5.2 Spatial Pulls and Platonic Solids

Spatial ideas that help organize and analyze movement

Punctuating the kinesphere are notable **spatial pulls** (listed in figure 5.2). While engineers tend to model space as an infinite continuum of possible directions, represented in Cartesian coordinates by three orthogonal real number lines, humans cannot perceive the difference between a vector pointing to (0,0,1) and (0,0,0.999); moreover, in the environments that humans typically inhabit, this difference is not often *meaningful*. Thus, the spatial pulls discussed in the Space category of the BESST System are a select and small subset of possible directions—perceptual fiducials that are useful for human observation. Because we have a sense for how a person might, can, or will move in the space around the self, the choices that a particular mover actually makes in the space are expressive. This is often described as a dynamic tension between the mover and the environment. It is most acutely felt as an ongoing interaction: rather than a list of absolute or even relative spatial locations, a spatial pull describes this relationship as indicated through the moving body. Thus, the process of change is what becomes meaningful rather than a set of coordinates or "places."

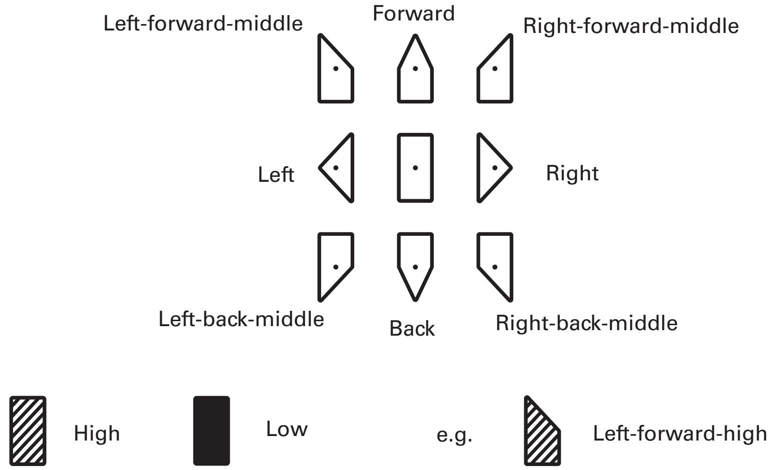


Figure 5.2
Symbols for spatial pulls. The nine shapes for the middle level (shown at the top and middle) can be shaded to indicate the high and low planes (shown at the bottom).

If one body inhabits the upper level of its adjacent area, it does not have to be *as far* up as another body to still be *up*. Likewise, a particular style of reach upward can actually intone a downward spatial attention, creating a different action entirely. Thus, we note that these twenty-six spatial pulls can be used to divide the levels and zones previously introduced, providing finer-grained, more detailed abstractions for seeing similarities in distinct bodies navigating space. In doing so, we name *dimensions, diagonals, planes*, and, later, Platonic solids (*tetrahedron, octahedron, cube, icosahedron*, and *dodecahedron*) as models of the kinesphere. These elements (see the symbol sets in figures 5.3 and 5.4) combine actions along the dimensions that are roughly aligned with the principal axes of inertia of the human form and are recognized as relative to the mover (up is always toward the head and down is always toward the feet). Boxes 5.4, 5.5, and 5.6 list the architecture of three of these models, the octahedron, cube, and icosahedron, in terms of dimensions, diagonals, and planes, respectively.

Figure 5.3
Symbols for indicating planes. Three planes bisect the mover—vertical, sagittal, and horizontal—creating opportunities for movements of different anatomical emphasis.

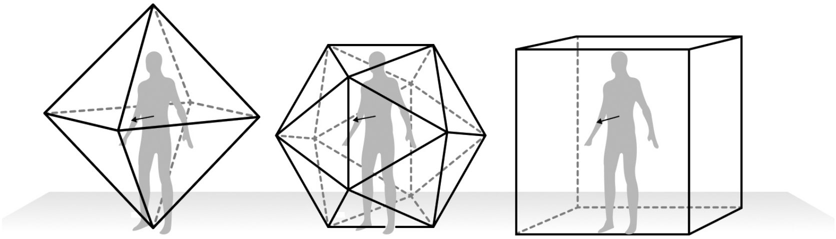


Figure 5.4
Models for a mover's kinesphere. Here, moving left to right, the kinesphere is imagined as an octahedron (with inscribed dimensions), icosahedron (with inscribed planes), and cube (with inscribed diagonals). The geometric forms, as well as the figures inside, are tilted on an angle (as indicated by the black arrows) to better show their spatial relationship.

Box 5.4

Spatial Pulls in the Octahedron

- Pure spatial pulls in the octahedron (formed by three orthogonal dimensions)
    - Vertical dimension (major axis of length)[5]
        - Middle[6]
        - High
        - Low
    - Sagittal dimension (minor axis orthogonal to length)
        - Middle
        - Forward (sometimes called “front,” defined by a sensory-rich face that implies a preferred heading for travel)
        - Back
    - Horizontal dimension (minor axis orthogonal to length)
        - Middle
        - Right
        - Left

Box 5.5

Spatial Pulls in the Cube

- Combinations of spatial pulls in the cube (three evenly felt spatial pulls, which form diagonals)
    - Right-forward-high
    - Left-back-low
    - Left-forward-high
    - Right-back-low
    - Left-back-high
    - Right-forward-low
    - Right-back-high
    - Left-forward-low

Box 5.6
Spatial Pulls in the Icosahedron

- Combinations of spatial pulls in the icosahedron (two unevenly felt spatial pulls)
    - Vertical plane (vertical dimension is primary and horizontal dimension is secondary)
        - Right-high
        - Left-high
        - Left-low
        - Right-low
    - Sagittal plane (sagittal dimension is primary and vertical dimension is secondary)
        - Forward-high
        - Forward-low
        - Back-low
        - Back-high
    - Horizontal plane (horizontal dimension is primary and sagittal dimension is secondary)
        - Right-forward-middle
        - Left-forward-middle[7]
        - Left-back-middle
        - Right-back-middle

The infrastructure of the octahedron is the dimensional *cross of axes,* which defines the vertical (height), sagittal (depth), and horizontal (width) dimensions. These orthogonal dimensions can be thought of as rather straightforward body frame coordinates that emanate from the center of mass of the mover. However, it is worth discussing the primacy of the vertical dimension (which is sometimes named the “longitudinal axis”). When standing upright, this dimension aligns with the downward pull of gravity. It is also the axis about which humans find it easiest to spin (it corresponds to the smallest moment of inertia in most adult humans). And, as referenced in the Body component, this verticality is one of the first things we look to in order to understand a foreign moving body (whether human or not). Puppeteers turn strips of foam into expressive characters by, among other things, creating a consistent relationship to gravity for the puppet. While all bodies can change that relationship, the vertical dimension remains a primary factor in our experience of movement in space (both our movement and the movement of other bodies).

The infrastructure of the cube consists of four diagonals that define three equal-dimensional pulls expressed simultaneously as one diagonal direction, with its equal and opposite pull at the other end. These three equally felt pulls create a sense of mobility and off-balance reactions in the body, revealing a key relationship between the Body and Space components. Often, it is observed that reacting to these spatial pulls creates (or requires) a complex spiral through the body. For example, the scapula of the arm indicating or responding to the pull will literally rotate down and around the shoulder joint in order to afford greater access to space by the arm. Moreover, shifting weight through the lower body can continue this spiraling action through the pelvis to the pads of the feet. These bodily changes can create mesmerizing patterns in the human form, particularly with performing artists who are trained to emphasize and reveal these changes to observers. For example, the diagonal directions are often leveraged in proscenium-based performing arts like ballet, where performers will indicate the corners of the room through different bodily positions such as *epaulé derrière*, the body position where the right arm crosses in front of the body and rotates toward left-forward-high, while the left arm crisscrossed behind to right-back-low and the legs follow to reveal a similar facing.

The infrastructure of the icosahedron is the three planes: vertical, sagittal, and horizontal (each having two unequal pulls emphasizing the correspondingly named dimension). We often describe the vertical as the **door plane,** stable (as the human form is when stretched out, upright, in an *X*), with more up and down than side to side; the sagittal as the **wheel plane,** mobile (as the human form is when attempting a forward step or somersault), with more forward and back than up and down; and the horizontal as the **table plane,** a place most associated with manipulation (or expression) by the hands and arms, with more side to side than forward and back. These directional pulls are thought to be more natural, occurring often in everyday life, compared to the complexity of the diagonals in the cube or the austere purity of the single-dimensional pulls in the octahedron.

As we will explore further in the next section, moving among these spatial pulls creates immediate implications of geometric change, implying something inherent in the expressive nature and functional associations of each movement. Movements in the cube can be dramatic changes reversing three polarities (e.g., between right-forward-high and left-back-low) or off-balance actions that cause complex bodily accommodations (e.g., left-back-low to left-forward-low). Movements in the octahedron, on the other hand, require rigid severity in the purity of each pull (e.g., moving from back-middle to forward-middle without any hint of change in high to low or left to right). This pull, first, is an abstract ideal that we cannot achieve, and second, entails an unnatural strictness that can be tiring. The icosahedron is thought to invite much more natural movements. That is, gliding between the two unequal pulls in this form may be a “Goldilocks” solution to physical movement commonly inhabited in the kinesphere: changing neither too abruptly nor too gradually, but just right.

Embodied Exercises

- 📹 **Finding your own personal, affective associations with space:** Use the prompts here as free movement responses. When responding, think about the following question: Which areas of your kinesphere did you visit more frequently? Jot your responses down on paper and compare across prompts. It may be instructive to record yourself in order to observe separately from moving (or, feel free to observe simultaneously with your movement response).
    - Bright, bubbly
    - Deep, dark
    - Peaceful, placid
    - Exhaustion
    - Jumping for joy
    - Apathetic indifference
    - Catching slippery soap bubbles

In enlivening your kinesphere with your own interpretation of these different energies, what patterns emerged? How does the form of your body, including your own range of motion and prior movement experience, inform these patterns?

- 🎥 **Indicating versus revealing space:** In this exercise, we will zoom in on one spatial pull—right-forward-high, a diagonal—but invite the reader to try it with other directional pulls as well. It will be instructive to record yourself here too.
    - Keeping a neutral body posture, employing a forward gaze and even distribution of weight between two feet, reach your right arm straight up, then out to the right, and then forward, aiming for equal measures of each change.
        - You are now *indicating* a point in space that is relatively right, forward, and high of your center of mass. This, however, is not the same as *revealing a spatial pull*, where your entire body responds to a pull from far outside your own body. In fact, if you half-heartedly stood from a chair to complete the exercise, your body may be more likely to exhibit an attraction to that chair than to the right-forward-high diagonal, as expressed through a downward, slouched relaxation in your lower half.
    - From a neutral body posture, employing a forward gaze and even distribution of weight between your feet, imagine that a valuable, priceless object of great personal sentiment is located just out of reach along the same right-forward-high diagonal that you indicated in the previous step. Now, reach for that object. How is this end state, with your arm reaching to a similar location, different than in the previous step? What happened to your gaze? What happened to your posture?
        - If you are reaching with every ounce of your being toward this imaginary object, you are likely recruiting your gaze, a shift of weight, the deformability of your torso, muscular tension, and other features of your movable body to *reveal* the right-forward-high diagonal. Whereas in the first step, your shoulder socket likely remained neutral, with the scapula at rest on your back, now your shoulder is probably experiencing a rotation, with the scapula sliding down, maybe even beginning to wrap under your armpit, in order to facilitate a more engaged reaching action of your body. This reach does not end—because the object is out of reach—but

an observer will now be able to *perceive* where you are reaching with greater clarity.

- Try to find the same diagonal (a spatial pull in the cube) from the octahedron (reaching first to high, then right, then forward) and the icosahedron (reaching first to right-high and then toward forward-high, without losing the right component of your intention). Which form is easier for you to start at in order to find the diagonal pulls of the cube? Notice how moving between these forms helps—even forces—you to become clearer in your movements (and your perception of them).

We encourage you to revisit these exercises in chapters 7 and 8 to further analyze the changes in your body used to reveal this direction, understanding them as part of Shape and Effort.

5.3 Movement Scales

Identifying and practicing patterns in space

In much the same way that music is practiced and learned through the study of scales and arrangements of notes in a progression, the BESST System names **movement scales** that map the space of the human kinesphere. These scales are an arrangement of spatial pulls in a progression that, similar to musical scales, are practice sequences designed to hone techniques for accessing—moving in—space. They are not an end in themselves, but a means to an end. Established movement forms use a similar approach to learning the technique of that form through a codified movement vocabulary. For example, ballet requires a barre and a set of actions to be practiced over and over (*tendu*, *degaje*, *plié*, *port des bras*, to name just a few). These sets of movements are designed to enhance the expression of the form. Likewise, they are a means to the end of ballet choreography and performance.

The movement scales provide a way to explore pathways, landmarks, proximities, and spatial pulls, as well as enhance the articulation of the mover in the space. Moreover, they can be used to compare styles of motion to one another (just as different styles of songs may use different keys). As such, they are models of how a mover might access space rather than of the space itself. In the same way that a road map provides a means of navigation, the BESST System scales provide a map to the kinesphere. Using the movement scales to practice spatial movement can reveal and clarify action, in terms of both its functionality for the task at hand and its expressive character.

Practicing and utilizing the scales become important for allowing the mover to experience the different qualities of spatial expression, as well as the functionality of patterns in accomplishing goals and actions in the environment. The scales used in the BESST System emerge from a study of the tetrahedron, octahedron, cube, icosahedron, and dodecahedron, with the main emphasis on the octahedron, cube, and icosahedron. The various scales progress in a manner of either **abrupt** change (all pulls changing), **gradual** change (only some pulls changing), or some combination of both, alternating in a sequence, which reveals the character or feeling of the scale itself. The sense and process of change constitute where the meaning is expressed and the functionality of the space is able to be accessed. All the movement scales are expressed as a "loop" or sequence that repeats itself from beginning to end and consequently can be started and finished by beginning the movement in any pull and sequencing through it.

To illuminate the character of the scale itself, let us compare four particular scales: the **dimensional scale** (using all central pathways), one of the **girdle scales** (using all peripheral pathways), the **diagonal scale** (alternating central and peripheral pathways), and the **A scale** (using all transverse pathways). These scales are described in box 5.7. For a full explanation of all the movement scales, including the spatial pulls in each scale listed in box 5.7, refer to appendix B.

By looking at these particular scales, it is clear that moving through space with certain pulls, pathways, and maps for organizing expression reveals different experiences and, ultimately, meanings. For example, the girdle scale outlines the container of the mover's kinesphere, while the A scale explores the fullness of the contents of the mover's kinesphere. The way in which a moving body uses space can signal intent (particularly when unfolding over differing periods of duration), create boundaries, invite connections, and accomplish the ongoing negotiation of the mover to the environment and self to other. Thus, the use of space becomes meaningful, making it important in human-human interaction and, eventually, human-robot interaction (HRI).

We can begin to use the patterns in movement isolated by these scales to recognize that there can be a harmonic relationship between aspects of

Box 5.7
Descriptions of Some Movement Scales

- **Dimensional scale (in the octahedron):** When executed with all central pathways, the dimensional scale presents a body poking out and in as each dimensional pull is expressed, followed by a return to middle before poking out again to the next dimensional pull. There is a duple sort of rhythmic pattern created (out/in, out/in, out/in) that builds a repetitive sense of polarity in the movement expressed.
- **Girdle scale (in the icosahedron):** A girdle scale reveals a different sense of expression as it develops through all peripheral pathways in the icosahedron. A girdle scale forms a sense of "going around" or "encircling" as each spatial pull is ordered in sequence next to a nearby neighbor. This circular expression engenders a sense of alertness and clarity of consciousness. There is a sense of being on "the edge" that defines a container of space, which is in stark contrast to the poking through space that is revealed in the dimensional scale.
- **Diagonal scale (in the cube):** The diagonal scale uses alternating central and peripheral pathways. From right-forward-high (moving with the right side leading) to left-back-low, the mover traverses a central pathway through the center of the cube; from left-back-low to left-forward-high, the mover traverses a peripheral pathway along the face and at the edge of the solid. Moving through the center of the cube and then out along the face creates turbulence between stability and mobility.
- **A scale (in the icosahedron):** The A scale uses all twelve icosahedral directions, connecting them with transverse pathways. It loops around the diagonal of right-back-high/left-forward-low. As a result, the most powerful expression of diagonal space is absent. The sequencing of planal organization creates a defensive feeling, which has been likened to the minor scales of music. While the transverse pathways can be expressed in different rhythmic patterns, the overall feeling of the A scale is one in which the full volume of the kinesphere is revealed due to the rather dramatic changes in spatial organization exhibited by its geometry.

movement that layer, integrate, and work in concert in order to illuminate seeing, experiencing, and understanding our relationships both with ourselves and the environment. Rudolf Laban (1966, p.195) called this idea "harmony of movement" in *Choreutics*, and Irmgard Bartenieff (1980/2013) refers to this integration as "coping with the environment" in the title of her seminal text. More recently, Studd and Cox (2013/2020, p.165) describe the practice of movement scales as they encourage the mover to “connect the changing form of the body in its dynamic expression in space”. Like harmonies in music, where the design of sounds that delight, intrigue, confound, or otherwise engage the human spirit, the idea of harmony in movement is another way of languaging the idea that human movement is a complex, ubiquitous, and textured design space. Just as color theory highlights triplets of colors that designers can use (or not) to create harmonious interior spaces and rooms, movement studies highlight canonical sequences that can be used as tools for practice, observation, and creation.

