that anticipated imitation is not particularly sensitive to group membership. These conclusions have to be taken with caution for several reasons, however. For one, neither of the two experiments on anticipated imitation replicated common effects of group membership on the imitator's side and they also did not yield any effects of the group manipulation on closeness ratings to ingroup and outgroup members (Weller et al., 2020). For another, recent re-assessments of the effect of group membership on reactive imitation have questioned earlier findings (De Souter et al., 2021; Genschow et al., 2022, 2023).

A major difference between anticipated imitation and imitation of physically perceivable stimuli, however, is the role of different features that become represented in both situations. The experiments discussed up to now do not address such a question because each experiment focused on one single feature to distinguish different actions, i.e., facial expression (Kunde et al., 2011), duration (Lelonkiewicz et al., 2020; Pfister et al., 2013), or spatial location (Müller, 2016). Research on automatic imitation, by contrast, has shown that motor priming relies on rich representations that cover different features of the model's action if multiple features were included in the experimental design (Boyer et al., 2012).

When participants perceive the model action of lifting the left index finger, this movement obviously comprises spatial features relating to the location and direction of the movement in allocentric coordinates. It also comprises anatomical features of which body part moves, and temporal features relating to movement kinematics. Each of these features can be expected to trigger motor priming in its own right. Empirical studies have confirmed this prediction (Bertenthal et al., 2006; Boyer et al., 2012; Catmur & Heyes, 2011). One way to disentangle different features is to manipulate two or more features orthogonally across conditions. Figure 8.2 shows an exemplary setup for corresponding studies. When two participants sit face to face at a table and each have their index and middle finger rest on two adjacent keys, a study can implement spatially compatible or spatially incompatible conditions by asking the imitator to respond with operating the key that spatially corresponds or does not correspond to the key operated by the action model. Assuming that the model operates their pair of keys with the right hand, asking the imitator to use the left hand will result in a joint variation of spatial compatibility and anatomical compatibility in the sense that a spatially compatible condition will also be anatomically compatible. For example, lifting the left finger from the

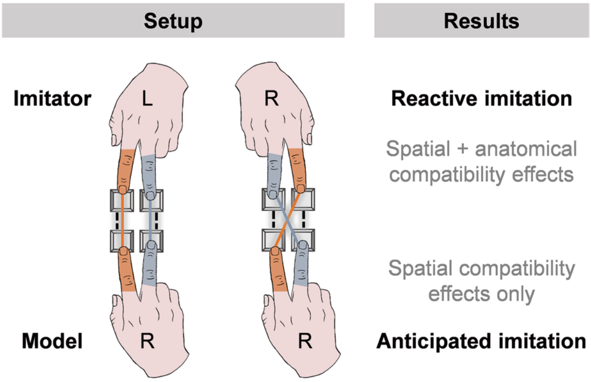

Fig. 8.2 Experimental setup for contrasting spatial coding (dashed lines) and anatomical coding (solid lines) with corresponding results. Models and imitators sit face to face at a table. They both operate a pair of keys with index and middle finger of one hand. If the model uses the right hand for operating the keys, spatial and anatomical compatibility go hand in hand if the imitator uses the left hand. Both are pitted against each other if the imitator uses the right hand, however. Studies in this design shows a joint influence of spatial and anatomical features for reactive imitation (Bertenthal et al., 2006; Boyer et al., 2012; Catmur & Heyes, 2011) whereas anticipated imitation has been observed to draw only on spatial features (Weller et al., 2019)

left key as a model will make the imitator lift the left finger from the key on the same side during imitation, whereas the imitator would lift the right finger from the key on the opposite side in the counter-imitation condition. Asking the imitator to use the right hand, by contrast, renders spatially compatible mappings anatomically incompatible, and vice versa. Evidence suggests that spatial and anatomical features both contribute to motor priming (Bertenthal et al., 2006; Boyer et al., 2012; Catmur & Heyes, 2011). Observing a movement to the right thus primes imitative responses to the same spatial location just as observing a movement of the index finger primes imitative responses with that same body part.

