11

A Kinesiological Approach to Gesture Analysis

Dominique Boutet and Alan Cienki

1 Introduction

This chapter presents the physiologically based approach to gesture analysis that was developed by Dominique Boutet (1966–2020). It was commissioned for this Handbook because of the uniqueness of this system and its rich potential for application. The chapter provides the most extensive presentation of the kinesiological approach available in English; for a shorter introduction to it see Boutet, Morgenstern, and Cienki (2018a) and Morgenstern et al. (2021). An extensive explication of it in French is available in Dominique's *Habilitation* (Boutet, 2018), with the short original overview of the ideas having been introduced in Boutet (2010) and in Boutet and Morgenstern (2020).

As explained below, looking at gesture with this system provides insights into the biophysical bases of what someone does when producing a gesture, as opposed to most existing systems, which are based on descriptors of how observers see others' gestures. In essence, the kinesiological approach looks at gesture from the inside, rather than the outside. The chapter begins with looking at the *what*, the *how*, and the *where* of the traditional approach to gesture analysis before turning to the "muscle and bones" of the kinesiological system. The description goes into some depth in terms of physics and human physiology, the latter in part reflecting Dominique's original training in the field of medicine. However, even readers not conversant with the technical terminology involved can derive insights from the general principles of the

The first, rough draft of the chapter was submitted by Dominique Boutet just months before he was hospitalized with Covid-19, from which, to our great sadness, he eventually passed away. Alan Cienki then took on the final writing and editing. Thanks to Claire Danet for providing access to Dominique's image files and editing them or even recreating them, where needed. Many thanks to Aliyah Morgenstern for detailed feedback on drafts of this chapter. The research leading to Figures 11.12, 11.16, and 11.17 was supported by Russian Science Foundation grant No. 14–48-00067П awarded to Moscow State Linguistic University for the project "Verbal and co-verbal means of event construal across languages."

system. The system will also be of interest to those working with motion-capture analysis of gesture, as the parameters can be translated for use with such technology.

2 Outline of the Classical Frameworks for Analyzing Gestures

2.1 On the Hand Only (the "What")

The typologies frequently used for gesture analysis in the past few decades may have been influenced by, and may be entangled in, an old tradition of taxonomy coming from antiquity (Quintilian & Cousin, 2003, Lib. XI). Quintilian's classification is based on the hand and fingers. Witness the exaggeration of the hands in the early medieval illustrations of the Roman dramatist Terence's works (Aldrete, 1999; Radden Keefe, 2021), and the focus on the hands continuing into Bulwer's (1644) *Chirologia*. Efron (1942/1972), too, classified gestures focusing on the hands, leaving the other segments of the upper limb "in limbo." Kendon's (2004) taxonomy is a hierarchy based first on hand shapes, second on the orientation of the palm, and third on the movement of the hand. Calbris' (1990) typology of gestures highlights the importance of the palm of the hand, the fingers, and the head as "bodily vehicles" of meaning. In all of these approaches to gesture studies, the hand as a tool of interaction with the world is literally considered as the core of gestures. For Sign Languages, the tradition is similar. The first such notation system, created by Bébian (1826) for French Sign Language, also focused on the hands. The twentieth century was no different, from Stokoe (1960/2005) to Sandler (1989), Brentari (1998), Cuxac (2000), or Liddell (2003). They all present a modeling of the hand excluding, in fact, the forearm, the arm, and the shoulders. The four parameters of Sign Language – the hand shape, the orientation of the palm, the location of the hand in space, and the movement – are all centered on the hand.

The distal part of the upper limb, the hand, is considered as the effective part of bodily communication. In the main studies of gesture, especially during the twentieth century, the part carrying the essential meaning is the hand: the rest of the upper limb is merely considered as a mean of displacement for the hand, allowing it to reach a given location. Reading between the lines, the conception of the meaningful part of gestures has probably been influenced by the practical dimension of gestures and the usefulness of the grasping part of the upper limb – the hand and the fingers.

It is true that analysis of certain gestures considers other segments of the upper limb, for example: shrugs of the shoulders expressing some kind of incapacity (Darwin, 1872/1998; Debras, 2017; Streeck, 2009); quick forward movement of a shoulder expressing disinterest (Boutet, 2010); a posture of arms akimbo as a mark of social supremacy (Spicer, 1991); crossed forearms in front of a speaker meaning prohibition (Caradec, 2005, p. 145); the phallic forearm jerk as an insult (Calbris, 1990, p. 6); the "sidearm gut punch," as

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Calbris wrote, expressing a retort (Calbris, 1990, p. 4); the forearms beneath one another on the chest in medieval illustrations depicting a situation of distress (Garnier, 1989, p. 152), to name but a few. However, most of the analyses made during the last century seem to be cut off from or a bit disconnected from this reality of gestures.

2.2 Visuality as Exteriority (the "How")

Beyond the potential influence of manual praxis on the way gestures have been analyzed, taking the more distal segment – the hand – as the locus of gestural activity could also come from the conception of what is relevant for speech in linguistics. The externalization of speech as a signal cut it off from the body. Apart from an articulatory approach to phonology (e.g. Browman et al., 1984), which seems to constitute a minority in the field, the main trends in phonology are based on acoustics. Therefore, what is seen as significant in speech is the externalized signal and not the possible bodily structuring leading to its production, which could also have been considered as speech. The constraints on how the most widely analyzed means of communication – speech – is most commonly studied skews how most researchers consider gestures.

The attention to externalization, noted above, detached from the producing body, focuses, de facto, on the receptive modality of language: the auditory channel. For gestures, the receptive modality – vision – is obviously sensitive to the segment that moves the most. This trend, considering meaning as an externalization ("ex-pression"), pushes attention toward that side of things more than to the gesture in its own right and in its unfolding. The image produced or the trajectory created, as results, are perceived as having more value than the gesture which builds them. Therefore, awareness of such significance is diverted from the track of production to the manual gesture and the trail it traces. In other words, preference is given to studying frozen drawings (artifacts) over analysis of the quality of the movement – the kinematics of the hand – which comes far before the construction of a gesture along the upper limb, and which has its own geometry, giving rise to how it moves. The latter is what constitutes a kinesiological approach.

Beside the praxiological argument and the "external" one (which is actually more of an epistemological issue), a third reason explaining the focus on the hand may exist. It is linked to the frozen representation we have of symbolic phenomena. As linguists, we are used to working with transcriptions of speech adapted from systems of writing. The flow of the speech is segmented and labelled. Writing fixes speech into static representations (e.g. letters, for languages written with an alphabet). Except for work by linguists who research prosody, a vast majority of publications deal with static representations of language because of the transcriptions used. Our difficulty in grasping dynamic phenomena is related to this kind of representation, namely a writing system. We do not know clearly what is at stake. The writing system could be the basis

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of our difficulty in understanding the dynamics of what is involved, but, more ontologically, writing could be a solution, coming from our difficulty with embracing dynamics. Regardless of the direction of the causality, transcription leads us toward tracks (writing, in this case) – leaving out, in the shadow, the trails traced and the articulatory gestures of the speech. This has consequences for the visual analysis of gesture, noted above.

Despite the existence of transcription systems for Sign Languages (such as HamNoSys [Prillwitz, Leven, Zienert, Hankke, & Henning, 1989], SignWriting [Sutton, 1995], and the Berkeley Transcription System [Hoiting & Slobin, 2002]), none of them have become prominently widespread in their use; they are usually applied locally (e.g. in Hamburg or Berkeley for the systems mentioned). No conventionalized writing system exists for cospeech gestures. This lack is compensated for by using drawings or screenshots of gestures, chosen for their prototypicality, and sometimes complemented by arrows or lines indicating the direction of the movement (trajectories). These photographic representations, appearing to respect what is going on with peculiar gestures, provide the illusion of reality. They freeze gestures into postures, removing the dynamics. These representations cut off the gestures from the naturalness of their embodiment (kinesiology) and, then, the process of their production (kinematics) is devalued, yielding only the benefit of information on the direction of the movement of the hand (sometimes depicted by arrows).

These three reasons give arguments that explain the focus on the hand and the static conception we have of gestures. We describe and preferentially analyze one segment of the gestures, and do so according to an image of one moment; this sort of compression of time primarily creates a representation at the expense of leading to a genuine study of gestures and their deployment. Following the presentations above of the object studied and the conception of time in which it is placed, we present now the frame of reference of the space with which gestures are described.

2.3 Egocentric Frame of Reference (the "Where")

The question of the space where gesturing unfolds has actually been addressed by Kant (1768/1991) in a wider spectrum. The issue tackled in his essay concerns the potential bases for differentiating a region of space as a relationship between two entities (situated in relation to one another) as opposed to absolute space – in other words, the question of the grounds on which the geometry rests. In the absence of any Cartesian coordinates or any measurement units, we can situate any object in relation to the living body. The categories *left* and *right*, which we always have "on hand," establish the ultimate ground of this differentiation. In this sense, we do not need any coordinate to localize any entities (Richir, 2005). In this way, a hand is situated up or down, a bit higher or less so, at the left or to the right, in front, far in front of myself, or behind. The body as the tool of this conception of measurement seems to be particularly appropriate as the origin and the frame of reference for gestures.