Embodied Exercises

- **Exploring spatial pulls in sequence:** In this exercise, you will begin to sequence spatial pulls in each of the Platonic solids to explore the different textures and tones of moving in these spatial forms.
    - Begin by choosing any three spatial forms that you would like (see figures 5.2, 5.3, and 5.4) and move among them.
        - What are you expressing? What are you doing?
        - What does this space elicit for you?
        - How are you transitioning from direction to direction?
        - What type of pathways are you using?
    - Choose three spatial pulls from the octahedron (one-dimensional) and move between them.
        - What sort of pathway are you using to go from direction to direction? Central or peripheral?
        - Can you order your space to allow both central and peripheral transitions?
        - What is your experience of the difference between the two?
        - Do you experience this pathway as stable or mobile?
    - Now choose three spatial pulls from the cube (three-dimensional) and move among them.
        - What sort of pathway are you using to go from direction to direction? Central or peripheral?

    - Can you order your space to allow both central and peripheral transitions? What is your experience of the difference between the two?
    - What do you experience when moving through a complete diagonal where all three pulls change on a central pathway?
    - What do you experience when moving between two diagonal directions when two pulls change along the face of the cube versus through the center of the cube?
    - What about moving between two diagonal directions when only one pull changes (along an edge of the cube)? What is your experience of that space?
  - Now choose three spatial pulls from the icosahedron (two-dimensional planal pulls).
    - Do you experience new and different pathways in this form? Can you order your space to go from vertical to sagittal to horizontal and find a transverse pathway?
    - Do you experience this space as somehow happening between the edge and the center of your kinesphere?

For the three experiences given here, consider whether it was difficult or easy to experience space in one form compared to another. Was one use of space more comfortable or familiar to you? What places were easier to access? How did you feel during each pull? Did any images or thoughts come to mind? Notice the images, thoughts, and feelings that you experience in the different Platonic solids and how that elicits varying expressions, as well as a sense of functionality.

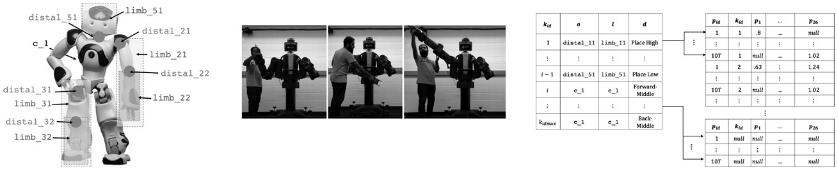
5.4 Application to Machines: Generating Humanlike Telepresence

Enabling configuration space control through choreographic technologies

Sharing movement ideas, or commands, with others is a common occurrence. For example, a statement like “Pick that red cup *up* and place it to the *right* of the blue one on the *bottom* shelf” uses many spatial references. The BESST System formalizes this idea, creating a symbolic system for aspects of movement related to Body (see chapter 4) and Space (in this chapter). Research exploiting these two elements of the system has developed a platform-invariant movement specification method and related teleoperation scheme that enable functional and expressive pose (or configuration space) control of articulated robots.

First, an extension was established to the standardized robot description system, the Unified Robot Description Format (URDF), creating labels that *overlap*. While a machine needs to have only a single label for each joint and linkage of an articulated body to unambiguously control it, humans refer to body parts redundantly (as is clear from chapter 4). Thus, these overlapping labels, shown in figure 5.5, allow human specification to better align with machine morphology. In this way, the framework uses a choreographic technology to simulate an artificial embodiment that better aligns with how humans describe their own movements. Next, a user moves the robot through a simple scale, establishing body poses for each spatial pull. These poses are stored in a database that is indexed by parameters inspired from Body and Space component symbols from the BESST System. Users can then specify movement through a simplified form of motif, as shown in figure 5.6.

Evaluating the efficacy of this motion specification scheme was accomplished by checking whether the resulting machine behaviors effectively imitated the original human performance of the movement sequence, evaluated by human subjects (Jang Sher et al., 2019). It is impossible for such an imitation to *physically be the same*; instead, the interest lies in *perceptual similarity*. Likewise, associating these symbols with buttons on a game pad, the scheme can be used in real time to generate improvised, complex movements on robotic platforms as shown in figure 5.7 (Zhou et al., 2019). This scheme has outperformed traditional joint-space control methods in



k_{id}	o	l	d
1	distal_11	limb_11	Place High
⋮	⋮	⋮	⋮
$i-1$	distal_51	limb_51	Place Low
i	c_1	c_1	Forward-Middle
⋮	⋮	⋮	⋮
k_{idmax}	c_1	c_1	Back-Middle

p_{id}	k_{id}	p_1	...	p_{26}
1	1	.8	...	*null*
⋮	⋮	⋮	⋮	⋮
$10T$	1	*null*	...	1.02
1	2	.63	⋮	1.24
⋮	⋮	⋮	⋮	⋮
$10T$	2	*null*	...	1.02
⋮	⋮	⋮	⋮	⋮

⋮

p_{id}	k_{id}	p_1	...	p_{26}
1	*null*	*null*	...	*null*
⋮	⋮	⋮	⋮	⋮
$10T$	*null*	*null*	...	*null*

Figure 5.5

Leveraging concepts of space and body to design robotic algorithms. Left: the Body component supports establishing a redundant labeling scheme, similar to that found in section 4.1 of chapter 4. Middle: the Space component lends the concept of movement scales for providing an architecture of the kinesphere. Right: a database establishes relationships between Body and Space. Modified from Jang Sher et al. (2019), used with permission.

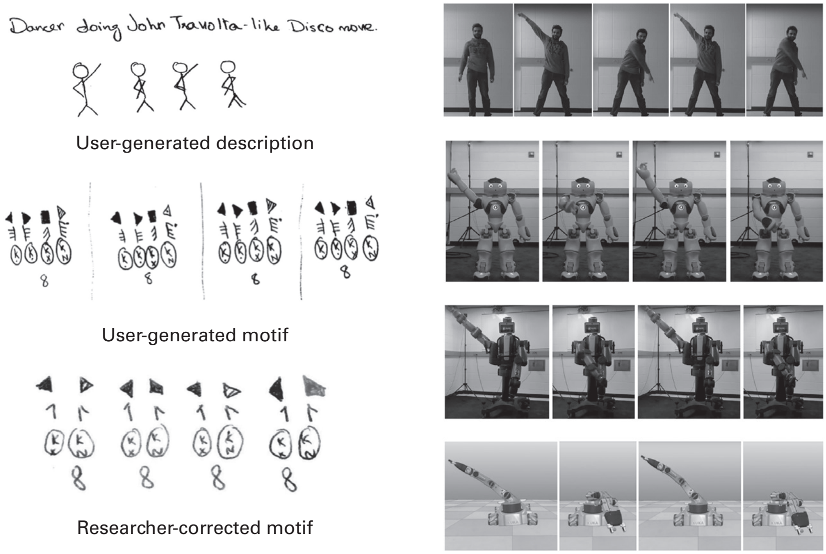


Figure 5.6
Movement specification through movement notation, which allows execution across distinct robotic platforms. Left: movement notation provided by users and corrected for accuracy by researchers. Right: "the same" sequence on four different bodies, from top to bottom: a human subject, the Softbank NAO robot, the Rethink Robotics Baxter robot, the KUKA youBot. Modified from Jang Sher (2017) and Jang Sher et al. (2019), used with permission.

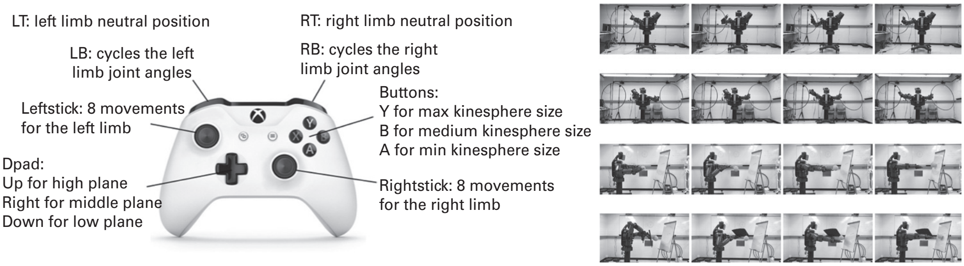


Figure 5.7
Leveraging choreographic technology for a joint-space control teleoperation scheme. Left: mapping between Space and Body component elements and buttons on a gamepad, used to control the Baxter robot. Right: snapshots of a human subject operating the robot after a half-hour training session across four different tasks, shown in each row. Modified from Zhou et al. (2019), used with permission.

a variety of tasks that required users to improvise in order to accomplish unknown or unanticipated goals (Bushman et al., 2020).

Embodied Exercises

- **Distinct bodies in shared space:** Consider the three robotic platforms in figure 5.6.
  - Describe the body morphology of each in a paragraph, noting not only how the robots differ from each other, but how each differs from the human body.
  - Which machine has the greatest access to the following levels and zones of its kinesphere?
    - High level
    - Low zone

    Note how the mobile manipulator robot (youBot) has a full range of motion in its high level, whereas the "head" of the small humanoid (NAO) offers interference in this level. On the other hand, only the small humanoid (NAO) can lower itself by bending its "knee" joints, affording some access to the low level.

    - Back zone
    - Front zone

    Note how the large robot (Baxter) can rotate each of its arms 180 degrees, affording full access to both the front and back zones, unlike the small humanoid (NAO), which has limited back zone access (as do humans).

  - How would you express the following spatial pulls on each device?
    - High
    - Right-forward-high
    - Back-low
    - Left-forward-middle
- **Movement specification on distinct bodies:** Use the concepts introduced so far in this chapter to create and describe three movement behaviors. Write your descriptions and then enact them in your own body. See appendix E for a version of this exercise for a group.

5.5 Exploring the Themes: Space through the Lens of Function/Expression

Highlighting the utility of expression

Changes in space affect both the expressive meaning and functional purpose of a movement. In the BESST System, this principle is understood through the Function/Expression theme.[8] For example, similar gestures performed in different reach spaces can have very different purposes, and therefore different meanings. Consider a hand waving back and forth with an open, relaxed palm facing away from the mover. When made close to the body, in near-reach space, contacting the nose, the act might be to the functional end of scratching an itch on the nose—and similarly interpreted by onlookers as an expression that the mover has an itch on the nose. In mid-reach space, the action might be a gentle wave to serve the purpose of signaling to a nearby friend—and seen as a friendly expression of "hello" by onlookers. In far-reach space, the action might be used to ward off unwanted attention—and seen as, quite opposite to the previous example, a signal to "go away." Thus, the same movement performed from a different aspect of the kinesphere will influence the meaning of that movement.

The relationship between function and expression is used by dancers training to complete complex tasks with functional efficiency and economy, expanding their personal palette of available movements and, thereby the ideas that they can express with their bodies. In other words, by becoming functional, efficient movers, they become more expressive artists. The inverse is true as well. Factory artisans who complete complex, nuanced, and skilled physical labor employ a wide range of movement styles and qualities of expression to execute tasks like polishing, painting, and assembling. In other words, a broad palette of available actions allows them to complete concrete, functional tasks in their workplace.

The Function/Expression theme can be applied to any component of the system, where it is constantly revealing the indivisibility of these ideas. Developing varieties of salient movement profiles for robots is often described as "bringing expressiveness to movement," but this framing is in conflict with this fundamental duality. In fact, all movement is both expressive and functional, but some movement *systems* (be it a particular dancer or athlete, or even one robot versus another) can be more expressive than others—which also makes them more functional tools. In discussing function and expression in the BESST System, we therefore often talk about *foregrounding* one concept over the other. We can certainly work on developing a new movement pattern or robot to an expressive (or functional) end, but we must always recognize the relationship expression has to function (and vice versa).

Embodied Exercises

- **Choreography and meaning:** This exercise uses the BESST taxonomy to generate movement and your imagination to invent uses for that movement.
    - Develop a movement sequence through changing levels: start from lying on the floor, then move to sitting, and then to standing.
        - Come up with a reason for the movement: invent a context, situation, and environment where the sequence takes on meaning.
            - Try one meaning that foregrounds the function of the movement (e.g., lying on the floor for rest).
            - Try one meaning that foregrounds the expression of the movement (e.g., standing up for oneself against a bully).
    - Try the sequence by only moving in near-reach space, then mid-reach space, and then far-reach space.
        - How do the potential expression and function, identified in the previous step, change for each iteration of the same sequence in distinct reach spaces?
    - Compare and contrast the functional efficiency and expressive capacity of the sequence as it morphs through other terms we have learned so far.
- **Observation and analysis:** This exercise uses the taxonomy and the Function/Expression theme to analyze movements found in your environment.
    - Go to an area that you frequent that is good for people watching. Identify changes in elements introduced in this chapter.
        - Come up with a reason (or meaning) for the movement you see, observing context, situation, and environment where the sequence takes place.

- Try one meaning that foregrounds the function of the movement.
- Try one meaning that foregrounds the expression of the movement.

Chapter Summary

This chapter has described several abstractions for organizing human movement (and thus human perception of nonhuman movement) in space. We have introduced the idea of the kinesphere and shared dissections of space ranging from refined, pointlike pulls to broad, swathlike areas that help describe movement—across distinct bodies—in their kinesphere. We have also described the practice and some of the theory behind movement scales, listing these scales in appendix B for the reader's further exploration. Then, a review of a project in movement specification showed how these concepts can be applied to creation with machines. Finally, we visited the Space component of the BESST System through the theme of Function/Expression, allowing some integrated examples and opportunities to absorb this larger principle. We learned that the organization of animate bodies in space is not simply a task of measurement (which traditional tools in engineering, design, and robotics are well equipped to accomplish), but also one of broad perceptual strokes that are applied in a relative way to physical bodies in their environment.

6 When Is the Movement Happening? The Temporal Perception of Movement (Time)

Chapters 4 and 5 have examined elements of answering "what" and "where" questions about movement. By establishing a rich set of descriptions for moving bodies and the space in which they move, we outlined the Body and Space components. In this chapter, we are going to answer questions related to "when," completing a basic triad of concepts that describe bodies moving in space and time. That is, in order to perceive change, and thus in order for movement to occur, we need a body moving in space *and* time; thus, we now consider the Time component as introduced in (LaViers & Maguire, 2022). Time is foundational to the experience of change, and thus the perception of movement. In these three components, we find the foundational bits of movement that even basic, ordinary machines can potentially generate and interpret. More complex ideas like quality, intent, and meaning will be covered in later chapters, which will further complicate the kinds of patterns that people perceive about (and enact on) bodies in space and time.

In explicating a fifth component,[1] we are expanding on the concepts traditionally covered as "phrasing" and creating a needed taxonomy for discussing the temporal aspect of movement. Humans today have an increasingly prominent and quantitative relationship with time: devices track user screen time, measure the length of exercise activities, and predict when passengers will arrive at their destination, updating them with estimates about how disturbances like traffic will affect their arrival time. Moreover, in the movement arts, choreographers have access to video recorders, can create lighting cues with precise timing, and fit their work into increasingly varied event durations.

It is especially useful to explicate the Time component when working with machines, which must deal in user-specified and -designed quantitative units of time. Some machines do not portray clear ideas about intent and relationship from their movement, but we can always measure the amount of time an action took and frequently see phrasing through stops and starts of various machine parts. Thus, while a particular example of artificial movement may not rise to the level of creating a clear dynamic quality (which we discuss in chapter 8 about the Effort component), it will use elements that we are collecting in this component of Time. For example, an acceleration of a distal linkage of a machine, which creates a whiplike snapping action, may or may not manifest as a recognizable shift in movement quality, as reading significance in such an action greatly depends on the features of the movement preceding and following it, as well as other contextual factors. Likewise, algorithms interpreting human movement do not always recognize motivation or intent but can often segment motion into salient pieces.