Anticipated imitation, by contrast, shows a distinct picture that seems to rely entirely on spatial coding (Weller et al., 2019). That is, expecting the imitator to respond at the same spatial location will expedite action planning for the model, irrespective of whether this movement is made with the same or a different effector. These experiments further replicated a role of anatomical compatibility for imitators in the same experimental setup, so that imitator responses with the same finger as the model were faster than responses with another finger. It is an open question whether anatomical features may affect anticipated imitation for more extended, salient movements. In any case, the available data indicate that anticipated imitation is less sensitive to anatomical features than reactive imitation. Anticipating imitation therefore cannot be equated directly with actually imitating when it comes to priming motor actions.

Imitative Versus Non-social Action Effects

Differences in the role of spatial and anatomical features in anticipated imitation and in reactive imitation mirror findings from the literature on ideomotor action control in non-social settings. Whereas empirical studies on anticipated imitation find a non-social counterpart in research in the response-effect compatibility paradigm, research on motor priming resembles spatial stimulus-response compatibility paradigms in various characteristics (Boyer et al., 2012). The Simon effect, for instance, describes the observation that making spatial responses to a non-spatial stimulus attribute is facilitated if the stimulus appears at a compatible spatial location (Simon & Rudell, 1967; Hommel, 2011). In a simple version, making a left or right response to the color of a stimulus that appears either on the left or right is easier if stimulus and response location match as compared to when they differ. Interestingly, the spatial stimulus location also primes anatomical features so that observing a stimulus on the right not only primes responses to that side, but also responses with the right hand (Heister et al. 1990; Klapp et al. 1979; Riggio et al. 1986; Simon et al., 1970). These conclusions emerged from experiments with crossed hands so that participants were asked to operate a left response key with their right hand and a right response key with their left hand. Spatial compatibility effects usually exceed anatomical compatibility effects by a substantial margin in these designs, but it is important note that both types of features are effective. Turning to response-effect compatibility designs, anticipating a spatial action effect was observed to prime responses at that spatial location while anatomical features in terms of left or right hand did not bear any relevance here (Pfister & Kunde, 2013; see also Hoffmann et al., 2009).

Viewing the evidence from studies on imitation and studies on compatibility effects in non-social settings side by side suggests that anticipations are surprisingly sparse in that they only draw on selected features of upcoming stimuli. Alternatively, the absent impact of anatomical features for anticipated stimuli might be explained by the overall lower effect sizes for anticipated as compare to perceived stimuli (Müller, 2016; Müller & Jung, 2018; Pfister et al., 2013). With a smaller overall effect size, detecting the weaker effects of anatomical as compared to spatial features would be more difficult and require more statistical power. Until such findings are available, however, we suggest that anticipations might actually be selective in what features become represented and what features are ignored. Crucially, these points suggest that different sensitivity of anticipated and reactive imitation derive from relatively broad differences between anticipation and perception.

The striking parallels between imitation and non-social compatibility effects raise the question whether effects related to imitation can be reduced to stimulus-response and response-effect compatibility effects in the non-social domain or if these should be regarded as separate phenomena. For reactive imitation, the empirical evidence shows a clear picture: Compatibility effects observed during imitation are stronger than stimulus-response compatibility effects obtained in paradigms where participants respond to non-social stimuli (Brass et al., 2000). Although these differences could also be a result of different stimulus properties in the social and non-social domain (Aicken et al., 2007; Jansson et al., 2007), other experimental methods that compared automatic imitation to other classes of stimulus-response compatibility, also found that the phenomena can be dissociated (Boyer et al., 2012). In the case of effect anticipation, the picture is less clear. Some studies that compared the influence of imitative and non-social action consequences found effects that could only be observed with imitative stimuli (Kunde et al., 2011; Flach et al., 2010). However, in these cases, the confounding effects of stimulus saliency or stimulus complexity were not controlled properly and more nuanced manipulations have not yet been used to assess the question. In the case of other (non-imitative) social effect types, recent results indicate that their influence on actions is surprisingly similar to the influence of non-social action consequences (Neszmélyi et al., 2022), but it has yet to be tested whether this also applies to imitative effects.