Considering the way gesture has been studied so far, the object of study is roughly unique (the hand), and is as if cut off, at least intellectually, from the upper limb; its representation, in drawings or screenshots, is unique as well, and, hence, determined by the singular point of view of the image. The hand (at the tip of the forearm) is the most mobile segment. It can translate (move without rotation or angular displacement) or rotate in space, if not freely, at least in almost all locations. Considering its distal specificity, almost detached from the body, a similar frame of reference could suffice for the nature of this segment seen in this way: (1) distal, (2) still dependent on the body[1] but not really linked to it, and (3) lateralized. Among the three frames of reference described by Levinson (1996) – absolute (and usually geocentric), intrinsic (and centered according to an entity), and relative (generally oriented according to the speaker) – the last one meets the three features mentioned above: (3) A lateralized, egocentric frame of reference (henceforth: "ego FoR") applies simultaneously to the (2) specific features, still dependent on the body, and (1) the distal feature of the hand. McNeill (1992) situates the location of the hand as being around a speaker, in an ego FoR, as Kendon does (Kendon, 2004). All of the approaches in Sign Language phonology (e.g. the Hand Tier Model [Sandler, 1989], the Prosodic Model [Brentari, 1998], and the Hold-Movement Model [Johnson & Liddell, 2010, 2011]) are based on this type of FoR. The terminology could change (ipsilateral vs. contralateral for the lateralization, distal vs. proximal for the distance from the body), but the principles of the location still rely on an ego FoR.

The choice of the ego FoR has another consequence for gestural phenomena. It is quite impossible to situate simultaneously two segments attached by a joint without having to refer to a local landmark situated on the segment considered (maybe an intrinsic FoR) or without any reference to the orientation. The description of any free moving entity in space – as the hand seems to be considered – entails six possible degrees of freedom (logically independent parameters along which values can vary): translational movements in the three directions of space (XX', YY', ZZ') plus three rotations of the entity on itself: the yaw (rotation in the horizontal plane along its vertical axis), the pitch (rotation along its lateral axis), and the roll (rotation along its longitudinal/sagittal axis).

Considering, for instance, a gesture produced with the hand in front of the chest, fingers aligned, pointing toward the central space in front of the speaker, the palm presents several possible locations. The palm might be in a frontal plane in either of two orientations: toward the speaker or away from him. Alternately, the palm might be in a transverse plane in one of two orientations: palm down or up. The palm could be positioned in any intermediate location between these two planes. In this transversal plan where the palm is facing down, the elbow might be elevated higher than the palm, for example,

[1] Even in the phenomenological tradition, the distinction made in German between *Leib* and *Körper* by Husserl (1931), or the one in French between *corps propre* and *corps matériel* by Merleau-Ponty (1945/1972), does not take into account this kind of disembodiment or dismantlement of the body.

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in a gesture of pushing down, or, on the contrary, it might be lower than the palm, as in the beginning of a gesture indicating a growing size. If the elbow is in the same transversal plane of the palm, the gesture might depict a size ("this high"), or the beginning of an expression of totality (with a horizontal movement outward), or any growing or lowering movement. A movement of the wrist might express a withdrawal (extension of the wrist upward), a rollover (rotation of the wrist), or (at least in French culture [Calbris & Montredon, 1986, p. 75]) a "go away" gesture (pulling of the hand outward to the side, away from the median axis of the body, in what is known as abduction of the wrist).

This suggests that the framework of spatial reference above is ill suited to describe the requirement of the movement, and that we need to situate all segments of the upper limb according to their potentialities. A kinesiological basis for gesture analysis thus seems to be needed.

3 Conditions for a Kinesiological Description

The way gesture researchers traditionally use an ego FoR situates the entities and actually blocks any attempt to spell out the interrelations between the segments of the upper limb. It seems to be paradoxical to consider that a unique FoR, covering the whole body, prevents full comprehension of the kinematics of its chained elements (shoulder, arm, forearm, hand, fingers). However, it is a consequence of both gesture researchers' isolating the hand from the rest of the body, and of the tautology of applying a measure coming from the body to a body.

The fact that we use the ego FoR as a means to situate the hand – considered as an independent segment, which has such mobility that it is almost detached from the body and able to be a complex tool for our communication – forces us to locate it with six degrees of freedom (*dof*), as we could any free-floating object in space. This conception of gesture is antithetical to the notion of chaining. We certainly know that segments of the upper limb are interrelated, but our habit of analyzing gestures in this way hides this reality.

The second reason for this difficulty with invoking the ego FoR for the analysis of gestures is related to the (too) narrow proximity between the FoR and the object measured. Applying this tautological measurement from a greater distance leads at best to *situating* segments. Using a bodily form of measurement to characterize the body itself reifies the body as an object. This reification de facto takes away the reality of embodiment (Bottineau, 2012; Guignard, 2008). The measuring tools we need should not just *situate*, but must provide the exact potentialities of each segment, no more and no less.

3.1 Intrinsic Frame of Reference on Each Segment

An intrinsic FoR locates the environment according to the entity considered. For the hand or forearm, their environment matches the possibilities of motion, that is, categories grouping the axes of the movements of each

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segment, in and of themselves, named *proper movement*. We differentiate a *proper movement* from a *displacement*. A forearm might be displaced by a proper movement of the upper arm and hence move incidentally, without any proper movement of the forearm itself, carrying the hand to the same location as the one that could be reached by a proper movement of the forearm.

The geometry of the joints between the segments determines the possible proper movement of each segment itself. Anatomy is relevant here. Movements are categorized according to *dof* which in this context correspond basically to a rotation of a segment around an axis which is usually situated on a joint. Nevertheless, we distinguish two types of dof: the one whose axis crosses joints, and the other whose axis runs along bones. The second type is distributed in two places: along the humerus (the bone from the shoulder to the elbow), and along the two bones extending from the elbow to the wrist: the radius (the outer and slightly shorter of the two bones) and the ulna (the inner and longer of the two). The other, whose axes cross the joints, are in the complex of the shoulder, in the joint of the arm, in the elbow, in the wrist, and at each knuckle of the fingers.

These dof involve a specific geometry per segment. All movements are generated on axes and each segment turns around them to a certain amplitude. This fact has consequences. It means that straight movements are not simple, but complex, requiring the involvement of at least two segments and three dof. They need a high level of coordination. On the contrary, arc movements may involve just one degree of freedom from one segment. Our conception of gesture complexity is changed. We are not dealing with a disembodied Euclidian space where arcs are the addition of a translation (movement along a line) coupled with a rotation, where circles are the continuity of a certain arc, and where lines seem to be the simplest geometric realization. With the body, space(s)[2] is/are not just a locus where the hand traces a form, but one(s) where potentially all segments are able to "inform" us. A hierarchy can be drawn up. First, gestures inform us thanks to proper movements. They delineate both forms and the information so designed. We need to find out which gestures are concerned with which forms. Second, movements of segments can be recruited, by the tip of the upper limb – the hand or the fingers – or by any of the dof of any segments, to gesture in order to draw or point to something significant. These latter gestures might be seen in a Euclidian space, and we can speculate in these cases that the traditional ego FoR is available to *situate* the form drawn.

Two types of gestures have thus been identified here. In the first type, the embodied gestures design meaning by forms in non-Euclidian spaces of gestures, sometimes through their deployment along several segments. The second type depicts meaning in space through the form that is deployed.

[2] This kind of space is not to be apprehended as a location. It is not situated but could spread out. For instance, an extension of the hand which we could label as "posteriority" can appear with the hand in different locations. Other degrees of freedom delimit other spaces. The hesitation above between the singular and plural forms to determine the notion of space is justified by this fact: these gestures are not dependent on a Euclidian space.

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3.2 Gestures Are Embodied before They Are Seen

Gestures are embodied before being seen and interpreted as drawings. Their structuration is made first logically and then physiologically by the production part of this gestural/visual channel of expression. The visual way of structuring gestures (categories of depiction and drawings of them, à la Müller, 2014) comes afterward. Embodied gestures inhabit gestural forms produced in certain spaces. Obviously, these motions are made in space, but this fact is relevant just for gestures as structured by vision. A gesture structured by the arm puts the hand in a wide but delimited zone. For example, when the arms are pulled backward along one's sides, with the palms of the hands facing forward (as in Figure 11.13.1), expressing *incapacity*, the hands might be in a zone which could be covered by a cone with its widest part on the sides of the trunk and in front of the speaker. Within this cone, the space usable by the hand or the forearm when they are not involved in the expression of *incapacity* might involve gesture structured by the environment – oriented, for instance, toward a situation on the side of the speaker. If the gesture is structured with the hand indicating a *refusal* (in the traditional description with the palm facing away from the speaker), the hand could be in one of several locations, facing the position of the object refused. For embodied gestures, space is not valuable; the forms of the segments with their movements or their postures are the only elements of meaning. These kinds of gestures can be structured visually at a secondary level, in that their meanings can be anchored in the space of interaction or in the environment. Certainly, the form of the gestures then seems to belong to the environment and, therefore, to be structured by how they are seen, but this only adds an indexical part to the already structured meaning. For the *refusal* gesture – an embodied gesture – the location of the hand in space certainly comes from the visual structuring. Whenever possible, embodied and visual structuring add to each other in gestures.

We will present the characteristics of embodied gestures through the dof distributed over the segments of the upper limb, focusing on their geometries, and their chaining. We will show how movement is transferred from segment to segment and concentrate on one of the key principles of the distribution of movement: the flow of gestures.