Creating machines that move (or interpret movement) with variations in time that are meaningful to human observers is a crucial challenge. For example, pedestrians at crosswalks observe the oncoming cars and get some sense of how long they have until the cars reach the intersection. They also interpret temporally meaningful actions taken by the driver: if the driver speeds up, for example, a pedestrian will not cross. However, even if the car slows such that the actual time-to-arrival allows the pedestrian safe passage across the intersection, the pedestrian still will not cross if the driver's braking does not clearly advertise an intent to yield.

As this example of pedestrian and driver suggests, there are quantitative and qualitative aspects to time that we will discuss as part of the Time component and are critical to meaning-making. Moreover, the driver and the pedestrian each have different prior experiences, personal preferences, and goals in the context of their interaction; thus, they have distinct relationships to time. In general, a mover's relationship to time is subjective and personal, as expressed through an idea called "dynamosphere," which is introduced in this chapter.

6.1 Sequencing

Creating patterns through temporal context

The order in which actions occur and unfold over time affects the perceived meaning of the movement expression. What comes first provides context to what follows, and what follows reframes what just happened, influencing where and which patterns are evident. The **sequencing** of movement events affects the perceived emphasis—and therefore the experience and interpretation of the event. What happens first, what follows, and what comes after that creates a sequence that can be viewed in terms of a beginning, middle, and end. When the sequence of what happens first and what happens next changes (but the same set of movements is kept), the meaning of the movement will sometimes change as well. For example, consider the marshaller who directs planes on the ground at airports. This person uses a set of predesigned movements that indicate to pilots how to drive airplanes in particular ways. The sequence in which these gestures are performed becomes critical to the movement response of the aircraft pilot. To get the plane safely away from the gate, the marshaller will signal to back up, and then turn, and then go forward. If the turn signal is given before the backup signal, the plane will hit another plane at an adjacent gate, so the task will not be effectively completed. The sequence of baton gestures will indicate a particular meaning in one order, and if the same gestures are done in a different order, the meaning is changed and the outcome will be different. Even though the same movements are being performed, a different order creates a new meaning.

In observing or experiencing movement in sequence, we can further differentiate whether more than one thing is happening at the same time. When more than one thing is occurring at the same time, we say that these events are using **simultaneous sequencing** (i.e., in parallel). When individual actions follow upon one another, these events are using **nonsimultaneous sequencing** (i.e., in series). In the example of directing a plane on a tarmac, the "backup" baton gesture is done with the right and left arm moving at the same time, with the arms parallel to each other, and the "turn" baton gesture is done by putting both arms up overhead and *then* moving the other arm in the desired turn direction.

Nonsimultaneous events include the other two types of body-level phrasing first described in box 4.5 in chapter 4: **successive sequencing** (adjacent body parts following a movement expression) and **sequential sequencing** (nonadjacent body parts following in a movement expression). The observation and experience of successive and sequential body-level phrasing as nonsimultaneous sequencing will rely on body morphology. Thus, we articulate an affinity between concepts in the Body and Time components. The adjacency of body parts is different for a body with two limbs protruding from the core than for a body with forty-nine limbs. The idea of adjacent and nonadjacent body parts—what those parts are and how they move in concert—is determined by the individual context of each body's form. For example, the successive movements of a jellyfish and its waving tentacles moving from the pulse of its bell opening and closing are quite different from those of the cheerleader who makes a series of sequential gestures to complete a "Go, team, go!" chant. Likewise, robots that are just an "arm" and a "hand" will have different expressions of these ideas than those that have a "head," "trunk," two "arms," and two "legs." We suggest that movement phenomena are easily perceived as either at the same time or not at the same time and, given our propensity for finding and seeing patterns, sometimes things that happen at different times look behind or ahead with respect to one another.

There are choreographic techniques that manipulate how movement unfolds over time across multiple bodies using more complex aggregates of these basic sequencing ideas. Such tools include **unison, out-of-step, repetition, reversal, retrograde, accumulation, canon, echoing,** and **theme and variation.** These structures, listed in box 6.1, describe manipulations of how many times and in what sequence movement events occur, using sequencing to create pattern and emphasis.

In some of the sequencing strategies listed in box 6.1, emphasis on a particular moment within a movement phrase or expression is created through contrast. That is, emphasis can emerge when a sequence of actions is similar and then a very different type of action occurs relative to the movement events before and after. The moment of difference will often stand out, although crucially, not every moment of contrast is perceived in the same way by every viewer. For example, the airplane marshaller may see an unexpected change in the environment, causing the need for a pilot to quickly change course. The marshaller may then, after executing several evenly timed and similarly moved actions, quickly tense his arms and bring them overhead rapidly, indicating that the pilot should stop immediately. This change in movement tone or quality signals new information to the pilot through contrast.

Some mechanisms used to create contrast, and thus, for some observers, emphasis include *changing movement complexity, condensing action, muscular tension, spatial arrangement, contact,* and *sounding*. These structures, listed in

Box 6.1

Choreographic Terms for Sequencing Strategies

To illuminate the differences in these ordering structures, each description uses the following set of basic body actions: expand, condense, rotate, jump, and locomote.

- **Unison:** Performers do the "same" series of actions at the same time. This is a baseline case, from which these other strategies may be seen as variations.
- **Out-of-step:** Each mover again performs the same sequence, but not exactly at the same time as every other mover.
- **Repetition:** Any action or set of actions that is repeated more frequently inside a longer sequence will emerge as significant to the understanding and emphasis of that moment in the meaning of the whole sequence. Regardless of whether these actions are repeated in succession or across a longer sequence where they are mixed with other actions, but repeated noticeably more times than all the other actions, the effect is an emphasis on that action or set of actions as being more prominent than the other actions in the sequence. So, if the sequence is performed as *expand*, *expand*, *expand*, *condense*, *rotate*, *jump*, *locomote*, the action of "expand" is emphasized. Likewise, if the sequence is performed as *expand*, *condense*, *expand*, *rotate*, *expand*, *jump*, *expand*, *locomote*, "expand" again becomes the emphasized action. At some point, after many repetitions, a process of desensitization can also occur.
- **Reversal:** The original sequence would be ordered as *locomote*, *jump*, *rotate*, *condense*, *expand*. Thus, the same set of actions performed in reverse order changes each movement in the sequence, as each action needs to connect to a different action than in the original sequence.
- **Retrograde:** This can be understood as akin to putting a video in rewind mode. The order is reversed, but the movements are also performed by tracing backward the actions that occurred going forward in the sequence. Enacting this structure will create a different sequence of actions altogether, but each action within the sequence preserves its original form (just in "rewind").
- **Accumulation:** This way of ordering movement relies on repeating the previous set of actions and then adding a new action. Using the previous example set of actions, a mover creates a sequence of *expand* (1), *expand*, *condense* (2), *expand*, *condense*, *rotate* (3), *expand*, *condense*, *rotate*, *jump* (4), *expand*, *condense*, *rotate*, *jump*, *locomote* (5). By the fifth repetition, the entire phrase is revealed.

(*continued*)

Box 6.1 (continued)

- **Canon:** Two movers both use the same sequence of actions, but shifted in time. The first mover performs *expand*, *condense*, *rotate*, *jump,* and *locomote,* while the second mover waits (often a measure of music) to perform *expand*, *condense*, *rotate*, *jump*, and *locomote*. This type of ordering is also seen quite clearly in singing a "round" such as "Row, row, row your boat (1) gently down the stream (2), merrily, merrily, merrily, merrily (3), life is but a dream (4). The first singer would begin with "Row, row, row your boat" and continue through the sequence. The second singer begins the sequence after the first singer has completed the first set of words. However, both sing at the same time and follow the same sequence, just shifted in time.
- **Echoing:** One mover performs *expand*, then the second mover performs *expand* as an "echo" to the first mover, and so on through the sequence. This strategy uses the same time shift as canon, but not the same accumulation.
- **Theme and variation:** Riffing on a movement theme, creating a slight variation in the form of a new movement, allows a larger multiplicity of sequencing choices. Some examples include:
    - ABA ("theme" is A, "variation" of the theme is B)
    - ABACADAE (C and D are further variations of A)
    - ABCABDABE (the theme can now be seen as AB in this sequence)
    - ABABCABABDABABE (the theme is either ABAB or a repetition of AB, interrupted with C, D, and E)

box 6.2, describe manipulations of how movement is presented over time, using contrast to create pattern and emphasis within a temporal stream of actions.

By noticing the relationships of actions in time with greater detail, we open up new options for design and interpretation. Sequencing (the order of actions) creates contrast (a measure of action relative to temporally adjacent actions) and emphasis (the value, prominence, or importance of actions), creating a temporal pattern and context. This contrast or emphasis can be created through an *abrupt* (or *gradual*) change that stands out among the actions temporally close to it. An abrupt action seems like a dramatic moment of intense change, while a gradual action seems to unfold slowly, with less change happening in any given moment.

Box 6.2

Choreographic Terms for Creating Contrast

- **Increased (loading), or decreased (unloading), movement complexity:** Actions that dramatically change in their complexity may be perceived as being in contrast to those around them. This could happen through many lenses of movement. For example, using a central pathway is often seen as a simpler spatial choice than a transverse pathway through the kinesphere. So a series of central pathways could be seen in contrast to a transverse pathway, which would be emphasized through its distinct sense of complexity; or vice versa, a central pathway among many transverse pathways could be emphasized through its simplicity. Often, this idea is called *loading* or *unloading*, respectively.
    - **Stillness:** An important subcase of this idea is going between active movement and stillness in the body such that a viewer perceives stillness (simplicity) versus action (complexity).
- **Condensing dynamic expression:** Actions that happen with force and impact, speed, piercing focus, and extreme binding (see also the discussion of condensing effort qualities in chapter 8) draw attention and create emphasis. This idea is also sometimes called an *accent*, especially in word pronunciation (which is a subset of movement behavior), where this is sometimes understood as the loudest syllable of the word when spoken. Contrast can also be created through a moment of softness and relaxation amid stronger action.
- **Muscular tension:** Actions that require extreme change in the attitude of the musculature (especially contraction, but also relaxation) can create emphasis.
- **Spatial arrangement:** The place within the environment where an action unfolds can create emphasis. A sequence that goes toward the audience compared to the same sequence moving away from the audience will create a different impact. For example, according to the choreographer Doris Humphrey, the diagonal from left upstage to right downstage was considered the strongest diagonal on the stage, and movement on that pathway would have the greatest emphasis (Humphrey & Pollack, 1959). This may have been true for Humphrey's style of movement on a traditional proscenium stage, but every specific environment has a spatial structure with which movement can engage for particular emphasis.
- **Contact with self/other/the environment:** Actions that involve touch or contact of some kind can emphasize the impact of a sequence. Take, for example, a mover that begins with an exaggerated clap (expand, condense),

(*continued*)

Box 6.2 (continued)

opening the arms and then clasping the hands together, or does a "high five" with another mover, or slaps an object in the space. These moments of contact draw importance to the "condense" event inside a larger sequence of movement. Or, in contrast, in a series of movements that all use contact, an action that disengages contact from the environment will be emphasized.

- **Sounding:** Using percussive action that creates sound, such as a slap or the voice (the basic body action of vocalizing), can draw attention inside an otherwise silent movement. The moment of sounding stands apart as different from the other moments in a sequence that does not involve using the voice. Or, in contrast, in a series of movements that all use vocalization, an action conducted in silence will stand apart from them.

This forms an affinity between the Space and Time components. In section 5.3 in chapter 5, we described abrupt and gradual *spatial* changes occurring in movement scales. Here, we recognize that an abrupt spatial change that happens in a short period of time will seem even more abrupt than one that occurs over a longer period. This is an example of the Space and Time components reinforcing—or heightening—expression in movement.

Embodied Exercises

- **Transforming movement through time:** This exercise invites you to consider the physical and interpretive implications of order.
  - Make a short movement sequence that starts by lying on the floor, goes to sitting, and finally to standing (as in the first embodied exercise of section 5.5 in chapter 5).
  - Now reorder the sequence from sitting to standing to lying on the floor, and then from standing to lying on the floor to sitting.
  - How many ways can you order these three actions? What changes when you do each combination? Consider the answers to this question through the lens of Body, Space, and Time, as well as possible interpretations of motivation and intent.
- **Reordering beginning/middle/end:** This exercise invites you to reorder and repeat (forming emphasis) gestures that may create a different narrative depending on how they are structured in time.

  - What is happening when you point, wave, and beckon? Is it different if you beckon, wave, and point? Or if you wave, beckon, and point?
  - Now choose one of these actions to repeat; for example: point, point, point, wave, beckon.
  - What does the sequence reveal now? How does the sequence of events and repetition change the possible meanings of the movement event?
- **Changing the sequence of emphasis:** This exercise uses a familiar inroad to movement (vocalization) to explore emphasis.
  - Try speaking the words, "Who am I."
  - Now try emphasizing the first word (e.g., with increased volume compared to the other two words) "*Who* am I"; then the second word, "Who *am* I;" and finally the third word, "Who am *I.*"
  - How does the meaning and experience of your expression change based on which word is emphasized? Is one version a statement and one a question? Note your experience and responses to each version to begin to understand the role that emphasis plays in meaning-making.
  - Try recreating the "same" phrase without speaking. How do you create emphasis in your body without using your vocal cords?

6.2 Duration, Tempo, and Rhythm

Marking time and our perception of it

Our perception of movement is affected by **duration** in multiple ways. It changes our sense of whether a mover was moving "fast" or "slow" (both relatively and absolutely); it affects our estimate of the mover's intent and inner status; it often governs whether an action is judged to be salient and complete or unintentional and errant. The limit of human perception of duration occurs at the scale of milliseconds and has been measured by scientists in experiments with human subjects. This limit is generally accepted to be 100 milliseconds: any event that occurs at this rough threshold is typically judged to be instantaneous (or, events that occur in less than ~100 milliseconds typically go unnoticed by the human viewer). This is an important threshold that probably evolved based on the types of activities that humans typically engage in: most activities do not require perception below this threshold; however, this is a domain where machines, like high-speed cameras and precision lasers, aid—and help quantify—our natural abilities. Thus, we first establish a taxonomy of *relative duration* and *absolute* *duration* to describe measurable features of time. This taxonomy is given in box 6.3. Later in this section, we introduce a notion of quality in order to further distinguish what we can experience from what we can measure.

Actions of different durations may be more salient for different application areas. Here, we rely on existing, established measures of time to create a taxonomy of activity levels[2] to provide descriptive power enabling statements like "a contraction of the pointer finger that lasted with *twitch level duration*, which was *shorter than* that of the overall expansion of the entire hand." In this case, these terms help us resolve the temporal scale of different bodily actions, indicating that a small contraction of a finger does not negate the overall expansion of the entire body part of the hand. In this book, we consider duration to be interchangeable with **speed;** that is, the same action done over different durations will have different speeds. (We do not explicitly consider velocity vectors, as these are well understood inside traditional robotics texts.)

Box 6.3
Relative and Absolute Duration

- Relative duration
    - Short or shorter than
    - Equal to or the same as
    - Long or longer than
- Absolute duration
    - Micro (patterns in movement; the focus of this book)
        - Instantaneous (less than 100 milliseconds)
        - Twitch level (tenths of a second)
        - Action level (seconds)
        - Phrase level (minutes)
        - Activity level (hours)
    - Macro (broader patterns in behavior)
        - Days
        - Weeks
        - Months
        - Years

As soon as we begin considering duration, we can think about temporal patterns in duration, specifically **tempo** (as measured, for example, by beats per minute) and **rhythm** (as described, for example, by **meter**). Rhythm is a way of marking time and is inherent in our experience of our bodies moving in the world. Our biological functioning is based on rhythmic patterns that coordinate different body parts for the purpose of successful movement. Take, for example, the fundamental expression of our heartbeat. Ideally, it pumps with a steady, duple (two-phase) rhythm, but when the beating of the heart changes, it is called "arrhythmia" (out of rhythm). Our breath also functions on a duple rhythm (inhale/exhale), but that rhythm can also change and be quite impactful on our experience. Take, for example, the statements "I can't catch my breath" and "I'm out of breath." These refer to experiencing the breath in different or unusual rhythmic relationships.

In the BESST System, we identify certain skeletal/muscular rhythms to enhance and optimize our range of movement and clarity of intent. These ideas relate the movement of body parts to temporal patterns. Moreover, musical structures such as three-four (or three-quarter) time also provide known temporal patterns that can be used to modify the practice of movement. Common rhythms discussed in movement studies are both internally and externally manifest, described in box 6.4.

