5 An Ideomotor Approach to Imitation

Wolfgang Prinz

5.1 Introduction

When it comes to explaining human action, psychological theory has two major frameworks to offer: the *sensorimotor* and the *ideomotor* framework. In sensorimotor approaches, everything starts with stimulation, and actions come into being as consequences of that stimulation. Actions are considered responses to stimuli that precede them. Conversely, in ideomotor approaches, everything starts with intention, and actions come into being as the means for realizing those intentions. Actions are considered the means for certain ends that follow them.

Over the past decades, if not centuries, theorizing in the behavioral and brain sciences has been dominated by sensorimotor approaches, whereas ideomotor approaches have played only a marginal role (cf., e.g., Hommel et al., 2001; W. Prinz, 1997b, for possible reasons). In this chapter, I argue for the reanimation of ideomotor theory and the assigning to it a strong role in future theories of human action. More specifically, I will show that the ideomotor framework offers an attractive account of imitation and related behaviors. Part of this attractiveness comes from the fact that ideomotor approaches have ways to accommodate the operation of similarity between perception and action that sensorimotor approaches are lacking. Another reason is that ideomotor theory offers a broad approach that allows us to view imitation as a specific instantiation of a more general principle and to classify it among a larger family of socially modulated actions that all share the same representational background.

My argument has two parts. First I give a brief outline of the major tenets of ideomotor theory and their functional implications for imitation and related behaviors. This outline will eventually boil down to what I call the principle of *action modulation through perception*. This principle then serves as a methodological guide for the second part, in which I give an overview of some experimental paradigms we have recently devised to study certain patterns of action modulation in dyadic social settings, such as action imitation, action induction, or action coordination.

5.1.1 Ideomotor Theory

Imitation implies performing an act after and by virtue of seeing it done by someone else. Hence, some form of similarity between the act perceived in the other and the act performed by oneself is the defining feature that classifies an act as imitation. If it is true that similarity is at the heart of imitation, any theory of imitation must come up with an account of how similarity can be functional between the perceived act and the performed act. As has been pointed out elsewhere (e.g., Hommel et al., 2001; W. Prinz, 1990; W. Prinz & Meltzoff, 2002), the sensorimotor framework has no such account to offer. This is because in this framework perception and action are subserved by separate and incommensurate representational structures. On the perceptual side, representations stand for patterns of stimulation in sense organs and their derivatives; while on the action side, representations stand for motor commands and patterns of excitations in muscles. Obviously, these representations are incommensurate. Accordingly, although there may be ample room for *rule-based mappings* between representations for perception and action, there is no obvious room at all for *similarity-based matchings*.

This is different in ideomotor approaches. At first glance they do not seem to offer anything that could help us to understand imitation. This is because in its historical beginnings ideomotor theory was meant to account for intentional guidance of action only, not for perceptual guidance. However, in the meantime, the theory has become extended to cover both perceptual and intentional guidance. It is this modern, extended version of the theory that offers a new grasp on the issue of similarity.

The ground for the ideomotor framework was laid by R. Lotze (1852) and W. James (1890) in their discussion of voluntary action. According to the Lotze-James account, voluntary actions require that two conditions be met: (1) There must be an idea, or representation, of what is being willed (Lotze: *Vorstellung des Gewollten*), and (2) conflicting ideas must be absent or be removed (Lotze: *Hinwegräumung aller Hemmungen*). When these two conditions are fulfilled, the representations of the intended goal states have the power of generating the action directly, that is, without the need for any further volitional activity. Accordingly, cognitive representations are by their very nature impulsive. This is in principle true of all representations, but it is particularly true of representations that refer to movements and actions. The ideomotor principle of human action applies to these representations. "Every representation of a movement awakens in some degree the actual movement which is its object; and awakens it in a maximum degree whenever it is not kept from doing so by an antagonistic representation present simultaneously in the mind" (James, 1890, vol. II, p. 526).