4 Core of the Kinesiological Approach

4.1 Characterization of the Degrees of Freedom (Geometry and Amplitude)

4.1.1 The Arm

The shoulder joint has three dof. Because of these three axes of rotation, it actually belongs to the enarthrosis family of ball and socket joints (Figure 11.1 inspired by Kapandji, 1997, p. 5). Considering axis 1 in the first image in Figure 11.1, the transverse axis that is contained in the frontal plane, this degree of freedom defines the flexion/extension movement of the arm (Figure 11.1, second image, inspired by Kapandji, 1997, p. 7), involving movement of the

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arm in the sagittal plane, passing through the shoulder. The amplitude of the flexion goes from 0° (Figure 11.1, first image) through 90° (Figure 11.1, second image), up to 180° (maximum, Figure 11.1, third image), whereas that of extension reaches a maximum at 50° (Figure 11.1, fourth image). These two extremes are only very rarely used in symbolic gestures and in Sign Language. On the other hand, a range between 30° of extension and 90° of flexion constitutes the usual zone of production for these gestures.

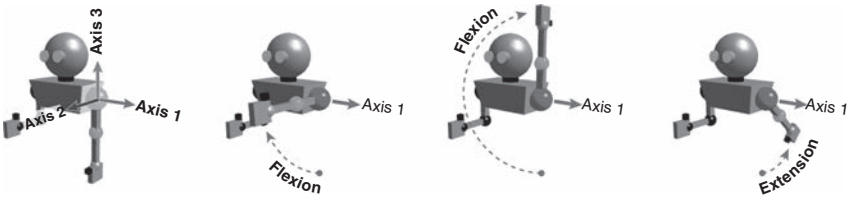

Figure 11.1 The three axes of the arm and the flexion/extension. First image: the three axes. Second and third images: the flexion of the arm. Fourth image: the extension.

The rotation of the shoulder joint around the sagittal axis (axis 2) brings the arm in a frontal plane to move away from the median plane by up to 180° by abduction (see Figure 11.2, second image, inspired by Kapandji, 1997, p. 9). In the other direction, the arm approaches the median plane by passing in front of the chest up to an amplitude of 30° (Figure 11.2, third image [cf. Kapandji, 1997, p. 7]). It should be noted that the presence of the trunk prevents a pure adduction (pulling toward the median axis of the body) from occurring. It is always made possible by a flexion of the arm so that it passes in front of the trunk or by extending the combined arm behind the trunk (Figure 11.2, third image). The adduction of the arm behind the trunk is very low. The abduction/adduction ranges used in gestures and Sign Language are between 90° and 20°.

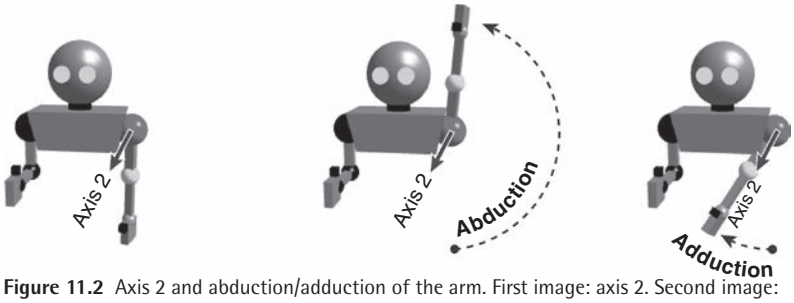

Figure 11.2 Axis 2 and abduction/adduction of the arm. First image: axis 2. Second image: abduction. Third image: adduction.

The third axis of the shoulder runs along the humerus (the bone from the shoulder to the elbow). It defines an internal and external rotational movement (Figure 11.3, second image, adapted from Kapandji, 1997, p. 11). The maximum amplitude of the exterior rotation is 80°, and the total amplitude of the interior rotation is 95°. The latter is about 30° when the arm remains stuck on the side of the body. To reach the remaining 65°, the arm must be shifted to the side by an abduction movement.

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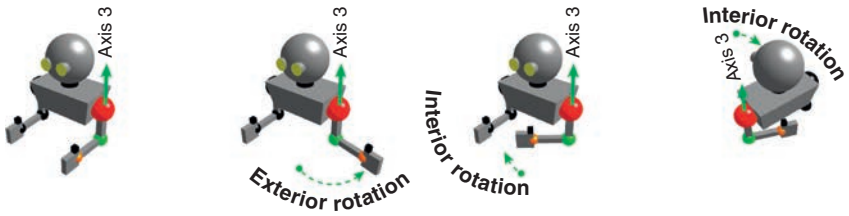

Figure 11.3 Axis 3 and exterior/interior rotation. First image: axis 3. Second image: exterior rotation. Third and fourth images: interior rotation.

4.1.2 The Forearm

The elbow joint is of the trochlear type (pulley-shaped), that is, it involves a fossa (depression or hollow area) on the humerus in front of a corresponding bone ridge on the ulna side. This type of articulation allows only one degree of freedom (axis 1, Figure 11.4). However, there is an overlap between the ulna and the radius (axis 3, see Figure 11.5, first image). It determines a second degree of freedom, as we will see. Thus, on the forearm, including the elbow, two dof exist (Figure 11.4, first image, and 11.5, second image, inspired by Kapandji, 1997, p. 99). The flexion/extension moves the forearm forward from the frontal plane (around axis 1, see Figure 11.4) or, in other words, it aligns the forearm with the upper arm. The reference position (aligned upper arm and forearm) sets the extension and flexion at 0°. The flexion amplitude does not exceed 145°, the limitation being given by the touching muscle masses. The extension can exceed the set 0°, especially in the case of hyperlaxity ("double-jointedness"). The entire amplitude of this movement is used in both gestures and Sign Languages.

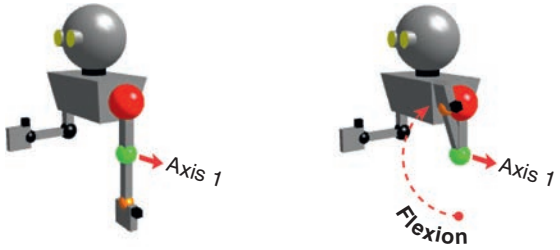

Figure 11.4 Axis 1 and flexion of the forearm. First image: axis 1. Second image: flexion of the forearm.

Pronation-supination is a rotational movement visible on the hand due to the overlapping bones of the forearm (around axis 3, see Figure 11.5). When the palm is turned forward, this is a complete supination position; the ulna and radius are in the same plane and do not cross each other (see Figure 11.5, third image). When the palm faces backward, the position involves a complete pronation; the two bones of the forearm overlap (Figure 11.5, first image). The axis of rotation of this movement runs along the forearm. The maximal amplitude of these two movements (pronation and supination) is 85° to 90°

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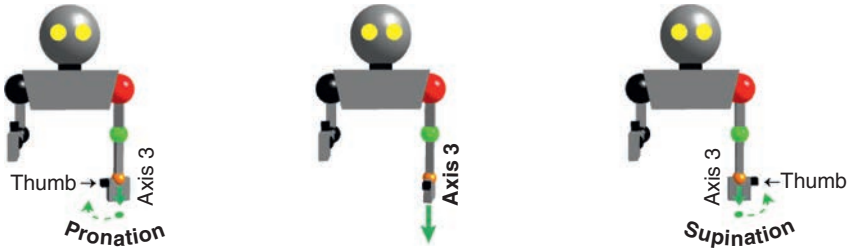

Figure 11.5 Axis 3 and supination/pronation of the forearm. First image: pronation. Second image: axis 3. Third image: supination.

each (Figure 11.5, first and third images; cf. Kapandji, 1997, p. 107). The neutral position, called the intermediate position of the hand, has the palm facing a sagittal plane, when one stands with one's arms hanging relaxed on the sides of one's body (Figure 11.5, second image).

4.1.3 The Hand

The hand has two dof. In the palm plane, an abduction/adduction movement and perpendicular to the palm plane, a flexion/extension movement. In what is called the anatomical position (with hands hanging by one's sides, but with the palms facing forward), the movement leading to an abduction pushes the distal end of the palm toward the side of the thumb. The amplitude does not exceed 35° (Figure 11.6, third vertical pair of images). Adduction, however, is carried out in the opposite direction, to the pinkie this time, and always in the plane of the palm. Its maximum amplitude is about 45° (Figure 11.6, first vertical pair of images; cf. Kapandji, 1997, p. 151). This pair of movements

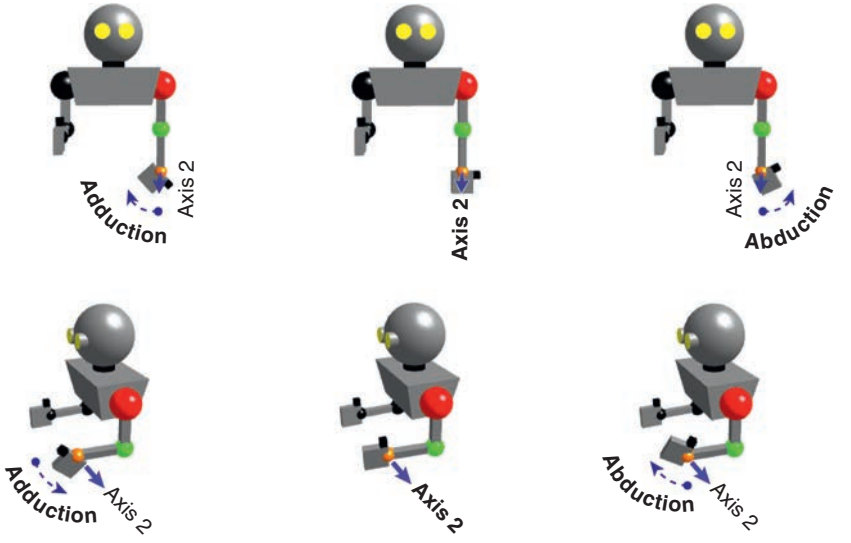

Figure 11.6 Axis 2 and abduction/adduction of the hand (two views of each). First vertical pair of images: adduction. Second vertical pair: axis 2. Third vertical pair: abduction.