Imitative Versus Complementary Social Effects

One aspect that separates non-social and imitative effects is the possible role of shared representations for action observation and action execution (see also Chaps. 5 and 6; this volume). Using the same system for planning one's own action and for processing the observed actions might contribute particularly in the case of imitation (see the double route model of Sauser & Billard, 2006). However, shared representations could also contribute to the processing of the co-actor's actions if these are not identical with one's own actions, which raises questions about the relation between imitative interactions and other action–reaction-type interactions between two human agents. Again, this topic is better explored in the context of reacting to actually presented stimuli: It has been shown that seeing the execution of an action might not only activate identical actions in the observer but, depending on the context, it can also facilitate complementary dissimilar actions (Newman-Norlund et al., 2007). Although different neural populations are responsible for facilitating identical and complementary actions, the two systems are assumed to work in unison, and some findings suggest that when signaled by context or kinematic cues, people can seamlessly switch from imitating a movement to performing a dissimilar but complementary action (Sartori et al., 2012, 2013). A system that could enable facilitation of movements with varying levels of similarity between observed and performed action would be plausible: Although previously we mentioned several examples where imitation is relevant in everyday situations, a substantial majority of human interactions is based on complementary rather than on identical movements. Even such complementary actions usually share some of their features, thus, it is difficult to draw a clear line between imitative and non-imitative interactions (Flach et al., 2010). Rather than assuming a sharp distinction between identical and dissimilar actions, it might be more useful to conceptualize interactions on a continuum of shared features.

Studies on reactive as well as anticipated imitation can therefore be seen as providing a flexible empirical tool to study all kinds of social action representations, including those that are related to social interactions other than direct imitation. Anticipated imitation in particular highlights the goal-directed nature of many social interactions, in which an action aims at eliciting a response from an interaction partner. In more general terms, observing that human actions can become represented and controlled in terms of the social effects they produce offers an exciting approach to human action (Wolpert et al., 2003). We have previously dubbed such findings to reflect "sociomotor" action control, i.e., direct associations between one's own motor actions and the responses they evoke at social interaction partners (Kunde et al., 2018). As in the case of actual imitation, the ideomotor mechanism that we propose to underlie (anticipated) imitation could also handle interactions with smaller overlap between the initial action and the social response. But such ideas are yet to be explored.

The present ideomotor view on anticipating and producing social action effects is surprisingly non-social, however, in that it does not propose any mechanisms on top of what is needed to explain interactions with the non-social world (Neszmélyi et al., 2022). Nor are there any findings from anticipated imitation that would require any specifically social additions to the theoretical framework. This conclusion stands in contrast to how strongly human agents are attuned to processing social stimuli perceptually. The contrast to social perception becomes evident when considering the impact of biological motion (Johansson, 1973; Lacquaniti et al., 1983; Shiffrar & Freyd, 1990) such that even perceptually impoverished point-light walkers are easily identified as stemming from a human agent (Hudson et al., 2016). Similarly, tuning towards social stimuli has been proposed for faces (Oruc et al., 2019), eye-direction (Baron-Cohen, 1994), and language (Chomsky, 1980). Whether this tuning relates to dedicated, specialized mechanisms or whether it derives from extended learning experiences is debatable (Jarstorff et al., 2006; Vogelzang et al., 2017). In any case, social actions can leverage such capacities in principle, but it seems as if the impact of anticipated imitation is rooted deeply in basic mechanisms of human action control.

Open Questions

The available evidence for the impact of anticipated imitation raises several intriguing questions for future research. A first question relates to specific input–output modalities. Research on anticipated imitation has typically relied on manual tasks with only few notable exceptions (e.g., Kunde et al., 2011; Müller, 2020; Müller & Jung, 2018). Special input–output modalities that have been highlighted in research on social perception have not yet been targeted (e.g., Lacquaniti et al., 1983; Shiffrar & Freyd, 1990). These modalities come with several features that go beyond previous manipulations such as spatial or anatomical compatibility, especially in the case of language (e.g., pitch, phoneme duration, or semantics in the case of language; see also Chap. 4; this volume). Such features lend themselves to experimental manipulations in studies of anticipated imitation and may eventually reveal genuinely social components for such types of actions or social responses (note that many moderators of automatic imitation also still remain to be tested for anticipated imitation; for a summary of known moderators, see Cracco et al., 2018).