In addition to specific rhythms, we are concerned with the qualitative experience of time, which is not always coherent with the measurable passage of time (in absolute or relative terms). For example, anticipation modifies our experience of time: waiting for the result of a job interview can *feel* endless, even if it is only a few days; on the other hand, watching children grow up can *feel* instantaneous, even though it takes years. Moreover, the way that bodies move around us changes our experience of the passage of time. For example, a room filled with people running timed agility drills and a room filled with people soaking in a hot tub have different aesthetic qualities, including that time seems to pass differently in each. Consequently, we draw a contrast between duration and perceived duration, which we call **time quality,** and enumerate some options of how the subjective experience of time may be described (or how time *feels)*. We organize these ideas as pairs along the dimensions of *gradual* and *abrupt* poles in box 6.5.

These qualities are modified by other elements of the Time component as well. For example, an event lasting 5 seconds can seem to have *an instantaneous time quality* if preceded by an event lasting 5 minutes, or seem to be

Box 6.4

Rhythmic Structures

Absolute

- Tempo[3]
    - Measured in beats per minute
- Scheduled events
    - Measured in years, months, days, hours, minutes, seconds, etc.
        - For example, Halloween creates an annual collective increase in candy consumption in households in the US.

Relative

- Internal (coordination of different body parts for successful movement)
    - Breath, heartbeat
    - Muscular/skeletal rhythms
        - Occipital/sacral rhythm (between the occipital bone and the sacrum, as in heel rock and knee drop)
        - Gleno/humeral rhythm (between the glenoid fossa of the scapula and head of the humerus, as in arm circle)
        - Ilio/femoral rhythm (between the base of the ilium and head of the femur, as in thigh lift)
    - Ultradian (hourly), circadian (daily), infradian (monthly) rhythms
- External (coordination of different bodies for successful movement)
    - Synchronization through rhythm
        - For example: dancers, rowers, people lifting a heavy object, switchboard operators, and assembly line workers use audible counting to coordinate action.
    - Rhythmic structures (meter)[4]
        - Three-four time
        - Four-four time
        - Six-eight time
        - Duplets
        - Triplets
        - Iambic pentameter
        - Dactylic hexameter

Box 6.5
Time Quality

- Gradual polarity
  - Lingering
  - Prolonged
  - Ongoing
  - Endless
- Abrupt polarity
  - Instantaneous
  - Immediate
  - Rapid
  - Stopped

prolonged if preceded by an event lasting half a second. Thus, the sequencing of events of different durations changes their perceived time qualities. Likewise, a movement event that is emphasized through some means may seem to last longer, as we are attending to it in more detail, sensing some importance in it, than the surrounding events in the sequence.

Embodied Exercises

- **How long is 1 minute?** This exercise will expose our qualitative relationship to time through one of our readily accessible tools for measuring time.
  - Get a stopwatch (or stopwatch app) handy.
  - Start the timer and, as you do, close your eyes.
  - Endeavor to wait exactly 1 minute.
  - When you think that 1 minute has passed, open your eyes. Did you overshoot or undershoot?
  - Try again. Did you get closer?
- **Relating duration and tempo to the body:** This exercise aims to be the reverse of the previous exercise, revealing how our movement patterns—in this case, we will explore breath and tempo—inherently possess quantity.

  - Find a pair of songs with different tempos (an upbeat, fast option and a slower-paced choice). Repeat the two experiences below for both pieces of music.
    - Use an even breathing pattern: inhale for four counts and exhale for four counts.
    - Use an uneven breathing pattern: inhale for three counts and exhale for six counts; and then reverse this relationship.
  - Reflect: How does experience change as you change the duration and tempo of each action? Which ratio of inhaling and exhaling felt most comfortable or familiar? Which tempo felt most comfortable for timing your actions?
- **How long do you think an activity will take?** Estimating time is part of our daily budgeting process. Check your estimate the next time you engage in a relatively unknown task (like reading one page of this book). How long did you think it would take? How long did it actually take? How long did it *feel* like it took? Which words from the list of time qualities provided here fit that activity best?

6.3 Phrasing

Patterns in time that manifest coherent and individual movements

In movement theory (as in music theory), **phrasing** refers to the idea of grouping movements (or notes) that belong together in a single temporal stream. These groupings affect how we understand a movement activity, answering the questions “How many things happened?” and “What was the relationship between these things?” A phrase is often thought of as having an initiation (beginning),[5] a main action (middle), and a conclusion or resolution (end). As phrases are perceived through the passage of time, the ideas discussed in the previous sections, like duration, begin to have an inherent impact on the perception of a phrase. Emphasis, in particular, is an important component of how we perceive phrases. For example, creating a sense of emphasis through rarified dynamic quality (a punch at the end of a series of softer, slower movements) can punctuate the end of one phrase and signal the beginning of the next.

The idea of phrasing exists throughout the movement components of the BESST System: in Body (for body-level phrasing, see chapter 4), in Space (for volute and steeple phrasing, see appendix B), and in Effort (for dynamic organization, see chapter 8). Often the interaction of these components produces a sense of phrasing. For example, seeing a series of movements sequencing along adjacent body parts (as in successive body-level phrasing) tends to group those actions as being related to the same phrase.

Phrases have malleable temporal scales across which one can exist. For example, a day can be perceived as a phrase of time over 24 hours and complete unto itself, but days are also parts of the longer phrase of a week. We can observe movement and activity for a day, but we can also observe the pattern that occurs over a week.

The same is true for any bodily movement: a given action can be seen as an event itself or a smaller piece of a longer, more complex task. Thus, phrasing is the way that the BESST System formalizes the idea of "a movement" compared to "a series of movements." What makes "a movement"? What makes a phrase feel like "four movements" versus "five movements"? The answer is contextual. Moreover, our sense of temporal phrasing interacts with our bodily, spatial, dynamic, and relational senses of phrasing. Imagine a piano player. We see the hands and fingers engaged in pressing keys with rapid succession to produce notes, but we also can see the feet engaging with the pedals on a different timescale, sustaining and dampening different notes for a desired effect. Although the whole body is moving the whole time, we can either see this as two simultaneous temporal phrases or one longer, more complex whole-body phrase. If the piano pedals were instead keys on the piano, which would constitute a new environmental context, we might perceive this differently due to the different body organization that is producing the sounds.

In chapter 5, the spatial phrase of moving from right-forward-high to left-back-low was an example of abrupt change in *space*. All three spatial pulls change from the beginning of the phrase to the end. Likewise, moving from right-forward-high to right-back-high is an example of gradual change, as only one spatial pull changes from the beginning of the phrase to the end. Here we introduce the notion that temporal phrases can be gradual or abrupt based on both their duration (as a phrase, which can be thought of as a single movement or multiple movements) and their time quality. Explicating temporal and spatial aspects of phrasing allows us to differentiate between temporal and spatial change as well as contextual features that impact how long an action *seemed* to take.

For example, the spatial phrase between right-forward-high and left-back-low could happen with a long duration, lessening the sense of abruptness overall. What we can say, then, is that the phrase has abrupt spatial change because it is moving between drastically different points in space, and gradual temporal change because it takes a long time. But if the change in spatial pulls occurs between actions of even longer duration, this context may produce an accelerating time quality for the phrase.

Thus, choices in temporal organization of movement change how we organize, experience, and perceive meaning based on where in the phrase the emphasis occurs. Naming the types of phrases and the relationship between them (as we do next) helps us tease apart (or analyze) and make sense of (or synthesize) movement in the temporal dimension. Box 6.6 and figure 6.1 present a list of and symbols for several types of phrases that reveal different patterns of accent, loading, and emphasis.

Identifying types of phrases and their character or quality based on emphasis, loading, and accent allows us to analyze phrases as a larger whole with meaning and organization rather than just a series of actions unfolding over time. The same set of movements phrased differently will change the meaning and experience of each movement, as well as the set of movements overall. Take, for example, the following set of actions:

- Get up from a chair at the kitchen table and walk over to the stove.
- Turn off the burner under a pot.
- Sit back down.
- Tap one foot.

Box 6.6
Types of Phrases

- **Even:** All actions have the same emphasis (without accent).
- **Impulsive:** The beginning actions are accented (loaded or emphasized).
- **Impactive:** The ending actions are accented (loaded or emphasized).[6]
- **Swing:** The middle actions are accented (loaded or emphasized).
- **Becoming (or increasing):** The actions build in emphasis over the course of the phrase (analogous to a crescendo in music).
- **Diminishing (or decreasing):** The actions become less emphasized over the course of the phrase (analogous to a decrescendo in music).
- **Vibratory:** The actions in the phrase rhythmically spike and wane, often with a fast tempo, but over time, they can appear to have the same value.[7]

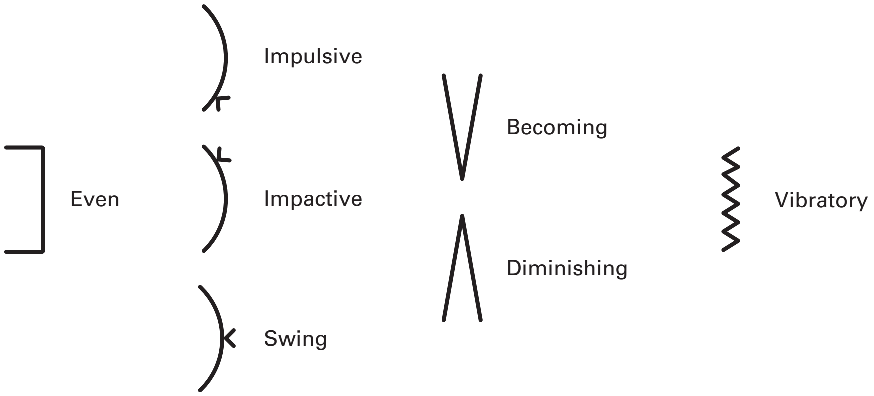


Figure 6.1
Symbols for types of phrasing. These "phrasing bows" wrap around other symbols that indicate action to denote the clustering of movements into distinct units.

If one of these actions is emphasized (say, the first action happens quickly, with increased muscular tension), as opposed to all the actions in the sequence being given the same relative duration and muscular tension over time (resulting, say, in even phrasing), a different meaning emerges. This choice of phrasing could be seen as simply attending to something that is cooking, while the impulsive phrasing of emphasizing the first action could indicate something urgent occurring (e.g., the pot boiling over) and a need for intervention to forestall a mess or other calamity. A constant (simultaneous) tapping of the foot in parallel to the other actions may be seen as an example of vibratory phrasing, creating a sense of nervous energy about the subject who is cooking.

Phrases can also be seen in relationship to other phrases as the action unfolds over time. Types of arrangements between phrases include those listed in box 6.7.

An example of consecutive phrasing can be seen in opening a jar lid. First, the jar is grasped. Then, the hand is placed on the lid and turned to loosen it. Finally, the lid is removed from the jar. Each phrase of movements completes before the next phrase begins. When someone juggles multiple objects, it is often possible to see how he is tossing with one arm while catching with the other before the toss has finished and preparing to toss again in the middle of a catch; we can name tossing and catching as two distinct phrases that alternate on each arm with an overlapping relationship. Simultaneous phrasing can be observed when the mover is

Box 6.7
Relationships between Phrases

- **Consecutive:** The phrases unfold one after the other, as each completes before the next begins
- **Simultaneous:** Two phrases happening at the same time
- **Overlapping:** A new phrase beginning as the previous phrase is ending

doing a set of actions with the arms while doing a different set of actions with the legs at the same time, as in the previously described example of the piano player (hands versus feet). Thus, the relationship between phrases adds further descriptive power to discerning the temporal structure of movement.

Finally, as we have described in this chapter, our experience of time has a qualitative, subjective component. This is captured in the idea of a **dynamosphere.** Just as a moving body has a *kinesphere*—a physical space where its movement is perceived—a moving body can be thought of as having a temporal "space" where its movement is perceived. This temporal component of our movement is often associated with intent: if something is very important to us, we may choose to do it first, whereas if it is not important, we may do other things first. This simple example relating sequence to dynamosphere reveals how personal our choices in time are. The dynamosphere becomes especially rich and complex when quality (see chapter 8) is considered as well, forming an affinity between the Time and Effort components.

Just as we perceive space around familiar moving bodies as capable of being filled with their presence (a concept captured by the kinesphere), we also perceive bodies as being able to make meaningful, purposeful, and personal choices in time (a concept captured by the dynamosphere). These dual concepts of kinesphere and dynamosphere parallel, to an extent, the use of the terms "kinematics" and "dynamics" in engineering: the kinesphere deals with the ability to move the articulated body (often thought of anatomically as our joints) in space, while the dynamosphere deals with the ability to move the weighted, physical body (often thought of anatomically as being created by our muscles) in time. However, the kinesphere and dynamosphere emphasize the personal experience of a mover rather than the universal experience of objects acting under gravity that kinematics and dynamics explain.

Embodied Exercises

- **Using vocalization to experience phrasing and its effect on meaning:** Using this sequence of four words, “I am here now,” try the following and how it changes the meaning of their expression.
    - Begin by stating the four words with equal emphasis (e.g., same duration and volume): “I am here now” (even phrasing).
    - Emphasize the first word: “*I* am here now” (impulsive phrasing).
    - Emphasize the second and third word: “I *am here* now” (swing phrasing).
    - Emphasize the fourth word: “I am here *now”* (impactive phrasing).
    - How does the meaning and story change depending on where the emphasis is?
    - Try vibratory, becoming, and diminishing phrasing for this sentence as well.
- **Explore spatial and temporal phrasing with gradual/abrupt change:** Revisit the spatial pulls in the icosahedron (as described in chapter 5) to explore different phrasing:
    - Move the actions described here (sequence A):
        - Using your right arm, move from left-side-high to forward-low to right-back-middle as one phrase.
        - Continue on from right-back-middle to left-side-low to forward-high as a second phrase.
    - Move the actions described here (sequence B):
        - Now start from right-forward-middle and go to left-side-high, ending in forward-low, moving this as one phrase.
        - Continue moving the right arm from forward-low to right-back-middle, ending left-side-low.
    - Note the common points of spatial direction (left-side-high, forward-low, and right-back-middle are reused) between the two sequences.
    - How many movements are in each sequence? Does each bullet point feel like one movement or two?

- How do these distinct choices in spatial phrasing change your temporal performance of the scale? Do you perform sequence A more slowly than sequence B? If not, try this out. How does this support a sense of gradual change in sequence A and a sense of abrupt change in sequence B?

These two sequences play with volute (sequence A) and steeple phrasing (sequence B). Typically, the two phrases in sequence A feel like one movement each, while the two phrases in sequence B feel like two movements each. See appendix B for more about these types of spatial phrasing.

6.4 Application to Machines: Perceived versus Actual Safety

Choreographing the motion of aerial vehicles

When programming the temporal patterns of robots, quantities like “time to collision” calculate how soon under given applied forces a known mass will collide with another (e.g., an aerial robot and an obstacle in its environment). In a traditional factory, where humans are typically separated from robots by safety measures like cages and other physical boundaries, such a calculation is enough to facilitate successful operations. Psychologists have studied a similar quantity in human perception, aiming to estimate how people judge such a “time to collision,” but in humans, such a benchmark carries both functional and expressive dimensions. Roboticists we’ve worked with have reasoned that robots are socially acceptable if they do not move too fast (because fast robots are scary).

But this is an example of the pitfalls of working with an incomplete framework for understanding expression. It is as easy to imagine a counterexample: for a really, really slow-moving aerial robot, it will be difficult to predict where it is going next, which becomes annoying—and eventually even creepy and unnerving. This is happening with autonomous factory robots that share spaces with human workers. Factory workers duck around these mysterious, monolithic devices that do not clearly advertise their internal state or broadcast their next movement with changes (including speeding up) to their temporal motion profile. Endlessly even phrasing patterns cause human attention to stray. This can create a dangerous situation—even if every quantifiable equation (e.g., the movement of the robot) says the opposite.

Consider the role of duration in the example referred to at the chapter's opening: a pedestrian steps into a crosswalk with cars still moving toward the intersection. Even if the drivers of the oncoming cars are in control of their vehicles at all times, the way that the drivers approach the intersection will inform the pedestrian's feeling of safety—situated in her own unique body and abilities—which will in turn inform her own behavior in the crosswalk. An oncoming car screeching to a halt feels like it is coming faster and will also arrive sooner, perhaps causing pedestrians to dodge or dash away, creating other safety concerns. Drivers use the motion of their cars to advertise to pedestrians that they will stop by using deceleration that is unnecessary from a functional point of view. Thus, the Time component is essential to finding somatic strategies for designing both aerial and terrestrial autonomous vehicles that share a space with humans.