How does the impulsive nature of cognition arise? Lotze and James both argue that it arises from previous learning. Whenever a motor act is performed, it goes along with a number of perceivable effects. Some are close to the action in the sense of being accompaniments of the act itself (kinesthetic sensations, etc.). Some others may be more remote consequences, such as the fact that a light goes on at a distance when one's fingers operate a light switch. Such regular connections between motor acts and perceivable bodily and environmental effects can then become functional in two different ways. One is *to expect certain effects, given certain acts*; that is, to predict an ongoing action's perceivable consequences. The other way is *to select a certain act, given an intention to achieve certain effects*; that is, to derive a goal-directed action from a predefined goal.[1] This latter relationship—which leads from intended effects to acts—forms the functional basis of the ideomotor principle: Any representation of an event of which we learn that it goes along with, or follows from, a particular action will afterward have the power to elicit the action that produces the event. This will apply not only to representations of body-related action effects (e.g., thinking of one's finger operating a light switch) but also to representations of more remote effects in the environment (e.g., thinking of the light going on).

This may be a nice principle, but it has so far only been concerned with how actions are prompted and guided through internally generated ideas. Yet, if it is true that thinking of an act (or its remote effects) has the power to prompt and instigate that act, this should be even more true in the case of perceiving that act, for instance as performed by someone else. An extension of the ideomotor principle along these lines was suggested by Greenwald (1970, 1972). Greenwald studied tasks in which certain responses were mapped to certain stimuli in such a way that the triggering stimuli could be same as, or similar to, feedback arising from their required responses. For instance, when a red stimulus light elicits a manual response that in turn triggers a red feedback flash, the triggering stimulus and the

1. The difference between these two perspectives corresponds to the difference between forward models and inverse models in motor control (see, e.g., Wolpert & Kawato, 1998). Forward models specify the sensory consequences of given motor acts, whereas inverse models specify the motor acts required to achieve given consequences.

feedback stimulus share the same color. In this case, the red stimulus light can take exactly the role of the movement-awakening thought or idea in the Lotze-James approach. It serves to prompt the respective manual response and it does so by its similarity with the perceivable effects (= feedback) associated with the action that it triggers (= manual response).

5.1.2 Similarity

With this extension, the Lotze-James-Greenwald approach offers itself as a straightforward framework for action imitation. It relies on the notion that the perception of an event that shares features with an event that one has learned accompanies or follows from one's own action will tend to induce that action. If this is so, the strength of the induction must depend on the degree of similarity, or overlap, between the stimulus event and the action-related event. In other words, perception may induce certain actions, depending on the similarity between percepts and acts.

The extended principle has two important functional implications: ideomotor mapping and common coding. The notion of ideomotor mapping refers to the learning requirements implied by this framework. In order for the principle to work, two requirements must be met. One is that the system must be capable of learning regular associations between actions and their (resident and remote) effects. This is the easy (and trivial) part. The other is less easy and certainly not trivial. Once established, these connections between actions and effects must also be capable of being activated and used in the reverse direction, that is, leading from representations of effects to initiation of actions (Elsner & Hommel, 2004; Elsner et al., 2002; Elsner & Hommel, 2001; Kunde, 2001; Kunde et al., 2004; Stock & Hoffmann, 2002).

The notion of *common coding* refers to the functional architecture implied by the extended principle. In the ideomotor framework action planning and action control are no longer separate from the perceptual representation of environmental events. Instead, a common representational domain for perception and action is invoked, with shared representational structures for perceiving events and planning actions (Hommel et al., 2001; MacKay, 1987; W. Prinz, 1984, 1990, 1997a). Since actions are represented through their perceivable effects, perception and action are no longer incommensurate—and this is why similarity can work.

5.1.3 Action Modulation Through Perception

I concentrate here on situations in which people watch other people's actions and/or their outcomes. For such situations, the ideomotor principle has a straightforward prediction to offer. The perception of particular actions and/or their outcomes in someone else should address those representational structures that are also involved in one's own planning and control of those actions. This leads us to the principle of *action modulation through perception*, according to which the planning and control of an ongoing action becomes modulated through concurrent action perception. Obviously, this modulation should be content specific in the sense that it should be dependent on the representational overlap between the actions that are being perceived and those that are being planned.

5.2 Experimental Evidence

The ideomotor principle can be read in two ways: as a summary of some implications of ideomotor theory or as a methodological guideline for designing tasks to study the social modulation of ongoing actions. In any case, its scope goes far beyond imitation proper. The principle should be applicable to all sorts of tasks in which people perform certain actions while they watch other people performing certain related actions. In this section I discuss evidence from three types of such tasks we have studied: interference between perception and action, action induction through perception, and action coordination in shared task environments.

5.2.1 Interference Paradigms

In interference paradigms we study people's performance when they plan certain intentional actions and at the same time watch someone else's related actions. I address two such paradigms: gesture initiation and gesture selection.