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involves the smallest amplitudes of the upper limb. We will return in Section 4.2 to the impact that these amplitudes have on the deployment of gestures and signs.

The second degree of freedom – flexion/extension – carries the hand in front of the frontal plane for flexion and behind the same average plane of the anatomical position. The amplitudes of these poles are similar: 85° for each (Figure 11.7).

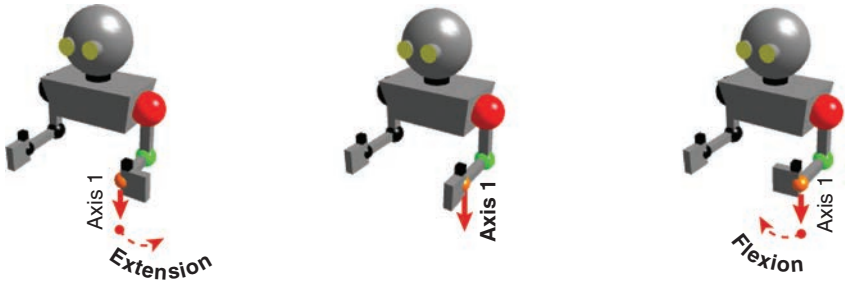

Figure 11.7 Axis 1 and extension/flexion of the hand. First image: extension. Second image: axis 1. Third image: flexion.

4.2 Variations of the Geometry of the Degrees of Freedom during Movement

Beside these simple movements, joints with two dof, such as enarthroses (ball and socket joints) and joints with condyles (bones with a rounded ending), when set in motion together, have an impact on a third dof when it is a longitudinal rotation (interior/exterior rotation for the arm; supination/pronation for the forearm). The two movements in question are referred to as diadochal movements, that is, successive movements around the same joint that are not performed in the same plane (MacConaill, 1946, 1948). To illustrate this type of movement, let us place the left arm along the body; the forearm, in a flexion of 90°, points forward; the hand is in a so-called intermediate position: the palm is in the vertical plane, the fingers pointing forward, the thumb is oriented upward (see Figure 11.8, first image). The forearm is then affected by a movement of exterior rotation (Figure 11.8, first intermediate position). In a second step, the forearm is carried upward by a flexion movement followed by an interior rotation movement that seems parallel to it (see Figure 11.8, second intermediate position). At this high point, the forearm is returned to its initial position by a simple movement of extension. The final position differs from the initial position in that the thumb is now inward, with the palm facing downward (see Figure 11.8, final position). In fact, an involuntary pronation movement has occurred between the initial and final positions without this degree of freedom being set in motion at any time.

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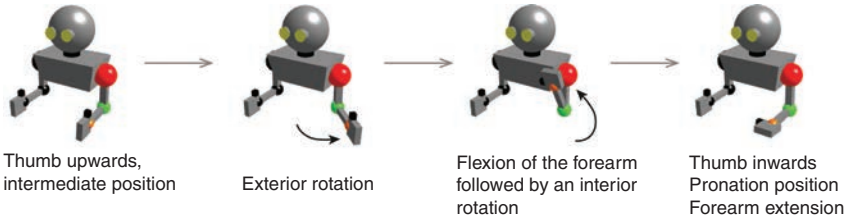

Figure 11.8 Pseudo paradox of Codman.

When we break down the voluntary movements, we notice that it is precisely in the sequence of the flexion of the forearm and the interior rotation that this pronation movement appears. The inversion of the order of movements has a repercussion on the dof affected by this involuntary movement. Let us put ourselves in the same initial position and reverse the movements. This time the forearm undergoes an interior rotation initially bringing the inside of the forearm against the chest and then a flexion followed by an exterior rotation. Finally, by the same extension movement of the forearm, we return to the initial position. The palm is in a supination position, turned upward this time. The order of the movements voluntarily activated on the forearm determines the repercussion it has in the involuntary movement.

The same mechanism of appearance of joint movement is at work in what is called Codman's paradox (Codman, 1934). This time, the movements of the arm are involved and the repercussion in the form of involuntary movements is spread on the arm as well as on the forearm. Let us start from a position with the arms and forearms along the body, with the palm of the hand in the sagittal plane, facing inward (see Figure 11.9, initial position). A first flexion movement of the arm of 180° carries the hand over the shoulder (see Figure 11.9, second position). A second 180° adduction movement of the arm also brings it back to its initial position on the side. The palm is still in a sagittal plane, but this time it is turned outward (see Figure 11.9, final position). Two conjunct movements have appeared: an exterior rotation of the arm and a complete supination. The hand has turned 180° (90° of exterior rotation and 90° of supination).

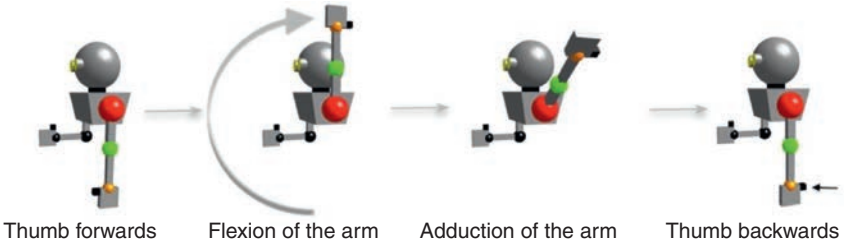

Figure 11.9 Codman's paradox. First image: the initial position. Second image: flexion of the arm. Third image: adduction. Fourth image: final position; notice the position of the thumb. (Adapted from Boutet, Morgenstern, & Cienki, 2018a, p. 150, Figure 5.4, with permission of John Benjamins Publishing Company.)

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To show that these last two conjunct movements take part in the cycle of voluntary movements (abduction and flexion of the arm), we start from the same initial position of the arm, but with the palm in the sagittal plane turned outward. The forearm is therefore in a position of total interior rotation and the hand in a position of maximum pronation. In this new initial condition, the abduction movement of the arm does not reach 180°; the arm remains locked around a 90° position. The interior rotation and pronation are already in place, blocking the movement of the arm. The involuntary movements on the forearm and hand therefore serve as an "escape." Like the diadochal movements seen on the forearm and hand, Codman's paradox is sensitive to the order in which the cycle of voluntary movement is set in motion.

The third place of conjunct movements is on the hand. It is also due to a biomechanical mechanism and relates to the kinesiological approach to gestures. The situation on the wrist is basically the same as for the elbow and shoulder. The wrist has two dof (flexion/extension and abduction/adduction) on which is added pronation/supination, a longitudinal rotation that corresponds to this escape of a diadochal movement seen for the elbow.

In the same way as forearm movements, hand movements, when combined or sequenced, have an involuntary repercussion on pronation. The sequence of the movements of the two dof specific to the hand gives rise to an involuntary repercussion: pronation or supination, as shown in the images in Fig. 11.10.

A few gestures attest to this type of association between manual abduction/adduction and pronation/supination. The "goodbye" gesture (waving the hand) can be done via a slight oscillation in abduction and adduction or by a repeated movement of supination and pronation (Figure 11.11, first image) when the hand is in a position of extension. In another context, a gesture of reprimand in French culture ("Beware of spanking!") shows the hand in a marked extension position also oscillating either slightly according to an abduction/adduction movement or according to an alternating and wider pronation/supination movement (Figure 11.11, second image, with the three robots). A third gesture in this extension position means a negation made with the index finger that presents an alternating movement either in abduction/adduction or in a wider way in a combination of pronation and supination (pronosupination, Figure 11.11, third image). A gesture with a marked meaning made in a position of flexion of the hand (expressing the exclamation "*Oh là là!*" in French) offers both possibilities of movement (abduction/adduction or pronation/supination) for the same meaning (Figure 11.11, fourth image). This last gesture – in a flexed position – reverses the associations. This time abduction is aligned with supination and adduction with pronation. The association of the poles is opposite for gestures in the extension position. These gestures therefore integrate perfectly a biomechanical/kinesiological fact without the alternation of abduction/adduction or pronosupination changing their meaning.