Robots can advertise their internal state through both their physical motion (which is limited by the physical capabilities, or dynamics, of the platform) and dynamically unconstrained degrees of freedom, such as lights (e.g., light-emitting diodes mounted to the robot body that can flash on and off faster than physical linkages can move and even faster than humans can perceive). Figure 6.2 shows an example of both of these from a project to create assistive mobile devices for older Americans who are aging in place. The general idea for this work was to develop a system that relies on tunable parameters corresponding to the dimensions of effort (for

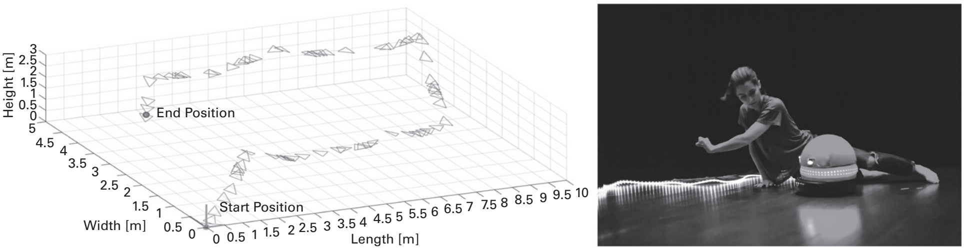


Figure 6.2

Using external changes to broadcast internal state. Left: modulating the movement of an unmanned aerial vehicle to create different textures, tones, and moods changes the duration and emphasis to the robot's motion (Cui et al., 2019). Right: adding lighted elements to a mobile robot creates different expressive modes, which can change the sense of time quality of the device's movement, as perceived by a human audience member (Pakrasi et al., 2018). Image by Keira Heu-Jwyn Chang, used with permission.

more about the Effort component, see chapter 8) and to produce motions of varying execution, which should cue human onlookers to the fact that the state of the system has changed. The system was to have specified waypoints that were required for correct function (the "task"); but the motion between the points also had to reflect the context and internal state of the system. For example, movement patterns for a leisurely Sunday morning when the system is checking whether the paper has been delivered should be different from those used in an emergency, when the system is fetching important medicine that the user needs.

The result of our simulated artificial movement was a body that varied its velocity and trajectory, creating ten distinct patterns of aerial vehicle flight (Cui et al., 2019). The variations in the machine's motion created a sense of lift, or buoyancy, at times, and at other times, they created stark, sudden dips that gave a sense of jagged sharpness. Inside the white, gridded "simulation environment," these changes happened for no apparent reason, making it difficult to judge a sense of agency or purpose in the various flight patterns. However, across broad notions of expediency, efficiency, and overall success (reaching the end point without a crash), the profiles can be judged: a profile with a direct path of short duration can be seen as more expedient and efficient than one that meanders or weaves back and forth before reaching a final location in the simulated space.

While the work initially used the idea of changes in movement quality, it seems in retrospect that a better approach would have been to consider the phrasing of the flight trajectory of the aerial robot. Notions of temporal pattern changes in the flight path, organized as phrases of movement with various patterns of emphasis, loading, and accent, may well have been a more effective way to broadcast internal states to a human observer. As it was, each flight path seemed like one long, stumbling flow of words, lacking any punctuation. A simpler temporal structure, defined by clear differences in action in the beginning, middle, and end of each behavior, may have created a more readable distinction between each profile. Rather than aligning our tunable parameters with ideas of dynamic qualities, we could have aligned them with the simpler ideas of temporal qualities. The temporal changes could have then been used to support positive human-robot interaction (HRI) for in-home devices. For example, a slow, even flight path where the whole path showed no temporal fluctuation could well support the internal state of "monitoring" or "scanning" for security. Likewise, a flight path in which the initial speed was fast over a short duration (impulsive) might well have broadcast an internal state of "urgency," of being responsive to an urgent situation.

Embodied Exercises

- **How long is 1 minute? (Revisited with machines):** This exercise will explore how machines change our sense of time. Repeat the first exercise from section 6.2 with a blender (or food processor).
    - Get a stopwatch (or stopwatch app) handy.
    - With the machine on its highest/fastest setting:
        - Start the timer, paying attention to the machine's motion.
        - Endeavor to wait exactly 1 minute.
        - When you think 1 minute has passed. Did you overshoot or undershoot?
    - With the machine on its lowest/slowest setting:
        - Start the timer, paying attention to the machine's motion.
        - Endeavor to wait exactly 1 minute.
        - When you think 1 minute has passed. Did you overshoot or undershoot?
    - Qualitatively, did the two experiences feel different? Quantitatively, did you let the stopwatch progress for different amounts of time? Using the vocabulary introduced here, compare and contrast how the machine settings contributed to your perception of time.

6.5 Exploring the Themes: Time through the Lens of Exertion/Recuperation

Taking cycles of rest as an integral part of productivity

The theme of Exertion/Recuperation is another lens through which we see patterns of phrasing unfold over time.[8] We work and are awake during the day; we rest and sleep at night. What is exertive for one person (and how he recuperates) may be different for another person, and different in different contexts. Take, for example, an office worker who sits at a computer most of the day. For that individual, a nice jog after work can be a recuperative activity. For an Olympic track athlete, however, running is her "work" and involves great exertion, so a nice jog might not be recuperative for her at all! For this athlete, sitting at a desk and doing computer work in the evening might well be recuperative.

In this sense, it becomes difficult to classify one type of movement activity as *either* exertive or recuperative as a static quality because the classification depends on context. Thus, as context changes, what is exertive becomes recuperative, bringing back the image of the lemniscate, where one surface (or idea) becomes indistinguishable from the other. Regardless of the activity, there is a rhythmic pattern in the actions of exertion and recuperation. Overwork and a lack of adequate sleep and recuperative activity—typically, too long a duration of work with too short a duration of rest—lead to a lack of productivity; likewise, too much lethargy, boredom, and inactivity lead to a lack of relaxation. The balance of both over time is important to preventing injury, fatigue, boredom, stress, and burnout.

Indicators to counterparts about our energy levels help humans understand each other and work in better harmony. This idea has been adopted for machines, too. For example, Apple has employed an indicator light that has different states to mimic the “on,” “off,” “sleep,” and “charging” states of their computers. A gently pulsing light (probably meant to imitate breathing) indicates that the computer is neither on nor off—recharging, but ready.

In the BESST System, there is a pursuit of balance that is reflected not only in the themes, but also in the entire system itself.[9] The theme of Exertion/Recuperation also speaks to the idea of balance, and as it is so clearly seen in the passage of time, it can be understood as a dualistic relationship that is especially relevant to the Time component. With that said, we could view it through the lens of any of the system’s other components.

Embodied Exercises

- **Manufacturing feelings of recuperation:** Commonly, we see actions like lifting weights as “exertive,” but in some contexts, such an act feels “recuperative.” In this exercise, you will explore the Exertion/Recuperation theme through repetition.
    - Pick an action that feels recuperative—maybe stretching your arms overhead or yawning.
    - Set a timer for 3 minutes and repeat that action until the timer ends.
    - Note when the action becomes taxing or exertive after you have repeated it so many times.

  - Observe the moment of recuperation that occurs when you get to *stop* doing that action that had felt so recuperative at first.
- **How long is 1 minute? (Revisited again):** Try some variations on this exercise from sections 6.2 and 6.4 (using a stopwatch to see if you can identify 1 minute of time) to explore how exertion (and recuperation) affect your perception of time.
  - Try the exercise looking at different stimuli (e.g., a video of rush hour traffic versus a video of Olympic sprinters).
  - Try the exercise at different times during your day (e.g., when you are rushing to complete another task or when you are waiting for water to boil). Often after rushing around in a hurry, you will be more likely to undershoot, whereas on a leisurely weekend afternoon, you may be more likely to overshoot.

Chapter Summary

This chapter has introduced vocabulary for better noticing patterns in and perceptions of movement over time. In addition, it has described the impact of order and relative magnitude of actions. We have discussed how changing the sequence creates contrast and emphasis, which modifies and helps create a sense of style, intention, narrative, and meaning. Ideas about dynamic change in time—namely duration, tempo, and rhythm—were presented as additional (but distinct) modifiers that further support one's ability to make and perceive patterns of movement in time. Like sequencing and contrast, these three ideas are interrelated: we need a notion of duration to set up a notion of tempo to set up a notion of rhythm. Likewise, duration and tempo may be revealed through the structure, design, and use of a particular rhythm.

The most important way we think about time in movement studies is in finding "movements" themselves. The idea that movement can be associated with discrete chunks of time relies on a notion of phrasing, which, as we have shown, relates to all the other components of the BESST System: Body, Space, Shape, and Effort, but lives primarily in the temporal dimension discussed here. Chapter 8 will further explicate how affinities between components of the system reveal patterns in our perception and experience of movement. Finally, we have provided examples of machine design, as well as the theme of Exertion/Recuperation, to further investigate the Time component.

7 For Whom Is the Movement? The Relationship between Mover and Environment (Shape)

In the previous three chapters, we have illuminated foundational aspects of movement (body, space, and time). The Shape component is, in our inverted triangle model of the BESST System, a higher-order idea of movement building on the prior three components (Body, Space, and Time). It is the connection between body and space that reveals the body's changing form (shape) in relationship to the environment. Thus, the Shape component necessarily speaks to "interaction and relationship" of some kind, and we say that it answers the question "For whom?" about movement.

In adult human movers, we typically see all the components of BESST simultaneously. In analysis, we learn to foreground or background different elements of the system to hone in on whatever the most salient or important feature is in a given context with a given analytical aim. For example, if using the BESST System to work with a client who is experiencing lower back pain, we may focus on the area of Body, foregrounding principles such as weight shift, dynamic alignment, and axis of length. But, if working to help a ballet dancer better express a particular role, we may move to an area like Shape to help them analyze how they are approaching their relationship to other dancers in the piece. However, we could also use Shape when working through therapy with the client in pain, asking her to repattern the way that she connects her lower body to a chair while sitting and typing at a keyboard. By the same token, we could use Body to support the dancer's execution of a complex lift with a partner. All the components of the BESST System help to create successful outcomes of movement intention and expression.

The interchangeability of the components of the BESST System can confound the process of seeing and understanding each element on its own.

Moreover, it may contribute to why the analysis of developing movers—that is, babies, toddlers, and young children—is so useful in the work. By looking at babies, we can see human movers who do not yet have cross-lateral patterning in their body organization (Body); who are not aware of their entire kinespheres (Space); who do not create intentional phrases in their movement (Time); and who do not shape their bodies to accommodate complex, three-dimensional interactions (Shape). Through their simplicity, babies provide a clarifying picture of complex patterns that form adult movement.

What about robots? Do artificial bodies always manifest all elements of this system? Like babies, robots are bodies that move in time and space, but they do not contain the same level of natural richness, complexity, and even meaning as adult movers. And, like babies, we find that there is sometimes less to see. This becomes increasingly apparent in this chapter, on Shape, and chapter 8, on Effort, where we endeavor to understand *relationship* and *motivation*, respectively. Moreover, the perception of these ideas is more subjective, more dependent on the experience of the viewer. In training movement analysts, a huge emphasis is placed on learning one's own bias and preferences—in part to recognize, acknowledge, and try to challenge our bias and in part to understand more deeply that our own experience, mood, and prior training changes how we observe the world.

Studying motor development has helped shape the BESST System: seeing simpler patterns in growing children helped name and codify the descriptions and principles that make up the system now. In our own work, we likewise find that robots afford a similar opportunity—one that has helped us refine and reframe some aspects of the work. In developing technology with these ideas, we have reached a clearer understanding of what the elements of movement studies are, can, and should be. This will become apparent in this chapter, for example, where we suggest new ways of discussing "shape quality" based on observations of successful robots that are teaching us new things about expression through movement.

7.1 Foundational Arrangements of the Body in Space

Beginning to explore the shape of the body

Shape is concerned with perceiving and experiencing the body as it changes form and arranges itself in space. As such, Shape is an outgrowth of the relationship between the Body and Space components, defining the bridge between the mover and its environment. Changing form can be experienced and perceived in a *self-to-self relationship* (in both the content and container of the body) and in a *self-to-other relationship* (objects and agents in the environment, as well as the environment itself). Shape can be experienced and perceived in static patterns, or so-called **still shape forms,** as well as in dynamic patterns, or so-called **primary patterns of shape change.**

The BESST System identifies five primary still shape forms: *pin, ball, wall, tetrahedron,* and *screw*. These forms are described in box 7.1 and symbols for each are provided in figure 7.1. Although the living body is never "still," we perceive forms in it; likewise, when a machine sits in the "off" state, the form of the body already takes on meaning. Either through one of the canonical forms listed in box 7.1 or some other shape, the still shape may imply a sense of mobility or stability, jagged or smooth edges, ample or lean dimensions, and so on. For example, the wall and tetrahedron are often associated with stability, while ball and screw are often associated with action or mobility.[1] People often exhibit still shape forms that are particular to their personal expression or movement signature, creating an association with one of these familiar forms, which affects our perception of that person and how they carry themselves.

There are two kinds of primary patterns of shape change in the Shape component of the BESST System: the body can have a *convex/concave* relationship and a *gathering/scattering*[2] relationship (see figure 7.2). The dynamic pattern

Box 7.1
Still Shape Forms

- **Pin:** An elongated and narrow shape (e.g., a tall, thin villain like Jafar in Disney's *Aladdin*)
- **Ball:** A rounded, spherical or circular shape (e.g., the typical rendering of Santa Claus)
- **Wall:** A flat, wide shape (e.g., a drill sergeant standing tall and broad)
- **Tetrahedron:** A triangular or pyramidal shape that has a wide base of support (often four points of contact) narrowing to a point (e.g., a person in a seated meditation)
- **Screw:** A twisted form, serpentine in nature (e.g., a Greek sculpture of an athlete preparing to throw a discus)

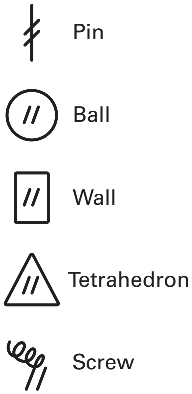


Figure 7.1
Symbols for still shape forms. Each symbol uses the Shape component symbol (a double slash) overlayed with an abstract representation of the form.

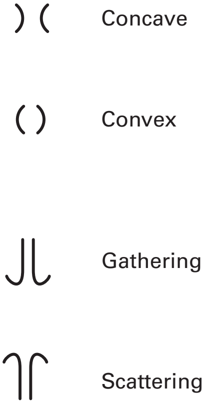


Figure 7.2
Symbols for primary shape patterns.

of concave/convex is seen in the motion of the body—especially focused on the core—opening or closing itself to the environment. Gathering/scattering identifies the relationship of the mover—especially focused on the limbs—acting toward or away from the environment (or elements within it). Our sense of self as distinct from the environment—although the mover is an entity in its own environment—supports the expression of these dynamic patterns of shape change.

These relationships are framed as pairs because if one is present, so is the other. When a concave shape is found (e.g., on the posterior surface in the lumbar curve of the spine), a convex shape accompanies it (e.g., on the anterior surface where the lower vertebrae cut into the internal viscera of the abdomen). Likewise, when gathering, with the inner surface of the palms curling in toward the mover, the body is also scattering on the back of the hands, which are opening away from the environment. Both of these foundational patterns of shape can be further differentiated into specific shape expressions and types of form change, which will be discussed in sections 7.2 and 7.3.

Examples of the convex/concave primary pattern of shape change include stretching in the morning to offer the front surface to the light (where convex is foregrounded) and bending over to reach your shoelaces (where concave is foregrounded). Examples of gathering/scattering include collecting a pile of laundry into one's arms (where gathering is foregrounded) and spreading grass seed (where scattering is foregrounded). Both types of change reveal dynamic, active relating to the environment for different expressive and functional tasks.

Embodied Exercises

- **Still shape forms:** In this exercise, you will explore still shape forms through common images.
    - Return to the images used in box 7.1 and listed here to "try them on" by imitating the still shape form they suggest. Notice your experience with, associations with, and relationship to the environment in each one. Does any one of them feel more familiar or comfortable?
        - *Pin*: A tall, thin villain like Jafar
        - *Ball*: A rotund, jolly Santa Claus
        - *Wall*: A drill sergeant standing at attention with legs spread and hands on hips, elbows to the side
        - *Tetrahedron*: A person in seated meditation, ankles crossed with knees bent and wrists resting on the knees
        - *Screw*: A Greek sculpture of an athlete preparing to throw a discus
    - Can you find examples of each of the still shape forms that create different associations than the ones here—while still revealing the form

itself? Do the associations you experience in the following change your sense of familiarity or comfort with the shape form?