Gesture Initiation In this paradigm we studied how the initiation of a predetermined finger gesture is modulated by the concurrent perception of a related gesture (cf. Brass et al., 2001). The participants were presented with randomized sequences of two stimulus gestures. One showed an index finger, first in a static starting position and then at an unpredictable point in time moving upward. The other stimulus gesture showed the index finger in the same static starting position, but then moving downward at an unpredictable point in time. The participants' task was to respond as fast as possible with one of the same two gestures using their own index fingers. It is important to note, however, that response gestures were kept constant within blocks. In other words, in a given block, the participants would see a randomized sequence of up- and down-moving index fingers, but they were required to always initiate one and the same gesture (say, moving downward). Accordingly, within a given sequence of trials, the actions to be performed were prespecified throughout, and the identity of the triggering stimulus (moving up versus down) was completely irrelevant. The question was whether the irrelevant stimulus gesture would still modulate the actions to be performed.

Over a number of experiments we observed huge compatibility effects for both of the response gestures. Prespecified upward movements could be initiated much faster when they were triggered by upward-moving stimulus gestures, and downward movements were initiated faster when they were triggered by downward-moving stimuli. Technically speaking, this pattern of results implies a substantial stimulus-response compatibility effect (and, it is important to note, does so under conditions in which no selection of response is involved). We have to conclude that even such a seemingly simple operation as initiating a particular preselected gesture involves representational structures that are also involved in the perception of these gestures (Brass, 1999; Brass et al., 2001).

Gesture Selection In the gesture selection task devised by Stürmer (Stürmer et al., 2000), one of two hand movements could be presented as a stimulus gesture—either a hand spreading apart (with fingers extending) or a hand grasping (with fingers flexing). Again, both gestures would start from the same neutral initial posture. On each trial one of the two gestures was randomly selected for presentation and the participants were required to select one of the same two hand movements as the response gesture. However, the stimulus gesture presented was once more completely irrelevant for the selection of the response gesture. Instead, the relevant cue for gesture selection was provided by a color superimposed on the stimulus gesture. If the stimulus hand was red, the participants had to spread their hand apart, but if it was blue, they had to perform the grasping movement.

In this task, too, we observed strong stimulus-response compatibility effects. The speed at which a particular hand gesture could be selected was strongly modulated by the (irrelevant) hand gesture on which the (relevant) color cue was superimposed. The selection of response gestures was much faster when stimulus and response gestures corresponded to each other than in trials with no such correspondence.

In some experiments we manipulated the time of the color onset relative to the onset of the stimulus gesture itself, so that the participants would first see the stimulus gesture unfolding in neutral gray before the imperative color cue was superimposed after some time. With this manipulation we expected to see a gradual buildup of the compatibility effect over time. What we observed, instead, was a pronounced compatibility effect from the outset, that is, even in the condition in which the onset of the color cue coincided with the onset of the stimulus gesture. In a further experiment we presented stationary hand postures rather than dynamic gestures. Actually we chose the two postures representing the final end states of the gestures of spreading and grasping. Again, we expected weaker effects with postures than with gestures, based on the consideration that static stimulus postures exhibit less overlap with dynamic response gestures than dynamic stimulus gestures do. Again, however, we observed substantial compatibility effects from the outset (they were even somewhat larger than in the gesture experiments).

In sum, we may then draw two conclusions. One is that, like gesture initiation, gesture selection is strongly modulated by the concurrent perception of irrelevant stimulus gestures. This finding lends further support to the claim that perceiving and performing actions draw on overlapping, if not identical, representational resources. The second, more surprising conclusion is that end-state postures are particularly effective primes for triggering the gestures that lead to them. This is surprising since postures do not contain any dynamic information (unlike full-blown gestures, which provide both static and dynamic information). We take this to suggest that end states, or action goals, may play a prominent role in the mechanisms underlying the compatibility effect in gesture selection. It seems that perceiving the goal at which an action is directed leads to an even stronger modulation of concurrent performance than perceiving the movements through which this goal is achieved.