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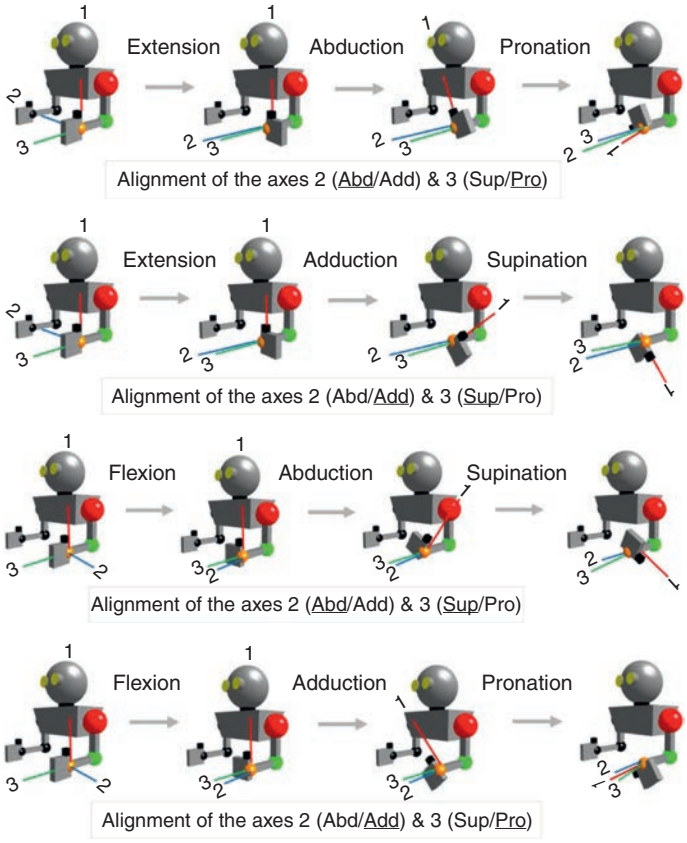

Figure 11.10 Gimbal lock on the hand. The alignment is sensitive to the pole maintained. In extension, abduction and pronation are linked, whereas in flexion, abduction and supination are aligned.

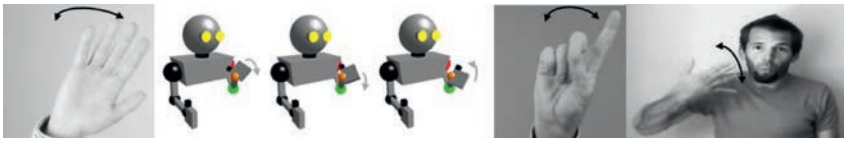

Figure 11.11 Examples of gestures with manual alignments. First image: "goodbye" gesture. Second image: "beware of spanking." Third image: negation gesture. Fourth image: "*Oh là là!*" gesture (screenshot from "10 Gestes et expressions françaises" https://youtu.be/qIJHm0wb3EE?t=102 by permission of the owner, Vincent Lefrançois).

The three sequences of movement – on the arm (Figure 11.9), forearm (Figure 11.10) and hand (Figure 11.11) – show (1) an involuntary movement on at least one degree of freedom, (2) a polar sensitivity of the involuntary movement to the sequence order, and (3) a physical problem of gimbal lock.

A gimbal is a ring suspended in such a way that it can rotate around an axis. On a ship, one may see several rings mounted inside each other in a fixed

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frame, holding the ship's gyroscope level thanks to the different axes of rotation of the rings. However, if two of the gimbals end up in a parallel configuration, one of the axes of possible rotation is lost, which is called a gimbal lock. Similarly, the occurrence of involuntary bodily movement, mentioned above, occurs when two of the three axes are almost aligned, and even as this alignment approaches. Thus, the spaces of the embodied gestures are not Euclidean and they also interpenetrate from one segment to another. Their geometry is modified, reducing the number of dof, in an apparent way. Is the transient reduction in the number of dof – physiological or even kinematic – integrated into the very structure of the meaning of gestures? Or, on the contrary, do these reductions not have any effect on the structuring of meaning? The polar inversion of involuntary movement observed on the hand (the combination of supination/abduction or supination/adduction depending on flexion or extension) answers these questions. The oscillating examples, seen above, show that the meaning of the gestures uses the constraints of the gimbal lock by stabilizing their shapes. In general, the involuntary movements are downward, that is, the gimbal lock exerts its action mainly on the adjacent distal segment (the forearm for the arm, and the hand for the forearm).

After detailing the components of upper limb movement and the kinesiological relationships between dof, it is necessary to define how movement propagates along the upper limb in order to better understand how a regularity of gestural forms provides the stability needed for the emergence of meaning.

After recalling the definitions of proper movement and displacement of each segment, and the movement transferred or received from another segment, we will see how to determine from which segment a gestural movement originates. Finally, after having defined the propagation and origin, we will see that the notion of movement propagation flow allows us to identify the course of movement along the upper limb.

4.3 Proper Movement, Transfer, and Displacement

A segment can move as the result of its own mobility (proper movement), or as a result of the movement of another segment (displacement). These two cases do not produce the same effect. The actual mobility of a segment participates in the process itself, while displacement seems to contribute more to maintaining the gesture during the stroke: to situate it, to show its extent. We can define the *proper movement* of a segment as the set of rotations around at least one degree of freedom of the target segment, without this movement coming from a degree of freedom of another segment. We will call *displacement* of a segment a (series of) translation(s) due to a more proximal segment, without any change in the position of the dof of the displaced segment. In cases where a movement affects a segment, a distinction must be made between proper movement and transferred movement. We will call *transfer of movement* all rotations around at least one axis of one of the dof of the segment involved due

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to movement of at least one other degree of freedom, that is: Movement of one degree of freedom results in movement of another. This transfer may come from another proximal or distal segment or from the same segment.

Let us consider how these characteristics of movement play out in the gesture of "presentation" (Calbris & Montredon, 1986, p. 29; Kendon, 2004, pp. 210–214, 265). A complete execution of this gesture involves movements of supination, abduction, and extension of the hand. This triple movement of the hand spreads over the forearm according to an extension and an interior rotation (see Figure 11.12).

Figure 11.12 Gesture of presentation while the speaker says, and seems to notice, "they have returned" ("*Ils sont revenus*"). This small clip corresponds to a decomposition of each image. There is a movement of extension, supination, and adduction of the right hand from image 1 to image 6. (Reproduced from Boutet, Morgenstern, & Cienki, 2018b, p. 119, Figure 4.6, with permission of John Benjamins Publishing Company.)

The movement(s) of supination, abduction and/or extension of the hand can therefore be totally transferred to the forearm, but then for this gesture to be identified as a presentation, the hand must be in a position of minimum supination. This is then a transfer of movement, and the hand is not "displaced," as the movement it undergoes is not only due to the movements of a proximal segment, since the movement of the forearm comes from the hand.

Let us now examine the case of a gesture where the forearm moves according to the same factors (extension and exterior rotation) but with the hand held in an intermediate position (neither pronation nor supination) (Figure 11.13, first image, Vladimir Putin's example).

Figure 11.13 Gestures expressing incapacity. In the first image, Vladimir Putin's hands are in an intermediate position (neither pronation nor supination), the forearms in an external rotating position and the arms in an abduction position due to the highly visible shrugging of the shoulders. In the second image, Nicolas Sarkozy's hands are in a position of supination, the forearms in a position of exterior rotation, while the arms stuck to the sides are in an adduction position. Kobe Bryant, the basketball player in the third image, has his hands in a marked supination position with a strong flexion position of the forearms, with his upper arms at his sides. It seems that the supination position does not condition the positions of the forearm or upper arm.

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This gesture (Figure 11.13) does not have the same meaning as the previous one (Figure 11.12); it expresses *epistemic negation*, in the sense that Gosselin (2005, p. 4) defines it, that is, a "de facto judgment resulting from a subjective evaluation," an *incapacity* (Kendon, 2004, p. 275; see also Calbris & Montredon, 1986, p. 80). Being held in this position, the hand is displaced this time. It could be in a more pronounced position of supination and extension (Figure 11.13 second image, Nicolas Sarkozy). The supination position, in particular, should be marked as in the previous gesture (see Figure 11.12) to allow a transfer of the manual extension as an extension of the forearm and the manual abduction as an exterior rotation. But this is not the case. It can therefore be concluded that the movement of the forearm does not depend on the movement of the hand. But, conversely, the movement of the hand comes from that of the forearm. The propagation of the movement along the upper limb is, this time, proximal-distal.

Does the segment that does not move constitute the origin of the total transfer of the movement or is it only affected by a displacement? To find out, we need to compare the number of dof moving on each of the segments, including the number that would have moved if movements had affected it. The number of oppositional types of movement involved (abduction/adduction, flexion/extension, pronation/supination) determines the origin of the gesture. The smaller the number, the closer we get to the segment that initiated the action. If we review some of the last gestures seen above, the one expressing *incapacity* (Figure 11.13) shows three kinds of manual movement (supination, extension, and abduction), two kinds on the forearm (exterior rotation and extension), and only one kind on the (upper) arm (adduction). The segment at the origin of this gesture is therefore the (upper) arm. The gesture of *presentation* – as soon as it shows a supination position, even an average one – can then be performed by an extension movement of the hand and can be transferred to the forearm by an exterior rotation and a movement of extension. The hand is therefore the segment at the origin of this gesture.

Another clue, more related to the deployment of the gesture, consists in looking at how the gesture runs along the upper limb, that is: determining the flow of propagation of the movement. This is what we will see in Section 4.4.

4.4 Flow of the Propagation of the Movement

The upper limb is a portion of the body across which movement propagates in a temporal order. Determining this order is difficult, primarily due to the fact that two time-delayed movements are in a causal relationship. For this, we need to set out rules.