    - *Pin*: Alberto Giacometti's famous sculptures of "elongated people"
    - *Ball*: Orson Welles portraying the bad cop Hank Quinlan in the movie *Touch of Evil*
    - *Wall*: Cheerleader holding pompoms with hands on hips and legs spread wide
    - *Tetrahedron*: A Graham technique trained dancer in the seated "fourth" position on the floor
    - *Screw*: A runway model walking away from the camera, twisting her upper body back toward the camera's viewpoint, as she throws a wink over her shoulder

- **Relationships to the environment:** Self-self, self-other (self-one, self-many)
  - As you are reading this, notice what small movements you are making—like tapping your foot, biting your lip, twisting your hair. What adjustments are you making to remain comfortable? When do you find you need to make a change, and why?
    - This series of prompts should help you identify a self-to-self relationship, where you are creating changes in the shape of your body and its relationship to itself.
  - Now, having noticed that, pay attention to the relationship of your body with the object you are in a relationship with (a chair, for example). Make a conscious change in your form in relationship with that object. What helps you to bridge your form and self to that object?
    - This should help you identify a self-to-other relationship, where you are creating changes in the shape of your body and its relationship to a particular object in the environment.
  - If you were to convey your experience to a room full of people, how would that change your form and support your connection to that large group?
    - This should help you identify a self-to-other relationship, where you are creating changes in the shape of your body and its relationship to multiple objects (other humans, in this case) in the environment.

- **Primary Shape Patterns:** This exercise will help you explore two modes of primary shape patterns.
    - *Concave/convex:* From a neutral standing position, drop your chin to your chest and then allow your head to move down toward your feet. Pay attention to the front surface of your body. How is the form changing as you take this action? What about the back surface? Notice that the front of your body is becoming move concave, but the back surface of your body is becoming move convex. Now reverse the process. Allow your tail to drop toward your heels and roll back up to standing. Notice the back surface becoming more concave and the front surface becoming more convex. How do these interrelated changes in your form change your relationship to the environment?
    - *Gathering/scattering:* From wherever you are reading this right now, decide that you are cold and tired. Gather a blanket and pillow from your environment, bring them toward you, and arrange the objects so the blanket is wrapped around you and you can rest your head on the pillow. Notice the changes in your form as you gathered those objects toward you to use for warmth and comfort. Now decide that you are hot and awake; scatter those same objects away from you back into the environment. Notice the change in your form as you put those objects away from you.

7.2 Modes of Shape Change

Introducing ways of connecting to the environment

In establishing our palette for Shape, **modes of shape change** illuminate specific and distinct ways that the body's form changes in relationship to the self and the environment. Each mode reveals a progression in differentiation of awareness toward the body/space relationship. First, **shape flow** is a self-referential pattern of shape change and is often seen in self-soothing, unconscious changes in form, and shifting and reorganizing the body; the relationship is between self and self. Movements of shape flow often occur in moments of preparation and recuperation. By contrast, **directional shape change** is a moment of connecting to—or bridging to—the environment. Finally, **shaping** is about accommodation, adaptation, and a more complex interaction with the environment. These terms are outlined in more detail in box 7.2 and figure 7.3.

Box 7.2

Modes of Shape Change

- **Shape flow:** The mover's form changing relative to the self. Often described as "me to me," it can be seen as "checking in with the self" and "readjusting for comfort." Examples include hair twisting while reading, stretching and rubbing out body parts to recuperate, a breathing check-in with the self prior to executing an event. The locus of control is "me," where "me" is often undifferentiated from the environment. This mode is supported by and closely related to the foundational body ideas of flow-sensing and weight-sensing.[3]
    - Shape flow is connected to change of the body, especially as related to the breath, through the following terms:
        - *Growing/shrinking*: Undifferentiated shape change affined with inhaling and exhaling, respectively.
- **Directional shape change:** These are characterized as bridging forms that occur in an arc-like path or a spoke-like path. This is described as "me to you" or "me to the environment." While the locus of control is still "me," there is a differentiation of what is "me" and what is "not me" (the environment). Thus, this mode is referred to as recognizing "you." These kinds of shape changes are often communicative and clarifying in producing outcomes (imagine giving someone directions, ringing a doorbell, or swiping a cell phone). This mode is supported by the body actions of flexion/extension and adduction/abduction.[4]
    - *Arc-like*: This mode of bridging to the environment often describes an arc and an edge or boundary. Using the image of a bicycle wheel, this mode of bridging would be moving along the rim of the wheel with a body part, especially one at the distal end of the body. Often, this may be seen in examples like directing traffic or swiping on the surface of a touchscreen.
    - *Spoke-like*: This mode of bridging to the environment often describes a more linear shape, coming straight from the mover to the environment. Using the image of a bicycle wheel, this mode of bridging would be moving a body part along the spokes of the wheel, connecting from the center to the rim. Often, this may be seen in examples like ringing a doorbell or tapping on a touchscreen.[5]
- **Shaping:** This mode describes changes in the form that accommodate and/or adapt and, as such, is often referred to as being about "us." There is a sense of engagement and cooperation with an "other." Examples of shaping

(*continued*)

Box 7.2 (continued)

include engaging with tools and objects (molding a piece of clay into a pot, twisting the lid off a jar) or with others (embracing a friend and changing your shape to accommodate his shape and form). This mode is often supported by the basic body action of rotation and can occur in the limbs and/or core.[6]

- Shaping is connected to the deformation of the body's innersphere, called **inner shaping,** employed most centrally during breathing and differentiated in each of the three ordinal dimensions as follows:
    - *Lengthening/shortening*: Torso shape change in the vertical dimension
    - *Bulging/hollowing*: Torso shape change in the sagittal dimension
    - *Widening/narrowing*: Torso shape change in the horizontal dimension

The modes are seen to increase in complexity and animacy and have even been likened to patterns of progression in human motor development. For example, the act of shaping requires a more developed motor skill—as well as mental capacity—than that of shape flow. Like all aspects of movement we have described so far, the modes of shape change are perceived and experienced in context, and the meaning will change based upon where, what, and when we perceive their expression (or function). Possessing a way to describe different kinds of relationships with the environment gives us more resolution in identifying evidence to support a particular conclusion about the meaning of a particular movement phrase.

Figure 7.3
Symbols for modes of shape change. Each symbol leverages the Shape component symbol (a double slash), and the symbol for directional mode of shape change is a superposition of the symbols for spoke-like and arc-like. Shape flow also relates to the flow axis on the Effort graph (discussed in section 8.2 in chapter 8).

Embodied Exercises

- **In the kitchen:** Explore each of the modes of shape change in the context of a kitchen as given in this exercise. Each provided example suggests an action that may be best suited (according to our experience) to help you find these patterns in your body, but you may successfully find each pattern in each example—these are rich, complex tasks!
    - Shape flow
        - Attend to yourself as you prepare to cook: adjust your apron, settle your glasses, and so on.
    - Directional
        - *Arc-like*
            - Stir a pot of soup.
            - Feed yourself.
        - *Spoke-like*
            - Spear a piece of food with a fork.
            - Take a hot tray out of the oven.
    - Shaping
        - Take a pot and wipe it out.
        - Open the lid of a jar.
- **In conversation:** Explore each of the modes of shape change in an imaginary conversation (this can also be done with a partner).
    - Sit in front of a mirror and have a conversation with yourself using only “Yes,” “No,” and “Maybe.”
    - Try each mode (shape flow, directional, and shaping) with each word in turn. For example, see how shape flow makes your “Yes” response difficult to hear or believe; see how a spoke-like directional mode of shape change makes an especially forceful “No”; see how shaping makes “Maybe” feel especially persuasive.

7.3 Shape Qualities

Complex relationship of complex bodies to complex environments

Section 7.2, on modes of shape change, describes distinctions in how a mover relates, or bridges, to the environment. This section explores a deeper idea of relating innersphere to kinesphere (or "inner space" to "outer space"), expressing intent, and sharing (or expressing) oneself with the world. We understand **shape qualities** as the most salient patterns in the relationship of body to space, relating complex changes in the container of the body to the environment and revealing a heightened relationship between movers and their environments. Analogously, the next chapter, which will introduce "effort qualities," addresses the relationship of the body to time.

Shape qualities are highly differentiated patterns of shape that leverage our three-dimensional bodily form. The BESST System identifies shape qualities as being related to three-dimensional space, but rather than being about space in simple terms (e.g., "up" can be revealed by myriad different body parts in motion), shape qualities utilize a full activation of the body to reveal a changing form in the environment. The experience and perception of shape qualities recognize our inner space and inner shape mobilizing in an externally observable shape pattern. Shape quality is a heightened moment of salience between a mover's body and its environment, which in humans is especially noticeable in the movement of our spine, muscular core, and breath, but it also can be seen to some degree in distal and proximal interactions, especially in less expressive platforms (like the robots discussed in section 7.4).

The list of shape qualities (outlined in box 7.3 and figure 7.4) are **rising, sinking, spreading, enclosing, advancing,** and **retreating.** Each of these involves complex, three-dimensional bodily motion (in humans, this is most saliently viewed in changes in arrangement of the core) that aligns with a dimensional idea in space.

To consider shape qualities in context, imagine a ballerina performing Juliet seeing the dancer playing Romeo onstage. She walks toward him, but she also extends her spine upward and forward, letting her breath expand into the space. She is rising, advancing, and even spreading, inhabiting the most indulgent state of shape quality in order to express, in this context, her joy at seeing her soulmate. In contrast, upon seeing Lord Capulet, the story's villain, Juliet may also walk toward him, but she would do so with recoil, condensing her core away from this character, exhibiting the shape

Box 7.3
Shape Qualities

- **Rising/sinking:** Up/down in the vertical dimension[7]
- **Spreading/enclosing:** Expanding/contracting in the horizontal dimension, e.g., expanding (or contracting) away from (or toward and across) the midline with one or both sides is spreading (or enclosing)
- **Advancing/retreating:** Forward/backward in the sagittal dimension

quality of retreating and sinking in order to reveal, in this context, frustration, dislike, and even hatred for this character.

Dancers practice manufacturing such expression; it may well be that these dancers do not get along at all in rehearsal, but onstage, they use their facile bodies to create salient movements that tell a story. They engage their inner complexities as fully as they know how in order to bring authenticity, artistry, and allure to onstage moments. In real life, this may not happen with the same salience—or it may happen in ways that feel less manufactured and more authentic because real emotions are involved. Shape qualities help reveal the continuum between inner and outer space in human movers. We often forget that our organs and their fleshy, muscular containers, supported by our facile spines, experience movement too, and shape quality is this idea that connects the shape and shape change of our core to externally visible expression.

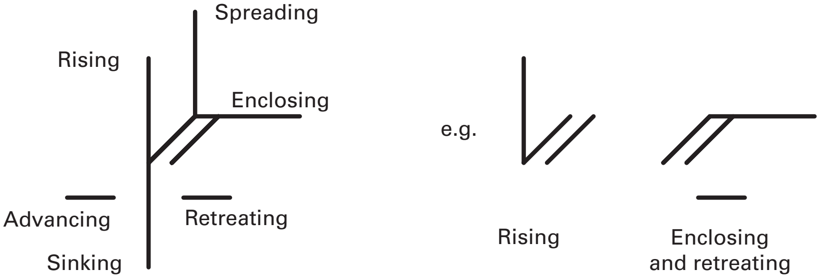


Figure 7.4
Creating symbols for shape qualities. Drawing subsets of the graph shown at left produces symbols for individual qualities and combinations of qualities (e.g., "rising" and "enclosing and retreating," shown at right). See appendix A for a complete list of combinations.

Embodied Exercises

- **Innersphere, breath, and shape quality:** In this exercise, you will find core support for shape qualities through breath.
  - As you inhale, feel levity through your abdomen, and as you exhale, feel grounding through the abdomen. This aligns rising with inhaling and sinking with exhaling. Try the reverse to see which feels more natural for you. Take note: the diaphragm moves up when you exhale, relieving your viscera of some pressure, and down when you inhale, compressing your viscera to make room for air in the abdomen.
  - Try associating your inhale with spreading and your exhale with enclosing (and vice versa).
  - Try associating your inhale with advancing and your exhale with retreating (and vice versa).
- **Hug a teddy bear:** In this exercise, you will interact with a favorite stuffed animal to experience how changing your form changes the experience of the interaction.
  - Hug a favorite stuffed animal with each shape quality listed here, and try creating the symbol from the graph in figure 7.4.
    - Rising and advancing
    - Retreating
    - Spreading, retreating, and sinking
    - Advancing and enclosing

Notice how your sense of relationship with the stuffed animal changes as you employ different shape qualities. What works best and feels most satisfying in engaging with the stuffed animal?

7.4 Application to Machines: Expressivity in Natural and Artificial Systems

Counting postures as an approximate measurement for expressivity

As discussed in chapter 1, the ways that machines outperform humans are well characterized. Robots exhibit greater precision and repeatability in their motion than human bodies do in theirs, and they also can exhibit a greater range of forces, torques, velocities, and displacements. But machines—especially automatic or autonomous machines—that match the variety of motion that humans exhibit have not yet been developed. Moreover, they lack many of the moving parts that humans use in our movement profiles; this alone could restrict their ability to communicate through movement.

We have up to this point told promising stories about how movement studies can help create more expressive machines. As we progress into elements of the BESST System that deal with higher-order, more full-fledged expression of complex ideas, it is worth stopping to ask: "Can machines exhibit the same ideas as humans in artificially generated movement profiles?"

For example, take the concept of shape quality introduced in this chapter. In humans, a concept like rising shape quality is typically seen most prominently when there is an articulation of our spines that creates a deep exchange between an idea in our innersphere and our kinesphere, a sharing from a rich inner to a rich outer space of movement. Can robots, which rarely have *any* articulation in their cores and often have relatively simple internal models of the world, accomplish such an act?

To try to answer this, consider the Boston Dynamics BigDog robotic platform. This hulking, quadruped robot has a physical form that does not even quite accomplish the list of features discussed in boxes 4.1 and 4.2 in chapter 4 (e.g., a shape that clearly establishes front/back, right/left, and top/bottom), as it lacks differentiation front-to-back. However, when the object is in motion, it establishes this sense of heading through a pronounced and clear line of locomotion. The device was designed to carry heavy loads for soldiers through varied terrain, and even a decade after its introduction, it remains—along with its suite of follow-up devices, including WildCat and Spot—one of the most successful robots at navigating distinct terrains and environments.

The robot has four legs, each with four active degrees and one passive degree of freedom where the leg can mobilize. The first point of mobility is where the leg connects to the platform, forming a proximal joint. Roughly a third of the way down the leg is another place where mobility can occur, forming a mid-limb joint, and finally two-thirds of the way down is another, more distal point of mid-limb mobility. Each distal end utilizes a round form factor that accommodates many points of contact in diverse terrains.

The four legs work in coordination, utilizing both homolateral (body half) and contralateral (cross-lateral) patterning to mobilize the robot in many directions, but there is no way to actually discern which is the front or the back, as the implement for carrying the load is simply a big, rectangular holding platform. However, some sense of directionality (which is more complex than simply identifying the object's front from its back) is evident through the device's motion as it moves toward, away from, around, and in other ways relative to objects in the environment. That is, we perceive spatial intent when the robot begins to mobilize because of our human experience of spatial intent in our own mobilization. The robot seems to be going somewhere (regardless of whether it is or not) and executing complex locomotor pathways through space as it navigates terrain—similar to what human bodies do, albeit through drastically different means and methods. This sense is heightened by the relatively short duration of the robot's steps alongside human counterparts that seem to step slowly; the robot's pacing is short and choppy next to its bipedal counterparts.

These initial observations concern the Body, Space, and Time components. All these observations are rooted in and related to the human form; seeing the body parts of the machine move through space and time suggests initial ideas about locomotion, direction, and pacing. As we view the robot in a wider variety of circumstances, however, we may see more complex movement ideas emerge.

In one of the most viewed videos[8] of this robot, we see it traverse a wooded hill, navigating chaotic layers of leaves, branches, and trees. This feat alone is a triumph in autonomous navigation, as it is much harder to navigate in this kind of chaotic environment than in the relatively well maintained and homogeneous roadways where cars navigate. But then we see the robot crossing a paved asphalt parking lot partially covered in ice, where a tall male wearing thick, heavy boots kicks the device with great force, causing it to stumble on the slippery ice. Amazingly, the robot maintains its stability, managing not to fall through a series of manic yet intentional swipes of its lower extremities, which twist viciously at their proximal connections to the static center of the device (where the payload would be carried).

For us, emphasizing the heightened environmental factors, we do see a sense of spreading shape quality as the "legs" rip outward to recenter and reorient the device safely upright. Perhaps it is not the same kind of supple, luscious spreading exhibited by the ballerina described in the previous section, but it is a moment of true environmental accommodation, which belies a sense of expression—*if only because we ourselves have been pushed and we ourselves have slipped on ice*; and, as a result, we contain the bodily memory of those experiences, which required complex changes in our own core.

Thus, we can say that in certain settings where the movement of a robot is tightly coupled to its environment, we can see that shape qualities—as well as other ideas about movement—are not limited to the way that humans express them. When we see an object in a situation familiar to us navigate that situation successfully—possibly using different physical means than us—we see, experience, and perceive the same movement idea. Thus, robots may exhibit some sense of shape quality through only their extremities (with their, to date, relatively fixed, relatively inflexible cores), even though humans almost always do so with the help of our mobile, flexible cores.