Goal-Directed Imitation A demonstration of conflict between movement- and goal-induced imitation has been provided by some recent studies with young children (Bekkering & Prinz, 2002; Bekkering & Wohlschläger, 2002; Gattis et al., 2002; Gleissner et al., 2000). In these experiments, 3- to 5-year-olds took part in a little game requiring the imitation of one out of four possible gestures: reaching for one's right ear with one's right or one's left arm and reaching for one's left ear with one's right or one's left arm. In two cases (left ear–right arm and right ear–left arm), the reaching arm had to cross the body midline, whereas no such crossing was involved in the other two cases. The children were nearly always correct in uncrossed tasks, but in crossed tasks a substantial number of imitation errors occurred. When a crossed gesture is demonstrated for imitation (say, left ear–right arm), two types of errors can be made: correct ear–wrong arm (effector error) or wrong ear–correct arm (goal error). Nearly all of the errors that actually occurred in these situations were effector errors; the children would copy the goal but choose a simpler movement to reach it. In a further study it was shown that this pattern is only exhibited when the gestures are really goal directed. In a control condition without goal attainment (i.e., where the same gestures were demonstrated without actually reaching for the ear), both types of errors were equally frequent (Gleissner et al., 2000).

Taken together, our interference studies provide an interesting lesson on what it actually means to perceive and perform an action. Not only must we conclude that action perception and production share common representational structures, but also that these shared structures contain more information than just the kinematics of the perceived or to-be-produced movement patterns. Instead, they seem to contain information about full-fledged, goal-directed actions, with goals (= ends) taking the functional lead over movements (= means). This is, of course, in full accord with ideomotor theory's central claim that actions are represented in terms of what they lead to.

5.2.2 Induction Paradigms

Further support for the prominent role of goals or goal-related intentions comes from induction paradigms. In induction paradigms we study how actions are spontaneously induced and/or modulated by the perception of other people's concurrent actions and their outcomes. In the literature, such spontaneous movements are often called ideomotor movements (W. Prinz, 1987). For instance, while watching, in a slapstick movie, an actor who walks along the edge of a plunging precipice, people are often unable to sit still and watch quietly. They will move their legs and their arms or displace their body weight to one side or another.

How is the pattern of induced body movements related to the pattern of the perceived events inducing them? Basically, two answers to this question have been suggested. The classical answer believes in stimulus-related, or *perceptual induction*, that is, in the working of similarity between the movements perceived and those produced. Perceptual induction occurs when people repeat through their induced movements what they see happening in the scene. Hence it considers ideomotor actions a special class of imitative actions—nonvoluntary imitation, so to speak. A competing answer is offered by goal-related, or *intentional induction*. Intentional induction occurs when people realize through their induced movements what they would like to see happening in the scene. Hence it considers ideomotor action a special class of goal-directed actions—futile instrumental activity, so to speak.[2]

In the following paragraphs I discuss evidence from two induction paradigms. In the first paradigm we studied the occurrence of unintended, spontaneous action while people watched the outcome of their own preceding actions. In the second paradigm we considered the spontaneous actions occurring while people watched the outcome of somebody else's concurrent action.

Own-Generated Actions We devised a paradigm that should allow us to study the relative contributions of perceptual and intentional induction to ideomotor action (Knuf, 1998; Knuf et al., 2001). The task was a computerized version of a simple bowling game in which the participants watched a ball moving toward a target on a screen, either hitting or missing it. At the beginning of a trial, the ball was shown at its starting position at the bottom of the screen, and the target position was shown at the top. Starting positions and target positions were always chosen so that the ball had to travel in either a northwestern or northeastern direction (leftward or rightward) in order to hit the target. The participants triggered the ball's computer-controlled travel and observed its course.

The ball's travel was divided into two periods, instrumental and induction. During the instrumental period (about 1 second) the participants could manipulate either the ball's or the target's horizontal position by

2. The discussion about the nature of ideomotor movements has a long history. Notably, a forerunner of the distinction between perceptual and intentional induction was proposed by the French chemist M. E. Chevreul. In his "Lettre à M. Ampère sur une classe particulière de mouvements musculaires," Chevreul drew a distinction between two possible cases of induced movements: "La tendance au mouvement déterminée en nous par la vue d'un corps en mouvement, se retrouve dans plusieurs cas, par exemple: (1) lorsque l'attention étant entièrement fixée sur un oiseau qui vole ..., *le corps du spectateur se dirige ... vers la ligne du mouvement*; (2) lorsqu'un joueur de boule ou de billard suivant de l'œil le mobile auquel il a imprimé le mouvement, *porte son corps dans la direction qu'il désire voir suivre à ce mobile.*" "The tendency to move which is induced in us when we see a moving object can be observed in several cases, for example, (1) when one's attention is entirely fixed on a bird flying [...] *the observer's body will tend to move in line with the bird's flight direction;* (2) when a player of billiards or boule follows with his eyes the ball he has just pushed along, *he will direct his body into the direction in which he would like to see the ball rolling.*" (Chevreul, 1833, p. 262; italics added).