With the *inertia rule*, proximal segments prevail as the movement proceeds along the upper limb. From the inertial point of view alone, the flow of movement is from the arm to the hand. Indeed, in relation to the body, the average adult proportion of the center of mass of each segment is 2.3 percent for the arm, 1.5 percent for the forearm, and 0.55 percent for the hand (Dumas,

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Chèze, & Verriest, 2007). There is therefore a decreasing gradient of the center of mass going from the arm to the hand. The inertia of these segments if they are in motion depends directly on the mass of each segment; it follows the gradient of the center of mass.

A second rule (*joint limit rule*) is counterbalanced by a gradient that marks the potential for transfers as a movement approaches its maximum amplitude. The effect of this rule may counteract the effects of the previous rule by shifting the transfer of movement to a larger inertia segment. Thus, maximum flexion of the hand boosts a transfer to the forearm, a segment with greater inertia. The abduction/adduction of the hand, whose amplitude is very limited, very often has its movement transferred to the forearm.

The third rule (*geometric rule*) concerns the parallelism of the axes of rotation between the segments. It concerns the direction of transfers. A motion transfer occurs under the necessary (but not sufficient) condition that the axis of rotation of the movement is parallel and adjacent to the one or ones on which the motion will be transferred. The direction of movement determines the type of the polar transfer (e.g. abduction vs. adduction).

The fourth rule (*diadochal rule*) concerns involuntary conjunct movements. Involuntary movements occur as soon as a joint has two dof and a movement affects both of them (so-called diadochal movement [MacConaill, 1946]). We then have an involuntary conjunct movement of the third degree of freedom.

The movements that appear in a gesture without being in this transfer ratio summarized in Table 11.1 constitute independent movements. Let us consider the cases of movements transferred along the upper limb. Three situations are defined: one for which the flow of movement propagation during a gesture or sign goes from a proximal segment to a distal segment (*proximal-distal flow*);

Table 11.1 *Summary table of the four rules that affect movement of the upper limb segments*

RULE	AFFECTS	DIRECTION of the TRANSFER
Inertia Rule	*From chest to knuckles*	*Proximal-distal*
Joint Limit Rule	*Essentially fingers and hand*	*Dependent on geometric parallelism and the amplitude of the dof. The smaller the amplitude between the joint limits, the greater the transfer. The amplitude of the abduction/adduction of the hand with that of the fingers is the lowest of the upper limbs. As the joint limits are approached, the direction of transfer may be distal-proximal*
Geometric Rule	*Potentially all dof with the exception of interior/exterior rotations and pronosupination*	*No particular direction*
Diadochal Rule	*Rotation interior/exterior and pronosupination*	*Sensitive to the order of movement on the other two dof*

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another for which the flow of propagation goes from a distal segment to a proximal segment (*distal-proximal flow*); a third possibility for which there is no flow (without flow).

These flows are generally detectable by the staggered movement of adjacent segments. The handshape of the sign [*PLACE*] ("location") in Figure 11.14 (upper image) in French Sign Language (LSF) starts with a movement of flexion of the proximal knuckles and spreads along the fingers with this movement of flexion before the fingertips come into contact with the pad of the thumb; this movement on the fingers corresponds to the transfer from the hand. The flow is proximal-distal. The handshape of the sign [*SAISIR*] ("grasp"), Figure 11.14 (lower image), shows an identical flexion movement of the fingers, but propagating from the tip to the root of the fingers. The flow is distal-proximal. The only difference between these two types of hand shape changes is the flow of the movement. Beyond the other differences between these two signs (one hand or two), the gestural expression of the idea of *grasping* and that related to *location* can only be distinguished from each other by the flow of the movement.

Figure 11.14 Sequencing of two signs in LSF. [LOCATION] (or *place* in spoken French) in the upper image and [GRASP] (*saisir*) in the lower image. The distinction between these two hand shapes is based on the flow of movement. Use of the images licensed by the online resource Spread the Sign (https://www.spreadthesign.com/fr.fr/search/).

The two gestures of "presentation" and "epistemic negation," seen in Figures 11.12 and 11.13, also present opposite flows: The gesture of "presentation" takes place according to a distal-proximal flow, while the gesture of "epistemic negation" shows a proximal-distal flow.

Behind these more obvious examples, some gestures and signs show less discernible flows. Here are some hints to be taken into consideration when determining the flow of movement of a gesture or a sign. The temporality of transfers is different depending on whether they respond to inertia (by a

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decreasing gradient from arm to hand [inertial rule]) or to a gradient from distal to proximal segments (the closer the movement is to a maximum amplitude, the greater the potential for transfer is [joint limit rule]) or when the movement transferred is involuntary (so-called diadochal movement [eponymous rule]). The latter is obviously the fastest since it is inseparably attached to the other two dof that move. Thus, a movement of flexion and exterior rotation of the forearm instantly implies the occurrence of an involuntary supination movement. In terms of differences in speed, the transfers coming in second place are those related to a movement of a distal segment close to its maximum amplitude (the joint limit rule). Finally, the slowest transfer is the inertial type that occurs on the more distal segments.

In the case of a total transfer of movement from a proximal segment such as the arm to a distal segment such as the hand, can the flow of movement be reversed? In other words, does the flow of movement depend on the gesture when it is moved to another segment or does the flow of movement depend on the segment and its situation? The answer seems to lean in favor of the second option. This is the case with the following "epistemic negation" gesture (Figure 11.15): The movement affects the hands according to an extension and abduction, and then it is transferred to the forearms. Thus, this realization reverses the flow from proximal-distal (seen in the gesture in Figure 11.13) to distal-proximal by motion transfer. It should be noted that the movement of the forearms is much less extensive than that of the hands.

The complete transfer of movement to a more distal segment can redeploy the course of the gesture or sign by modifying the flow of the movement. If the general shape of the gesture is not modified, the flow can be reversed. The flow does not define a gesture. In some cases, it makes it possible to distinguish between gestures (e.g. a gesture of presentation and a typical gesture of epistemic negation). The flow structures how the gesture unfolds, while encompassing, in the same entity of meaning, the forms captured on the dof or even the segments that the movement affects. Once the movement is extended through the segments, the meaning can be realized on a segment far from the origin of the gesture. Depending on the dof set in motion on this remote segment(s), the flow can be reversed. If this is the case, then the realization borrows the flow of the other gesture in the pair that has the opposing form

Figure 11.15 Political speech of Nicolas Sarkozy, April 5, 2012. While he says, "There is nothing we can do about it" ("*On n'y peut rien*"), we notice a movement of extension of the hand and a slight supination between frames 2 and 4 and an abduction of the hand for frames 4 and 5, finally an exterior rotation of the forearm and an abduction of the arm. Here it is a form of epistemic negation whose flow is inverted (distal-proximal) which is similar to that expected for a gesture of presentation.

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of flow. For example, in Figure 11.15, there is an "epistemic negation" gesture transferred to the hand and forearm with an inverted flow – distal-proximal – which, therefore, will have a presentational color; the shape deployed on the hand and forearm is still similar to that of the "epistemic negation" gesture. The gesture can then be interpreted as "the presentation of an external reality about which I can do nothing." The flow takes precedence over the form; it does not supplant it. The gestural form of epistemic negation persists but goes into the background in favor of the flow, which is indeed in this case that of "presentation." Hybrid gestural forms therefore appear; borrowing from a flow and the form generated by the opposite flow, their meaning is a kind of composite.

4.5 Transfer of Movement, Transfer of Meaning

When the movements are transfers, then the dof affected by them establish by habit a formal genealogy; we can see that the transferred forms share a family resemblance with the initial forms. This family resemblance brings together achievements played out on different segments. They can appear between two dof, for example, one on the hand and the other on the forearm. Thus, a lateral gesture of exterior rotation of the forearm (Kendon, 2004, pp. 262–263), sweeping up to its maximum amplitude along a horizontal plane at constant speed, expresses, according to Kendon, an interrupted line of action. The hand in pronation – the palm in the same horizontal plane – follows the movement of the forearm, and therefore does not have its own movement. The meaning ascribed to it, that we prefer to call "totality," lies in this type of movement of the forearm with this particular quality of constant speed (Figure 11.16).

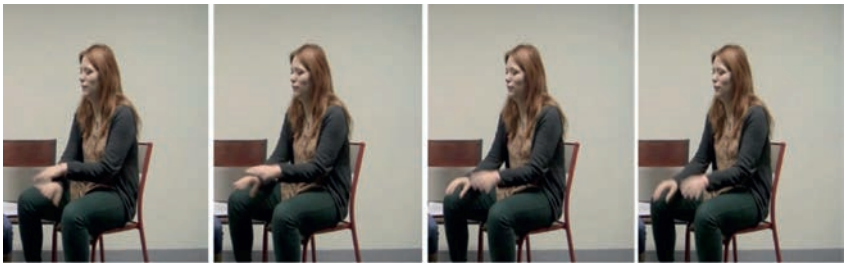

Figure 11.16 "So there was blood everywhere" ("*donc y avait du sang partout*"). The gesture begins with a movement of the forearm (exterior rotation of frames 1 to 3), then this movement affects the hand (frames 3 and 4) in the same direction, toward the outside. This gesture corresponds to the expression of totality. Note that the speed of it is important here (seen in the fuzzy image of the hand), remaining relatively constant and high. (From Boutet, Jégo, & Meyrueis, 2018, p. 147, Figure 5.2, with permission of John Benjamins Publishing Company.)