In fact, because movement studies are so centered around human bodily expression, it is typically taught that shape qualities always manifest as changes in the core. However, in our work with robots, we have found that sometimes we see brief, subtle ideas described in the Shape component in particularly successful or heightened navigation of the environment by a mechanical device (which rarely has a deformable core). Thus, this observation about BigDog is an example of how working with robots has changed our *own* understanding of movement. Moreover, it shows how easily we project our own experience of movement onto other animated objects in our environment (whether they are living, human, or neither).

We can look to the physical complexity of a given body as a way to understand its potential for expression. Prior work informed by movement studies has found trends in this dimension both from an analytic perspective (LaViers, 2019a) and from a perceptual perspective (Cuan et al., 2019a). Figure 7.5 shows how the ideas of shape presented in this chapter can help quantify robot capacity for artificial embodiment. Namely, when viewed as information sources (discussed further in section 9.4 in chapter 9), the multiplicity of possible action is ultimately the driver of capacity for choreography. One way to quantify this possibility is by measuring the number of distinct shapes that a body can form. Such a measure may be key to determining the capacity for a particular platform's artificial embodiment.

Embodied Exercises

- **Exploring animated, onstage characters:** In this exercise, you will consider the expressivity of animated characters. Although these characters are less complex than real animals, they are not constrained by the

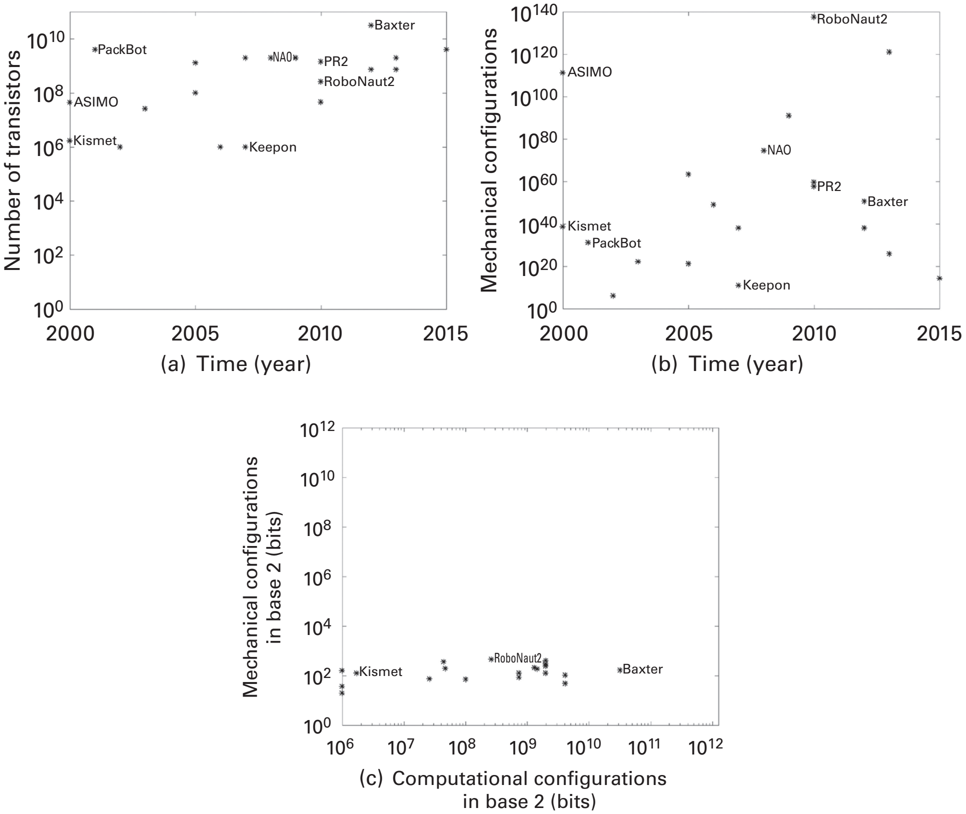


Figure 7.5

Measuring internal versus external capacity for choreography. Internal capacity (a): number of internal transistors on the central processing unit of robots versus their release date; in other words, the number of "shapes" on the inside of these machines. External capacity (b): number of shapes (instantaneous postural configurations) that each robot can make with external sensing and actuation capabilities; in other words, the number of shapes these machines can express in the environment. Comparing internal versus external capacities (c): internal capacity (number of transistors) versus external capacity (in bits) on a log-log plot, showing stagnation in external configurations (or shapes) over the fifteen-year period. This suggests an explosion of internal capacity (as predicted by Moore's Law) versus almost no change in external capacity. From LaViers (2019a, pp. 9–11).

dynamics of hardware, as robots (and humans) are. Moreover, talented artists create their motion profiles *in context* (using environment and narrative to construct situations for characters) for the express purpose of telling a beautiful, expressive story.

- Watch a movie (or clips from a movie) like the animated film *Toy Story*.
- Observe which of the animated bodies feels most convincing to you. Why?
- Are there elements of the convincing characters in which their form changes in a way that seems “successful” in relationship to the environment? Can you identify aspects of Shape that support that observation?
- What is something that this body *cannot* express? What is something that your *own* body cannot express?

7.5 Exploring the Themes: Shape through the Lens of Self/Other

Understanding the relationship between mover and environment

The Shape component can be seen as working to articulate the bridge between bodies and their movement in space, and, thus, it is useful when illuminating the theme of Self/Other. This duality is a lens through which it is possible to recognize the body as *self* and everything that is not the body (one’s own body, that is) as *other*. This “other” could be the environment, objects in the environment, and other moving bodies in the environment. We can bridge, accommodate, negotiate, and change our form to support our interactions and communication with all that “is not us” (other). So from this perspective, Shape can be understood as the continual negotiation of form (self) with the ongoing stimuli of the environment (other) and as revealing a very personal relationship with the world, clarifying the difference between *what is me* and *what is not me*.

As in the other themes we have introduced so far, there is in Self/Other an ever-changing sense of foreground/background. One of the embodied exercises of section 7.3 invited you to interact with an object of high personal value: a favorite stuffed animal. In this exercise, you may have explored how your body moves in response to an element in your environment with which you have a strong relationship. Unlike, say, a piece of garbage, your movement around this item may belie its importance to you: perhaps you cradle it with a complex, swirling sense of shaping, or if you see it hanging on the wall, your spine becomes alert, rising and advancing toward it. Any reaction is valid to your personal and bodily patterns. Using the Self/Other theme, identifying what is us, what is ours, and what is not, we can understand our personal point of view (and how our body may reveal aspects of it through motion) more clearly.

Embodied Exercises

- **Viewing art (relating self to other):** We often think about artists as expressing hidden, specific messages that viewers must decode. But, in fact, some of the most interesting art produces a myriad of varied responses, offering human viewers a chance to discuss, compare, and contrast their reactions. Take Leonardo da Vinci's famous *Mona Lisa*. While learning about its history and the artist's techniques and motivation behind the painting can enrich a viewing, the enigmatic expression of the woman herself captivates and confuses, providing fodder for centuries of discourse. In chapter 9, we will revisit the interaction of context, observer, and object in motion.
    - Visit a piece of art in your community. This could be a public sculpture, a painting in a museum, a movie, or another work.
    - Write the context in which you are observing the piece. Is it raining? Is the venue crowded? Are other people looking at the object (or performers), or is it just you? Is there a scent in the air?
    - Write how you are feeling. Are you hungry? Are people bumping into you? Do you feel like part of the group or are you alienated in some way? Does the scent in the air remind you of anything? What are your past experiences that are coming up as you observe the piece? Which senses are you using to observe it?
    - Now describe the work itself. Do not jump to an evaluation of it ("I like it" or "I hate it"); first, take some time to describe the colors in use, the kinds of lines employed, the textural qualities (this could be in a static object or in movement), and the compositional choices.
    - Finally, consider how the sum total of the components in the last three bullet points affects your viewing and assignment of meaning to the piece. Would it mean something different if it were not raining (or if it were)? Would it mean something different if you were not

  so hungry? Would it mean something different if blue were used instead of orange? Would it mean the same to any other viewer?

- **Viewing items of personal meaning (relating other to self):** Repeat the exercise with an object of personal significance. This could be a favorite stuffed animal, a favorite work of dance, an award you once received, or another important part of your life. It should be an object that you have owned/known through the course of many experiences.
  - How do the different elements shift in their contribution to the meaning of this object? Likely, your personal role has an outsized effect on the meaning of this item.
  - If you handed it to someone who did not know you or your history with the object, what do you imagine they would perceive?

Chapter Summary

This chapter covers ways in which a mover may relate to the environment. Outlining modes of relationship self-to-self, self-to-one-other, and self-to-many-others, we highlight static and dynamic patterns that reveal these relationships. We also name shape qualities, intentions that arise out of complex bodies moving in space. In humans, this complexity is most saliently revealed through core change, but machines demonstrate a refinement of this idea, showing how a heightened relationship to environment can produce the same sense through distal action alone. We also note that this relationship is perceived through meaning-making, and thus, the ideas in this chapter are especially sensitive to the specifics of the mover, the context, and the viewer. Moreover, there is a heightened impetus (above that described in chapters 4–6) on the information content of the movement phenomenon. Thus, this category defines higher-order relationships of a body moving in space. The next chapter, on Effort, will outline ideas about higher-order relationships of a body moving in time.

8 How Is the Movement Executed? Movement Quality Enables Shading of Motion (Effort)

The Effort component will address *how* a given movement is happening. Answering this question requires a notion of quality. So far, we have seen components that allow a description of an action such as reaching out for a handshake as: The mover's right arm (Body) reaches forward (Space) over the course of 5 seconds (Time) in a spoke-like manner (Shape). This answers the questions posed by the first four components: What is moving? Where is the movement? When is the movement happening? For whom in the environment is the movement? However, we still do not know as much about the inner motivation of the mover as we could. For example, is the arm thrust forward with a sense of haste and urgency? Or does it reveal a more relaxed attitude? Does it emerge with a sense of airiness or a sense of dense strength? The answers to these questions are often apparent in such a gesture—particularly an act of greeting, such as a handshake—but we have not yet provided a language to distinguish between them.

Effort models the varieties of ways that we try to perceive a mover's motivation (and the ways that we try to communicate our motivation to others). We find it is useful, particularly with regard to understanding machine movement, to examine effort as patterns of dynamic change over time. Here, we emphasize the hierarchical model of the BESST System (see the right image in figure 3.4 in chapter 3) where effort is the result of many bodily activities and relationships. Thus, in this chapter, we also introduce the affinities of the BESST System to demonstrate how effort manifests through complex action in the world.

Effort is one of the most tantalizing components of movement studies for researchers, with many hoping that it will help decode (or encode) the reasoning behind a given movement. Effort can be useful in this process, but it does not offer such answers independent of the other components of the BESST System and the movement's context. As with shape quality, these ideas rely on the manifestation of many components of the body and are revealed through context. We may need to watch a mover for a long time to learn how their baseline patterns modify the execution of any particular, single act. Moreover, we may need to understand more about what is going on in the scene around them. For example: are they greeting a long-lost friend with this handshake or someone who just sued them in court? Although the notion of motivation is an important piece of meaning (note that none of the terms introduced in this chapter or in the rest of part II have an inherent meaning associated with them), answering *why* something is happening remains a difficult task of subjective analysis.

8.1 Basic Effort Actions

Eight commonly identified qualities of motion

In dissecting the notion of *motion quality*, it is instructive to start with a list of already familiar terms. The **basic effort actions (BEAs)** are such a list (see box 8.1 and figure 8.1), offering common verbs that fit into the systematic framework that is presented in the rest of this chapter. As you consider each verb in the list, accompanied by one of its definitions from the Merriam-Webster dictionary,[1] notice the various contexts where you might observe these types of actions. This will help paint the notion of how movement style may suggest a different inner state, or motivation, of the mover.

Box 8.1

Basic Effort Actions

- **Float:** Drift on or through—or as if on or through—a fluid.
- **Punch:** Strike with a forward thrust (especially of the fist).
- **Glide:** Move smoothly, continuously, and effortlessly.
- **Slash:** Lash out, cut, or thrash about with—or as if with—an edged blade.
- **Dab:** Strike or touch lightly.
- **Wring:** Squeeze or twist (especially so as to make dry).
- **Flick:** A light, sharp, and jerky stroke or movement.
- **Press:** Act upon through steady pushing or thrusting force exerted in contact.

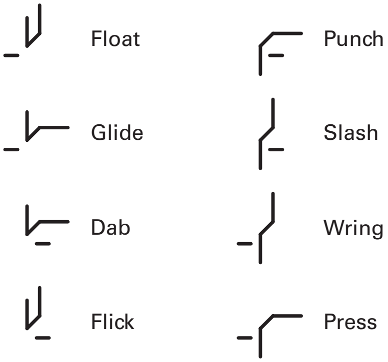


Figure 8.1
Symbols for the BEAs. Each uses the Effort component symbol (a forward slash). These are established from the graph shown in figure 8.2.

The term “effort” is translated from the German word *antrieb*, which also translates as “drive” or “impetus.” This word was used to describe an idea of inner motivation—a texture that can be lost in the English term “effort.” This list of verbs describes different qualities of movement that can be seen across many activities. For example, we typically associate “wring” with “wringing out a towel” or “wringing one’s hands” or even “wringing someone’s neck”—but we could also imagine, particularly in contemporary dance, a twisted, wrought solo expressing struggle and strength that did not contain any of those typical activities. That is, “wring” gets at a sense of movement that contains the application of strength, twisting nonlinearity, and continuous, unhurried action.

How does “wring” differ from “flick,” “dab,” or any of these other listed verbs? We can qualitatively describe the differences (as provided by the definitions) and distinguish contexts where we expect to see one or the other, but the BESST System offers a systematic way to express the differences between these qualities of motion, and many other qualities. This is done through the scheme described in the next section.

Embodied Exercises

- **Trying the BEAs:** In this exercise, you will explore the various BEAs through a kinesthetic channel in functional contexts.

  - Look at the list of BEAs given in box 8.1 and make an action with your own body that seems to fit each, focusing on functional tasks that you might encounter day-to-day and gathering any props necessary to fully execute the action. Note the contexts where such an action might typically arise.
    - For example, sliding a shower curtain across a smooth bar might elicit a “glide,” or squeezing liquid out of a dish towel might elicit a “wring.”
  - Looking at the list of contexts created from the previous step, find a different BEA or context that could fit as well.
    - For example, a gliding wave of your hand might elicit a sense of grace and pomp (as used in ceremonies by public figures like a queen). Or, instead of “wringing a dish towel,” now try dabbing with the towel, as on a spot of dirt that has accumulated on a shirt.
  - Reflect on how these distinct modes of movement give rise to the ability to accommodate different functional and expressive contexts.
- 🎥 **Refining expression with BEAs:** The BEAs are also useful for refining and expanding our palette as expressive movers.
  - Develop a phrase that uses “wring,” “slash,” and “glide.”
  - Calling up an arbitrary BEA can be hard to do well. Use a narrative to enhance your expression of these qualities. This can involve a literal story or a series of moods that you inhabit in a sequence that makes sense.
  - How does this idea of expression support your experience moving the prompt? (You can even try recording before and after to witness the change in your movement.)
  - Try repeating this with a few other BEAs.

8.2 Effort (or Motion) Factors

Modeling the quality of movement that belies motivation

The BEAs are described by a combination of **effort factors,**[2] which model how dynamic qualities come together to express some sense of motivation or intent (or the quality with which movers are organizing and expressing their attitude). There are four Effort factors: **weight effort, flow effort, space**

Box 8.2
Effort Factors

- **Weight effort:** Arises out of the fundamental body experience of weight-sensing (which was discussed in chapter 5). It is characterized as expressing intention and sensation and is related to the level of impact we employ in our movement. It relies on an association between one's sense of self and one's sense of one's own mass (and in this way, it is related to weight-sensing). The polarities are as follows:
    - Condensing: *strong* (a forceful way of moving)
    - Indulging: *light* (a delicate way of moving)
        - The expression of weight effort exists as a range between two extremes and can change incrementally without reinitiating action.
- **Flow effort:** Arises out of the fundamental body experience of flow-sensing (which was discussed in chapter 5). It is characterized as expressing progression and feeling. It relies on an association between one's sense of self and one's sense of one's own energy (and in this way, it is related to flow-sensing).[3] The polarities are as follows:
    - Condensing: *bound* (controlling and holding progression)
    - Indulging: *free* (releasing and ongoing progression)
        - The expression of flow effort exists as a range between two extremes and can change incrementally without reinitiating action.
- **Space effort:** Arises through our senses and the bodily ways that we focus on the environment. It is characterized as expressing attention and thought. The polarities are as follows:
    - Condensing: *direct* (channeled singular focus)[4]
    - Indulging: *indirect* (broad scanning multifocal)[5]
        - The expression of space effort must be reinitiated to reveal change; therefore, while a range of intensities might be possible to exhibit, a movement cannot become more direct (or indirect) without becoming something else first.
- **Time effort:** Arises from our relationship to chronological time and our attitude toward it. It is characterized as expressing commitment and decision. The polarities are as follows:
    - Condensing: *sudden* (urgency and possibly accelerating)[6]
    - Indulging: *sustained* (lingering and possibly decelerating)
        - The expression of time effort must be reinitiated to reveal change; therefore, while a range of intensities might be possible to exhibit, a movement cannot become more sudden (or sustained) without becoming something else first.