corresponding joystick movements. In the ball condition, horizontal joystick movements would shift the ball to the left or the right (after which it would continue traveling in the same direction as before). In the target condition, the same horizontal joystick movements would shift the target to the left or the right. In both conditions these shifts were required for obtaining a chance to hit the target, since the initial directions of the motion were always chosen so that hits would never occur without such shifts.

We were interested in studying spontaneous joystick movements during the induction period (which followed the instrumental period and lasted for about 2 seconds). Would such movements occur at all and how would they be related to the happenings on the screen? Perceptual induction predicts the same pattern of joystick movements for both conditions; they should always point in the direction the ball moves (leftward or rightward).

Intentional induction predicts a more complex pattern. First, it leads one to expect that spontaneous joystick movements should only become induced on trials with upcoming misses, not on trials with upcoming hits. On upcoming hits, the participants should anticipate that the ball will eventually hit the target, so that no further instrumental activity is required to reach the goal. However, on upcoming misses, the participants should be able to anticipate that the ball will eventually miss the target—which should then induce movements performed in a (futile) attempt to affect the further course of events. The details of these attempts should depend on two factors: the object under previous instrumental control (ball or target) and the side on which the ball is expected to miss the target (left or right misses). In the ball condition (where the ball was previously under control), joystick movements should act to push the ball toward the target (i.e., rightward in the case of a left miss, and leftward in the case of a right miss). In the target condition (where the target was previously under control), joystick movements should act to push the target toward the ball (leftward in the case of a left miss and rightward in the case of a right miss).

The findings from our bowling game lent strong support to intentional induction but not to perceptual induction. First, it turned out that the direction of the ball's movement (leftward or rightward) did not induce corresponding joystick movements by itself. This rules out perceptual induction. Second, on trials with upcoming hits, induced movements were virtually absent. However, third, on trials with upcoming misses, we observed pronounced induced movements, whose directions were dependent on both the object under initial control (ball or target) and the side of

the upcoming target miss (left or right), which is exactly in line with the pattern predicted by intentional induction. Once more these findings suggest that in this paradigm also, goal-based induction plays a stronger role than induction based on movements leading to those goals.

However, perceptual induction was not completely ineffective. For instance, when one studies movements that are induced in noninstrumental effectors, that is, effectors that are not instrumentally involved in initial joystick control (such as unintentional head or foot movements), one sees perceptual induction also. This seems to suggest that noninstrumental effectors tend to follow the direction of the ball's travel. However, at the same time, intentional induction was also effective in head and foot movements. Accordingly, the final picture will need to encompass both intentional and perceptual induction (for more detailed discussion, see Knuf et al., 2001).

Other-Generated Actions In this paradigm we studied spontaneous ideomotor movements in a situation in which participants observed the outcome of actions performed by someone else (De Maeght, 2001; De Maeght & Prinz, 2004). The participants observed the same task as before, that is, hits and misses in the bowling task. However, this time they did so in the understanding that they were watching the visible outcome of another alleged individual's performance.[3]

While observing the game, the participants were required to perform a tracking task that served as a means for recording spontaneously occurring induced movements. In their right hand they held a joystick that controlled a marker on the right margin of the screen. Their task required them to track the vertical position of the traveling ball with a marker (i.e., move the marker so that it always matched, as precisely as possible, the ball's height on the screen). However, in analyzing those tracking movements, we were not interested in performance on the (relevant) vertical dimension. Instead, we focused on the (irrelevant) horizontal dimension. If action

3. Not only does this paradigm come closer to the prototypical cases of ideomotor action, which all refer to action induced by watching someone else (W. Prinz, 1987), it also avoids a serious problem that cannot be circumvented with self-generated actions. When people perform spontaneous movements in response to watching the outcome of their own previous instrumental action, there is often no way to clearly discern true ideomotor movements (i.e., those induced by the actual stimulus pattern) from the aftereffects of previous instrumental actions (i.e., those induced by previously active intentions).

induction is also obtained under this condition, it should exhibit itself in spontaneous, unintentional drifts to the left or the right.[4]

Our first experiment had two parts. In the first part, the participants were required to play the bowling game themselves (player mode); in the second part, they were required to track the visible outcome of another (alleged) individual's performance on that game (observer mode). This experiment allowed us to assess the pattern of induced action in both the bowling and the tracking task. Actually, part one of the task was an exact replication of one of the experiments with self-generated actions—not only in terms of design but also of results. However, a different pattern of results emerged in part two. In the tracking task, perceptual induction was strong throughout, whereas intentional induction was clearly weaker (it was reliable in the ball condition but not in the target condition).