Continuing with pronation, if it is the hand that sweeps the horizontal plane of a necessarily shorter trajectory by a movement of adduction up to its maximum amplitude, then the same notion of "totality" emerges, on the express condition that this gesture is made at constant speed. This constant speed is

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a strong indication that the transfer of movement comes from the forearm. In the event that this hand adduction movement was performed with significant acceleration, then it would have responded to a distal-proximal flow and would have been generated on the hand, thus expressing a "negation" (Figure 11.17). We would then have left this genealogy of form, in favor of the expression of simple negation.

Figure 11.17 "Finally, there were not many of us" ("*Enfin, on n'était pas nombreux*"). This gesture begins with a movement of the hand (outward). This movement spreads to the forearm (frames 4 and 5) with the same external direction. This gesture corresponds to a negation. During the first three frames, when the hand is moving, the upper part of the right wrist remains in the same place (as can be seen in these frames, given the position of the left elbow in the background). In the sweeping movement to the outside of the hand, one can also see the expression of totality, the hand then covering the supposed extent that the people occupied. (From Boutet et al., 2018, p. 147, Figure 5.3, with permission of John Benjamins Publishing Company.)

4.6 What Is a Gestural Form?

The concept of gestural form as a carrier of a singular value remains to be defined. There is no constant form/meaning for gestures in the sense of a trajectory deployed in space, as we have seen. There is no single form for any meaning. Therefore, we cannot consider a form in itself. The system of values associated with shapes includes what the recurrent deployment of movements on the upper limb captures in the dof in terms of movement, but also in terms of position. If there is no form in itself independent of the degree(s) of freedom that generate(s) it, there is also no form without considering the flow of propagation of movement. *A gestural form (or gestural unit) is constituted by the degree(s) of freedom on which a movement unfolds over all or part of the upper limb and where this movement is frozen, as well as by the order in which this movement unfolds over the dof it passes through.*

A gestural form is based on kinesiological considerations of movements or positions transferred between segments. It is based on the stabilized unfolding of a gesture on the upper limb. *Let us call this stabilization an action schema. It is a grouping of movements or positions governed by a gestural form or unit determined by the organized sequence of movements of one or more segments.*

There are forty simple action schemas in embodied gestures. "Simple," because they are constrained only by kinesiological principles, without any other external constraints, be they iconic (in the sense of dependent on the environment which they depict or designate) or material (manipulation of

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objects or any form of coupling with the body). They are also "simple" because they are based on a free transfer of movement to the upper limb and a voluntary movement pulse of two dof on the two extreme segments of the upper limb. Boutet (2010) gives an inventory of the action schemas; here we provide the action schemas of just two gestural units as examples.

4.7 Circulation of Movement Transfers in Action Schemas

Figures 11.18 and 11.19 represent action schemas in boxes and movement transfers as lines between the boxes. We will look at this in two examples.

The first example (Figure 11.18) shows a distal-proximal flow. The gesture starts on the hand with an adduction and an extension. Any other movements can be considered as transfers of movement. In theory, only manual adduction (Figure 11.18.1)[3] and extension (Figure 11.18.3) are voluntary movements. The first transfer of movement spreads over the forearm and results in an extension movement of the forearm (Figure 11.18.2). The association of adduction and extension of the hand leads to a diadochal consequence: an involuntary pronation movement is quickly in place (Figure 11.18.4 *bis*). We can see it in the third photograph (frame 3), which shows an extension of the forearm at its maximum (first intersegmental transfer), a hand in an almost maximum extension position, a manual adduction movement already involved in a transfer in the form of an exterior rotation of the forearm (Figure 11.18.4) and a pronation at its quasi maximum (Figure 11.18.5).

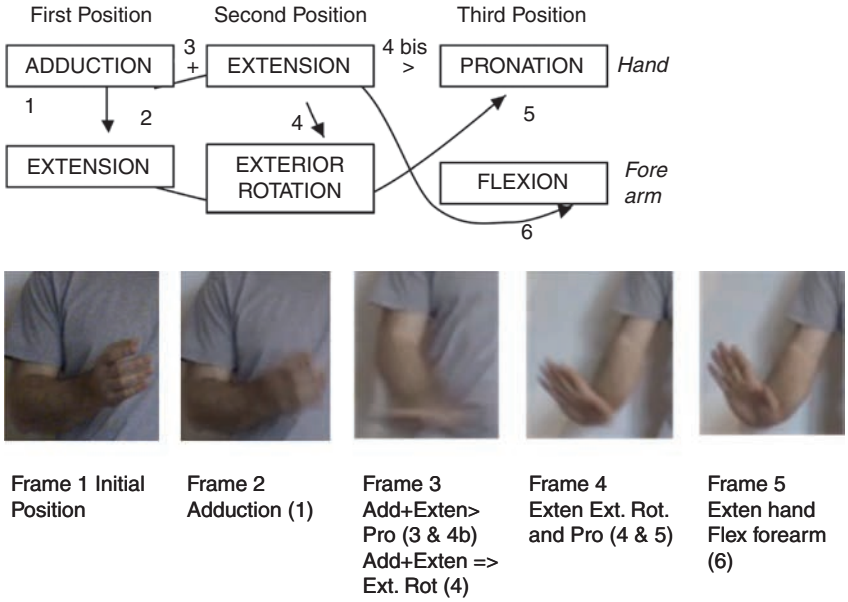

Figure 11.18 Action schema of the gestural unit "Refusal." The flow is distal-proximal and it comes from the two voluntary movements – adduction and extension – on the hand.

[3] The third number in each case indicates the movement number in the figure.

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As the palm changes orientation under the effect of pronation, which gradually changes it from an inward orientation to a downward orientation, the transfer of movement on the forearm is also modified: From an extension, it changes to an exterior rotation under the effect of manual adduction. When the extension of the hand is at its maximum (frame 4) and the exterior rotation of the forearm has itself reached the maximum position due to the transfer, then the transfer coming this time from the joint limit of the manual extension is reflected on the forearm by a flexion (Figure 11.18.6) that concludes the intersegmental transfer series.

In the second action schema (Figure 11.19), the gesture is initiated on the arm by two voluntary movements: an abduction (distance in a frontal plane from the plane of sagittal symmetry) and a flexion (movement in the sagittal plane in front of a frontal plane). The gestural unit corresponds to the meaning of disinterest (*je m'en fiche* "I don't care"). Abduction causes an interior rotation (Codman's paradox, Figure 11.19.1) while brachial flexion is transferred to the forearm by flexion for inertial reasons (Figure 11.19.2). In turn, the interior rotation and flexion of the forearm are immediately released by a supination movement (diadochal transfer; Figure 11.19.3). This transfer is done at

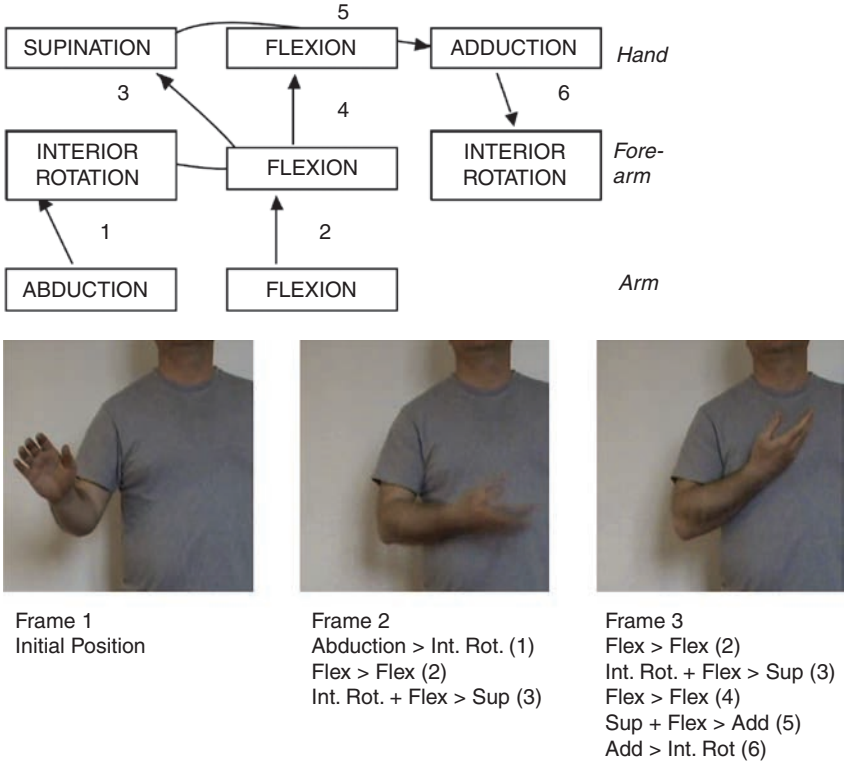

Figure 11.19 Action schema of the Gestural Unit *je m'en fiche* "I don't care about that." The flow is proximal-distal and it comes from the two voluntary movements – abduction and flexion – on the arm.

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the same time as the combination of the two forearm movements. It appears in the first position in the line corresponding to the hand. The flexion of the forearm is transmitted by the hand in a flexion movement (Figure 11.19.4). The succession of supination and manual flexion results in a manual adduction movement (Figure 11.19.5) which, in turn, accentuates the interior rotation movement that was already in place (Figure 11.19.6).

We have thus defined action schemas according to two criteria: movement and position.