A second question concerns subjective agency for imitation, i.e., feelings of control over action outcomes. The sense of agency for interactions with the non-social world has attracted considerable interest across psychology and neuroscience in the last decades (Haggard & Tsakiris, 2009). It can be measured explicitly by asking for ratings of how strongly participants felt as if they had caused a certain event. Such ratings are often made on a visual analogue scale to elicit a graded response. In a typical imitation setting, the model clearly stimulates the imitator's response so that the model should strongly feel as causally responsible for the ensuing imitator response. Previous work has further tried to relate the perceptual illusion of temporal binding to agency. Temporal binding reflects a subjective compression of action–effect episodes, or cause–effect episodes in general, so that it can at least be expected to occur in imitation, even though its relation to agency is debatable (Schwarz et al., 2019). Crucially, explicitly reported agency and implicit temporal binding might be even stronger for imitation as compared to contingent but non-imitative responses. Because imitation draws on directly mirroring what the model is doing, the social consequence maps directly onto the model action so that the resulting overlap in perceptual features can be expected to boost binding. Despite first studies on agency in social context (Pfeiffer et al., 2012, 2014b; Grynszpan et al., 2019; for a review see Silver et al. 2021), there are currently no studies to assess subjective agency in the context of imitation. The question of subjective agency is also highly relevant on the imitator's end. Research on motor priming has shown that imitative responses are much more fluent than responding in a non-imitative or even counter-imitative way (Cracco et al., 2018). Fluency has been suggested to be a particularly strong cue to agency (Sidarus et al., 2013; Sidarus & Haggard, 2016), though here this cue accompanies those actions that arguably involve less control (and thus causation) for the imitator. Situations with a dynamic, real-time interaction may further yield particularly strong confusions as to who caused what during imitation. An everyday example for such confusion arises on pavements across the globe when two pedestrians approach each other. This situation will often trigger one person to step aside which, in turn, triggers the other person to perform an evasive action in the same direction, resulting in both pedestrians facing each other again. Going through two or three iterations of such imitative maneuvers blurs the difference of who is model and who is imitator, while each person aims not to be imitated in order to break the loop.

A third question pertains to direct and predictable imitation by virtual avatars (Böffel & Müsseler, 2018; Müsseler et al., 2022). Here, imitation can be seen as a major tool to embody such a virtual entity if the avatar's behavior maps sufficiently closely onto the behavior of the user (e.g., Eck et al., 2022; Kokkinara & Slater, 2014; Sanchez-Vives et al., 2010). Such virtual reality settings can further be construed in two ways: Imitative behavior of the avatar may either be seen as a direct extension of one's own behavior in the physical world, or the avatar may be expected to have some degree of autonomy while choosing to mirror what the human is doing. It is a relevant question for future research how such different ways to construe the same situation affect cognition and behavior in virtual environments.

A fourth question relates to situations in which a model is imitated by multiple imitators. This situation occurs frequently when instructing other people, say when a yoga teacher instructs his or her course. Arguably, having multiple imitators renders it difficult to build up anticipations of how the entire group is going to perform, so that it is an open question whether anticipated imitation actually occurs in these settings. At the same time, having multiple imitators might make imitation particularly salient. This effect has been demonstrated for reactive imitation (Cracco & Brass, 2018; Cracco et al., 2015). Exploring the role of multiple imitators for anticipated imitation will thus provide relevant insights into designing instructional interactions, including strategies of instructors on how to take advantage of positive effects of anticipated imitation while avoiding issues due to potential mismatches or prediction errors. Such work could also assess the transition of gradually merging imitative instruction-following to synchronized performance.

Conclusion

Just as it takes two to tango, imitation involves two agents that influence one another. While the impact of the imitation model on the imitator has been subject to extensive research, the role of the imitator's behavior for the action model has received comparatively little attention. Research on automatic imitation in direct, dyadic interactions indicates that model's incorporate upcoming imitative responses in their action representation. In turn, anticipated imitation shapes how models select and perform their action, showcasing a remarkably dynamic interplay of imitative tendencies during social interactions.

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