In a further experiment we studied participants in the tracking task (observer mode) who had not been involved in the bowling task (player mode) before. The results showed that for pure observers, action induction was in general much weaker than for observers who had acted as players before. However, the basic pattern of induced action was unaltered. Perceptual induction was weak throughout, which, in the ball condition, again went along with weak intentional induction. However, in the target condition, intentional induction was absent.

Finally we aimed at weakening the participants' belief in an intentional agent behind the observed bowling patterns. In this experiment we had the participants again play the bowling game before we studied them in the tracking task. This time, however, the instructions would make them believe that the hits and misses they observed were generated by a computer (rather than an alleged individual in an adjacent room). Even under these conditions, some indication of intentional induction survived (at least in the ball condition), whereas perceptual induction no longer occurred.

4. The tracking task differs from the bowling task in two important respects. First, ideomotor movements arising in the observer mode will be free from the aftereffects of previous self-performed intentional actions. Therefore, intentional induction should be weaker in observers' tracking than in players' bowling. Second, since the tracking task requires tracking the ball, it requires attention to be focused on the ball's route. This is different from the bowling task, which requires (and allows) the subject to focus attention on the ball in the ball condition and on the target in the target condition. Therefore somewhat conflicting attentional demands may arise in the target condition of the tracking task, whereas no such conflict is entailed in the ball condition. This factor, too, may act to strengthen the inductive power arising from the ball.

In Sum At this point, we are far from seeing a full picture of action induction. Still, on the basis of the evidence collected so far, we may draw a few empirical generalizations. First, spontaneous induction of action through action perception is a widely occurring phenomenon and can be studied in controlled experimental settings. Second, there is clear evidence for both perceptual and intentional induction. Perceptual induction is stimulus triggered and goes bottom-up, whereas intentional induction is goal directed and goes top-down. Third, induction (both perceptual and intentional) is not an automatically occurring by-product of action perception. At best, it may be conditionally automatic in the sense indicated by Bargh (Bargh, 1989, 1997) and Hommel (2000). For instance, it is strongly modulated by context factors, such as (1) observing own- versus other-generated actions, (2) previous active involvement in the action observed, and (3) attribution of observed outcomes to intentional agents, and so on. Fourth and finally, it has become clear that action induction is not just a matter of imitation. Perceptual induction is imitative, but intentional induction is not. Instead, it makes people act as if they were able to correct what they see happening, rather than just repeating it.

5.2.3 Coordination Paradigms

In coordination paradigms we study the social modulation of action in tasks requiring a division of labor and coordination of action between two participants. More specifically, we study how the planning of intentional action in one participant gets modulated by his or her perception of the other participant's complementary actions (Sebanz et al., 2003).

In order to study such effects, we devised a standard two-choice interference task (figure 5.1a). In this task, a color cue served as the relevant imperative signal (i.e., red or green). The color cue specified which response key to press (i.e., left or right). In addition to the relevant color cue, an irrelevant spatial cue was presented that would also point to either the left or the right. In one experiment this cue was provided by two pointing gestures of a hand, in another experiment by two arrows. Over a given sequence of trials, the four possible combinations of color cues and spatial cues were presented at equal frequencies and in random order. As a result, there were two types of trials, compatible and incompatible. In compatible trials, the irrelevant spatial cue was compatible with the response required by the relevant color cue (left-left or right-right), whereas in incompatible trials, the two were incompatible (left-right or right-left).