4.8 Position or Movement

First, let us define position from a kinematic point of view. A position results from an absence of movement, maintained either by the absence of any muscle contraction or by a contraction of antagonistic muscles that maintain balance. In the case of an absence of muscle contraction, we call it a rest position. In this case, the position is not marked within any degree of freedom; on the contrary, it remains in an intermediate or quasi-intermediate position. In the case of a balance between two antagonistic muscles, the position can be extreme. A movement in a specific direction is obviously different from a position. However, a position maintained which entails a dynamic at work is not so different from a movement. In this case, a position returns to a suspended or maintained movement. This maintained movement is documented in the form of a *hold* (Kendon, 1972; Kita, van Gijn, & van der Hulst, 1998).

4.9 Semiotic Value and Actualization Modes

Another question is: In which cases does the position have the same semiotic value as the one carried by the movement?

The dynamic involved brings semiotic values to a degree of freedom, in the manner of Aristotelian material causality. The movement is then the realization of this dynamic – its implementation – whose value is updated in a coextensive way as it unfolds along the path traversed. Basically, a gestural value is reached by the movement; it does not reside in the movement, otherwise it cannot be present only in the final position. Therefore, this value is coextensive with the degree of freedom. Movement is a way of realizing it in real time. The position of a segment on the extent of its degree of freedom is another way. A position maintained in its movement amplitude is sufficient to carry a value. For the values staggered along a degree of freedom, the movement deployed and the position occupied are two ways to actualize a value.

The actualization modes – movement or position – do not have the same temporal repercussions. Movement cannot be considered outside a temporal sequence; it therefore updates a value within a given time period. Once reached, the position updates the value for the duration that it remains in

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place. The limits of joint movement are particularly useful for maintaining these meaningful positions. Thus, for the gesture of *refusal*, a palm forward position, fingers upward, reflects this meaning. The joint-limits rule, the diadochal rule (Add+Exten> Pro), maintains this extreme position and finally semiotizes the space of each segment. Thus, the positional mode of actualization of the values is persistent in time: it can be reached without precise ongoing movement. Its value lasts as long as the position is in place because it is marked by kinesiology.

Another type of position appears here: that of location, as in one of the four parameters that is traditionally used for Sign Language analysis. The particularity of these locations is that the segment that takes place there is not the one that creates the associated positional value. Thus, when the hand is above the shoulder and composes the *absence of responsibility* (incapacity + disinterest, see Figure 11.13, third image), the value of *disinterest* was not forged by the hand, but by the arm and forearm. The hand instantiates a position outside itself; this particular position of the arms and forearms becomes a location with a singular value within which the hands take on this particular color of disinterest. An important point, shown here, is that this parameter of location, easily readable in an egocentric reference frame, can perfectly derive from the notion of position, which is part of a so-called intrinsic framing, depending in fact on all the segments of the upper limb. One of the four manual parameters of signed languages thus emerges for gesture.

4.10 Outcomes of Tests Applied to 20 Action Schemas

Of the 40 gesture units (GU) based on action schemas, 20 were tested using independent judges (Boutet, 2010). To summarize this work, two concepts were tested: the semantic validation of a label for the 20 GUs and the structuring of the meaning involved, based on kinesiological principles.

Semantic validation was performed for 90 percent of the GUs. The only two GUs whose label did not correspond to that expected were for a label whose gestural realization corresponded to a more proximal segmental origin (the arm). It seems that semantic confusion almost systematically operates in the sense of a hyperclass. The fact that it is attached to a proximal segment raises the question of the history of development of gestural semantics. Is the arm the primary substrate of gestural meaning, which then extends to the hand, whose appearance remains to be discovered? Is this semantic subordination to the gestures generated on the arm a historical fact or a kinesiological fact, linked, for example, to the upper inertia of the arm?

Tests of the kinesiological structuring of gestural meaning were conducted by varying the form that the realizations of the 20 action schemas take on one or more segments. Here again, the average recognition rate was very good: 90 percent. It should be noted that the GUs that are structured on the arm are better recognized than those that are structured on the hand. We also note that the choice of labels, when they are not the expected ones, responds

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to a gradient that follows formal proximity. When proximity is a matter of amplitude, it is coupled with strong semantic proximity. The polar opposite movements (e.g. abduction vs. adduction) show quite clearly that semantic values are attached to them. The updating of these data is possible through the successive cross-references offered by these 20 units. Semantic features associated with the poles and positions in the action schemas must emerge from the formation of minimal pairs and polar inversions,.

5 Conclusion

Gesture does not consist of a simple trace of meaning deposited in space, but of a series of structures, as presented here. The structuring is not so much in the body or in the simple vectors of movement, but inside each part of the upper limb, at the level of each degree of freedom of its segments. We have defined the mobility parameters of the segments, in other words, what the dof over the entire upper limb are with their axes of rotation, as well as the geometric and kinesiological relationships that these dof maintain for each segment and between them. To occur, gestures (and signs of Sign Languages) require movement in the first place. While most of the time the movements are voluntary, some movements are involuntary and yet are involved in meaning-making.

Movement spreads over several dof according to a flow that can be characterized in terms of two main trends: (1) the propagation of the movement from a distal segment to a proximal segment (distal-proximal flow) or (2) the movement first affecting a proximal segment and diffusing toward a distal segment (proximal-distal flow). Determining the flow of movement makes it possible to go back to the origin of the gesture and, therefore, to where the meaning was forged. However, the flow of movement does not always correspond to a time delay in the activation of the segments. A non-temporal definition is therefore required: The number of types of movement per segment determines the origin of the gesture or sign. The smaller the number, the closer we get to the segment that initiated the action.

The foundations of the flow of gestures respond to four rules that guide the propagation of movement in a determined way. For proximal-distal flow, the inertia rule reveals a decreasing natural slope from the shoulders to the last knuckles. In terms of the diadochal rule, according to which for all joints with three dof, one of which is a rotation (exterior/interior rotation and pronation/supination), the setting in motion of the first two dof causes an involuntary and joint movement of the third degree of freedom. Conversely, for distal-proximal flow, the joint limit rule tends to move the gesture up to a more proximal segment each time the movement approaches the joint limit of a degree of freedom. The adduction/abduction of the hand is an essential element with its small amplitude. The transfer of movement that this stop rule brings about is dependent on the last – geometric – rule which concerns the parallelism of

the axes of rotation between the segments: The determinable part of a transfer of movement responds *ad minima* to the parallelism between the axis(es) of rotation of the segment at the origin of the movement and the axis(es) of rotation of the segment(s) on which the transfer takes place. If the flow adds an additional dimension to the circulation of gestural forms and increases the possibilities of meaning, the total transfer of a movement affecting a proximal segment to a distal segment can reverse the flow by reversing the movement backward. In other words, does the flow depend on the gesture when it is moved to another segment or does the flow depend on the segment and its situation? In a first approach, it seems that the flow depends more on the segment and the situation than on the gesture and its meaning. We can therefore consider that flow works as a direction distributor. When the transfer of a movement on a segment goes so far as to reverse the flow expected by more or less preserving the general shape of the gesture appearing without reversing the flow, then the meaning of the gesture becomes a composition of meanings of the two gestures. These gestural hybridizations need to be studied further.

The structuring of the gestures we have developed is based exclusively on kinesiological considerations. What is important to grasp in the general "magma" of gestures is the process of their individuation. We have shown that the latter not only responds to a formal aspect based on kinesiology but extends its influence to the emergence of the levels of Sign Language structure that constitute the traditional parameters of sign form description. Nevertheless, gesture units such as recurrent gestures (Ladewig, this volume; Müller, 2018) carry the meaning of formal stabilizations of action schemas.

The approach followed throughout this chapter, entirely bottom-up, shows how much the structuring of gestures depends on a very deep formal level: not the one that is played out on the segments, not even below that of the dof, but even lower, at that of movement parameters involving polar oppositions (abduction/adduction, flexion/extension, pronation/supination). The discovery of these levels of structuring has an impact on our conception of what the gesture or sign is. It is no longer a question of limiting it to a trace left in space, but to the trails that the execution of gestures leave. Their structure and meaning are based on structural and dynamic rules that we have begun to determine. For this reason, the kinesiological system is well suited to augment motion-capture analysis of gesture by providing categories for, and using principles of, movement analysis that mesh with those used for motion tracking. (For an example, see Boutet et al., 2018, which documents a pipeline for gesture analysis; the website Events and Gestures, n.d., includes a tutorial on its use.)

Iconicity then requires a different conception than that of image iconicity alone to account for the bodily structuring of gestures. A bodily based iconicity redraws what was seen from the imagistic point of view; it takes as analogous varied gestural realizations of a given instance of expression that can be deployed with the same action schema. This can allow us to see, for example, what a palm-up open hand gesture of presentation has in common

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with smaller renditions of it (such as a slight turn-out of the hand at the wrist, or even the lifting of a thumb when one's hands are folded as one sits at a table): Each of the successively larger gestural forms contains within it all of the movement elements of the smaller forms (Cienki, 2021).

Rather than kinematics, the rules considered here respond to a kinesiological level such that the hand is only one part of the segments that build stabilizations and meaning in which the forearm, upper arm, and fingers participate. Since stabilizations operate primarily on the body, their imagistic or iconic consequences are secondary; indeed, the faculty of vision that allows us to access the gestures/signs of others may only constitute an echo chamber that makes the image.

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