Not surprisingly, a marked interference effect was obtained. The responses were much faster and errors were less frequent in compatible than

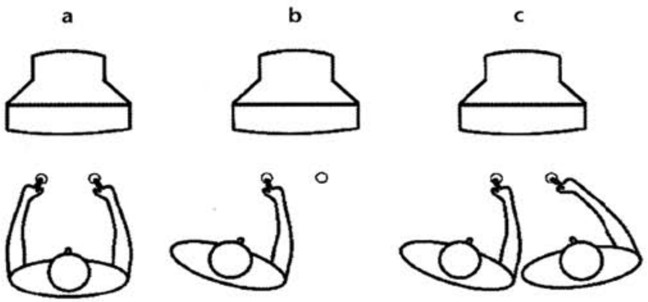

Figure 5.1
Schematic illustration of the two-choice interference task. (a) Standard version, (b) partial version, (c) shared version. (See the text for further explanation.)

in incompatible trials (and as results for a third condition with a neutral spatial cue indicate, this difference seemed to imply both facilitation in the compatible case and inhibition in the incompatible case).

This is the standard, two-choice version of the task. Consider next what one might call a partial version (figure 5.1b). By this I refer to a so-called "Go/NoGo" task in which the participants were required to respond to stimuli with one of the two colors (Go) and not to respond to the other color (NoGo). In this version, the participants were seated either to the left or the right in front of the computer screen so that the spatial cue was either pointing toward them or away from them. Accordingly, on both Go and NoGo trials, one can still distinguish between compatible and incompatible trials (although the reaction times are only available for Go trials, of course). This time, however, no interference effect was observed on Go trials. We take this result to suggest that action induction due to the (irrelevant) spatial cue requires that the *relationship* between the two stimulus cues (leftward as opposed to rightward pointing) be matched by the same *relationship* between the two responses (leftward as opposed to rightward responding).[5]

5. In other words, for the spatial compatibility effect to occur, mere overlap of features between stimuli and responses (left pointing-left responding, etc.) is not enough. What is required instead is dimensional overlap between stimulus sets and response sets; that is, a match between the dimensions for characterizing differences among stimuli and differences among responses (i.e., leftward versus rightward pointing and leftward versus rightward responding); cf. Reeve and Proctor (1990), Kornblum et al. (1990), and Kornblum & Stevens (2002).

After these preliminaries, we now come to the shared version of the task (figure 5.1c). What can we expect when we arrange the task so that two partial responders are sitting next to each other in front of the screen (one to the left and the other to the right), and one is in charge of red, the other in charge of green stimuli? Note that this arrangement implies, for each participant, exactly the same Go/NoGo task as before. Still, the shared task differs from the partial task in the social microcontext provided. In the shared condition, each of the two participants acts as a contributor to a common, shared task to which the other participant sitting next to him or her is contributing as well. Obviously, there are two options here. One is that each individual acts on his or her own, as in the partial task. The other is that each of them forms a joint action plan for the shared task in which the other's actions are functionally equivalent to one's own actions. If that were the case, the interference effect that was absent in the partial task should be back in the shared task. In the shared task, the opposition between one's own left position and the other's right position should re-establish the left-right dimension on the response side.

Remarkably, this is exactly what our results show. Therefore we may conclude that in a shared task environment, where a simple rule for the division of labor is agreed upon, two individuals coordinate their activities so that they act like the two hands of one person. Accordingly, in the shared task, action performance gets modulated by action perception in a complementary way; people treat the others' actions like their own actions. To be sure, by no means do they imitate them. They do not do what the others do. Rather, they do what their share of the task requires, but they take the other's actions into account.

It is important to note that further experiments have shown that the interference effect is not obtained when one participant is acting as a partial responder whereas the other sitting next to him or her is not acting at all. In other words, it seems that the mere presence of another individual is not sufficient to produce the effect. Rather, the spatial interference effect requires that one believe that the other person shares the task.

5.3 Conclusions

At this point the results of our studies on action modulation through perception suggest the following major conclusions:

- Ideomotor principle and imitation Action imitation may arise as a by-product of action perception. People tend to perform those actions they see (or would like to see) being performed by others.

- **Ideomotor principle and action modulation** Action perception modulates action planning in a number of ways (of which imitation is but one). Action modulation occurs automatically, but its details depend on task requirements and social context (i.e., conditional automaticity).
- **Common coding for perception and action** Perception and action share a common representational basis. Action perception and action planning are subserved by common representational resources.
- **Actions, action effects, and goals** Actions are represented in terms of what they lead to (i.e., their perceptual effects). Learning leads from actions to anticipations of perceptual effects. Conversely, planning leads from intended effects to actions.[6]

6. See the comments on this chapter by Arbib, vol. 1, ch. 8.6, p. 215, and by Donald, vol. 1, ch. 8.7, p. 217. ED.