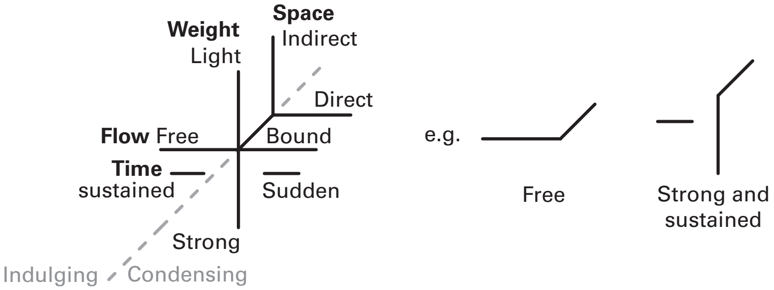


Figure 8.2
The Effort graph. All effort factors and their polarities are shown at left. Drawing subsets of this graph produces symbols for individual qualities and combinations of qualities (e.g., “free” and “strong and sustained,” shown at right). See appendix A for a complete list of combinations and their symbols.

effort, and **time effort.** Each factor has two contrasting polarities: **condensing** (making, fighting, going against) and **indulging** (allowing, going with).

To perceive these qualities, we need to notice relative change, so it is when movement changes in energy, tone, or attitude that we perceive effort. Each of the four factors is found rarely, in fleeting moments that punctuate our movement. It is in their combinations, phrasing, and organization that we perceive dynamic expression. The relationship between the factors is organized visually in figure 8.2, which forms the basis of how effort is notated symbolically.

Embodied Exercises

- **Comparing two BEAs:** This exercise will compare two BEAs to reveal what aspect of motion each effort factor aims to describe.
  - Dab/flick: Put a damp washcloth on your finger and “dab” at a spot on your shirt or pants, imagining that you have just spilled a bit of food that has been absorbed into the cloth. Then switch, instead imagining that the food is resting on the surface of the cloth and “flick” the food away.
    - How are these experiences different for you?
    - Notice that “dab” and “flick” differ by one factor: the use of space effort. “Dab” has a directed, attentive quality, while “flick” is more indirect and diffuse.

  - Wring/slash: Use a damp towel and "wring" out the water; now take the towel and "slash" it in the air, continuing the drying process.
    - How are these experiences different to you?
    - Notice that "wring" and "slash" differ by one factor: the use of time effort. "Wring" uses a luxuriating, indulgent attitude toward time, while "slash" is more hurried and chaotic.
  - Comparing dab/flick to wring/slash: What do these pairs have in common, and what is distinct? Notice that "dab" and "flick" have a sense of light weight effort, while "wring" and "slash" use strong weight effort.
    - How are these experiences different for you?
- **Exploring flow:** Use the images given here to experience free and bound flow effort.
  - Imagine you are an old-growth, solid oak tree covered in ice during the winter. A hearty breeze is blowing, causing movement in your branches, which is inhibited by the ice.
    - This image uses a common mechanical failure in trees to conjure an experience of bound flow effort: during icy winter storms, branches can seize up, covered in ice, losing their pliability and breaking under extreme stress.
  - Now imagine you are a young, supple stalk of bamboo in a moist and verdant jungle. A hard breeze is blowing, causing movement that is free and unrestrained. As the wind picks up, you continue to move more and more and more until you are whipping wildly back and forth—but not breaking.
    - This image uses the flexibility and strength of bamboo to encourage you to engage in free flow effort, creating large momentum shifts and an intensely energetic, ongoing movement experience.

8.3 States and Drives

Going beyond the BEAs to the full richness of motion

While the BEAs discussed here are highly crystallized manifestations of three efforts, these occur rarely, punctuating ongoing movement expression. Moments containing three effort factors reveal a heightened intensity and are labeled as **drives.** The BEAs are the articulation of **action drive,** and as such contain no flow effort. However, there are three other drives that do include flow effort, and they are the **transformation drives,** as "action" is transformed into something that includes progression and control. The three transformation drives, which we can identify through the missing effort factor, are **passion drive** (no space effort), **spell drive** (no time effort), and **vision drive** (no weight effort). These are listed in box 8.3, and symbols are provided for each one in figure 8.3. Appendix C further details the individual combinations—also called configurations—within these drives.

As is true with action drive, each transformation drive has eight expressions (varying combinations of the three effort factors contained in the drive), which are often referred to with the same names of the BEAs (e.g., a "passion drive punch," which uses the condensing polarity of flow effort instead of the condensing polarity of space effort). In perceiving and

Box 8.3
Drives

- **Action drive:** Combinations of weight effort, space effort, and time effort (having no sense of progression or feeling)
- **Passion drive:** Combinations of weight effort, time effort, and flow effort (having no sense of attention or thinking)[7]
- **Spell drive:** Combinations of weight effort, space effort, and flow effort (having no sense of commitment or decision)
- **Vision drive:** Combinations of space effort, time effort, and flow effort (having no sense of intention or sensing)

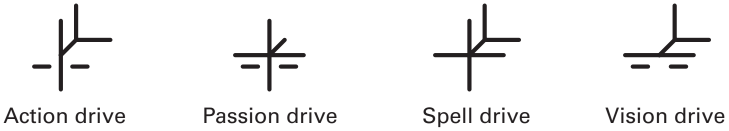


Figure 8.3
The four drives in the Effort component. The elements of action drive and all three transformation drives (passion, spell, and vision), illustrated with the Effort graph. See appendix A for the twenty four symbols that correspond to each configuration within the three transformation drives.

experiencing moments of drive expression, the factor that is missing is as important in characterizing the "tone" or mood of the drive as what is present. As with the BEAs, a moment with three effort factors combined into a single expressive event is one of rare, heightened intensity.

Most movement expressions are not quite so loaded: we more often see combinations of only two effort factors. Two effort factor combinations create **states.** There are six of these: **mobile state, stable state, remote state, rhythm state, dream state,** and **awake state,** listed in box 8.4 and with symbols provided for each in figure 8.4. Each state has four possible combinations of the two effort factors contained in the expression. Appendix A offers a complete list of symbols, and appendix C further describes the configurations within these states.

Box 8.4
States

- **Mobile state:** Combinations of flow effort and time effort
- **Stable state:** Combinations of weight effort and space effort
- **Remote state:** Combinations of flow effort and space effort[8]
- **Rhythm state:** Combinations of weight effort and time effort[9,10]
- **Dream state:** Combinations of weight effort and flow effort
- **Awake state:** Combinations of space effort and time effort[11]

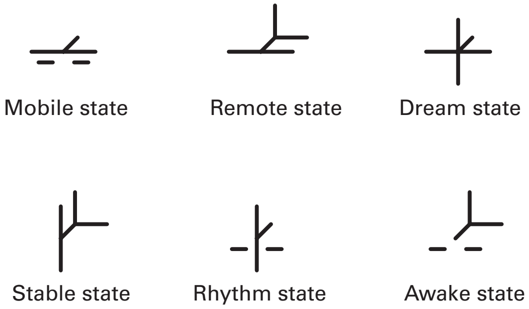


Figure 8.4
The six Effort states. The two factor combinations of the six states, illustrated with the Effort graph. See appendix A for the twenty four symbols that correspond to each configuration in the six states.

It is possible to notice in this list that there are pairs of states that can be seen as contrasting with each other and are named as such (e.g., mobile and stable states). We refer to these pairings as “oppositional states,” and one inroad into experiencing each state’s distinct qualities is to explore them in these contrasting pairings.

Most movement expressions are a sequence of multiple state expressions that fluctuate and modulate and might become punctuated by drive expressions. As such, they are constantly coalescing in various configurations, and as with all movement events, our experience and perception of effort expression are context dependent. It is also important to note that because effort expression is understood as manifesting an inner attitude or intention in bodily movement, there is also a difference between what is experienced and what is perceived—which are both processes unique to every individual. This means that a mover may be experiencing something different from an observer, especially when those two individuals have significantly different prior experiences, including training, culture, and situational awareness.

Thus, studying movement quality and its performance can improve communication, allowing a mover to better translate intent to others and to better perceive the intentions of others. Sometimes watching the same movement event over and over (e.g., on a recorded video) is required to come to a consensus about what is being expressed. Such refinement in performance and observation is the process of movement analysis—and an inherent element of any rehearsal in the performing arts.

Embodied Exercises

- **Using familiar images to invoke effort:** Each bullet point will provide you with images often (but not always) associated with these states; use them to explore movement qualities. (See appendix C for a complete list of the configurations.)
    - Being startled by something and freezing in response (bound and sudden configuration of mobile state)
    - Kernels of popping popcorn (free and sudden configuration of mobile state)
    - Gasping with a shiver (light and sudden configuration of rhythm state)

  - Filled with rapture (light/free/sustained configuration of passion drive; a passion drive float)
  - A witch cursing her sworn enemy with an incantation (strong/bound/direct configuration of spell drive; a spell drive punch)
  - Surveying a plot of land (bound/sustained/indirect configuration of vision drive; a vision drive wring)
- **Understanding your personal relationship to effort:** Create your own personal images to help invoke different configurations of effort. Such an effort bank is an essential piece of training movement analysts.

8.4 Affinities between Components

Relationships between components in the BESST System

We are coming to the end of part II, where we have presented each component of the BESST System in turn and, for the most part, in isolation. This works well for the linear arrangement of this book, but it has left out an important concept of the system. In aiming for holistic analysis of the experience of human movement, each component of the system shares **affinities** that highlight how concepts from different components reinforce and support one another. Affinities arise from our body-based movement experience. For example, as we move downward with the pull of gravity, the center of gravity in our lower body sinks and supports, through this bodily movement, our ability to express strong weight effort. We now briefly introduce this advanced concept by discussing Effort's relationship to each of the other components.

8.4.1 Effort-Body

The idea that Effort and Body share affinities has already been evident in some of the entries in the list provided in box 8.1, where certain body parts are mentioned or implied. For example, "punch" is strongly associated with a hand (body part) that is contracted (basic body action) and clenched (muscular tension), forming a fist. While we have discussed that punching can occur in other body parts through any sort of sudden, direct, and strong action, it is clear that actions with a clenched, closed fist read even more clearly as a "punch." Moreover, the physical body-level support offered by contraction is evident not only in "punch" but in other condensing qualities: "wring," "slash," and "press" are all supported through the engagement of body weight via similar muscular activation. Contraction of large muscle groups—for example, engaging the quads by lowering to the ground, curling the biceps even during overall extension of the hands into space, or contractions in the core—support the feeling that the mover is engaging the full weight of the body and exhibiting strong weight effort.

8.4.2 Effort-Space

Likewise, particular uses of concepts in the Space component can support those in the Effort component.[12] This is in part due to the geometry of our bodies: they have developed in an upright form with bilateral symmetry, creating a somewhat consistent relationship with space. It is also in part due to the shared context our movement occurs in: gravity pulls all moving bodies on Earth *down*. This relationship is formalized in box 8.5 where affinities are represented with a tilde (~), which can be read as "is affined with" (taking inspiration from mathematics where such a symbol might mean "scales with," "is proportional to," or "is congruent to").

The affinities in box 8.5 name relationships where particular spatial pulls enhance the expression of a particular movement quality. For example, when moving around low to the ground, the crouched, contracted position of the body and the required muscular attitude that is assumed (the muscles are really feeling the weight of the overall body here) create a natural affinity for accessing strong weight effort. Thus, spatial pulls in the cube affine with the BEAs as described in box 8.6.

Box 8.5

Affinities between Space and Effort (Dimensional Scale)

- Vertical dimension and weight effort
    - High ~ Light weight effort
    - Low ~ Strong weight effort
- Sagittal dimension and time effort
    - Forward ~ Sustained time effort
    - Back ~ Sudden time effort
- Horizontal dimension and space effort
    - Right (with right side leading) ~ Indirect space effort
    - Left (with right side leading) ~ Direct space effort

Box 8.6

Affinities between Space and Effort (Diagonal Scale)

- Float ~ Right-forward-high (with right side leading)
- Punch ~ Left-back-low (with right side leading)
    - Completing these two actions in sequence also serves to highlight their contrast with one another; each polarity of effort factor reverses as the body crosses abruptly through the central pathway of the diagonal, termed the **float-punch diagonal,** which involves switching from an entirely indulging to an entirely condensing BEA.
- Glide ~ Left-forward-high (with right side leading)
- Slash ~ Right-back-low (with right side leading)
    - This diagonal, the **glide-slash diagonal,** also reverses each effort factor and aligns with the spatial affinity, heightening the expression; here, however, the space effort factor's polarity is switched with respect to the other two factors: "glide," which is indulging in weight and time, has condensing (direct) space effort, and "slash," which is condensing in weight and time, has indulging (indirect) space effort.
- Dab ~ Left-back-high (with right side leading)
- Wring ~ Right-forward-low (with right side leading)
    - In the **dab-wring diagonal,** the right arm crosses the body affining with the directness brought on by crossing and closing the body, opening to heighten the sense of indirect space effort required for the expression of "wring."
- Flick ~ Right-back-high (with right side leading)
- Press ~ Left-forward-low (with right side leading)
    - Finally, the **flick-press diagonal** finishes the scale with a quick, open body that closes with sustainment as it passes down through the vertical dimension, switching from light weight effort to strong weight effort.

8.4.3 Effort-Time

The concept of dynamosphere (introduced in chapter 6) helps to explain affinities between Time and Effort. The Time component allows us to articulate the difference between duration and time effort, which are notably affined. An action of relatively short duration may be more likely to be seen as having sudden time effort, and vice versa. That is, there is an affinity between short and long duration and sudden and sustained time effort, respectively. However, these are not the same aspect of movement—and we can see relatively long durational movements as having a sense of urgency in their motivation, representing an example of a **disaffinity,** where two contrasting movement ideas coexist—and even contrast one another. Rather than heightening the expression of each, this contrast can create a notable expression as well.

Another important relationship to note is that of phrasing and condensing effort qualities. While any of the types of phrases listed in box 6.6 in chapter 6 can be perceived through emphasis, loading, and accent, there is a particular way in which we more easily perceive "accent." For example, impulsive phrasing (where the beginning of the phrase is emphasized) is most easily perceived when the first action in the phrase happens with condensing effort (i.e., a punch is often better at creating contrast than a float). However, a float can feel like emphasis inside the context of several actions of condensing effort. So, while it is not necessary for a short duration, sudden, strong, direct, and/or bound movement to occur in order to see patterns of phrasing, it is especially easy to perceive when an accent in the phrase occurs if these features are present at the same time.

8.4.4 Effort-Shape

As we have established in the hierarchical model of the BESST System, all of the components help to express each other, building up to concepts like shape and effort quality, which are most closely linked to relationship, intent, and meaning. Shape quality, which in adult human movers is typically manifest through changes in the spine, breath, and core musculature, helps express effort quality. One way of seeing this affinity is to consider how one would express light weight in their movement: there is an almost immediate sense of rising that helps communicate this idea. At the same time, consider when we feel a sense of lightness through our experience. Often this occurs in moments of joy or rapture when we feel a delicate, fleeting sense of release, or escape, from gravity. That is, the expression *and* experience of light weight in bilaterally symmetric bipedal bodies that work to stay upright in a gravity field correlate with vertical expansion through the core. This idea is directly embedded in the forms of the Effort and shape qualities graphs (figures 8.2 and 7.4 in chapter 7, respectively), which can be superimposed to reveal these affinities, listed in box 8.7.

Box 8.7
Affinities between Shape and Effort, Indexed by Spatial Dimensions

- Vertical dimension
  - Rising ~ light weight effort
  - Sinking ~ strong weight effort
- Sagittal dimension
  - Advancing ~ sustained time effort
  - Retreating ~ sudden time effort
- Horizontal dimension
  - Spreading ~ indirect space effort
  - Enclosing ~ direct space effort

The organization of the list in box 8.7 suggests further affinities between effort, shape, and space. Notice that in the diagonal scale with the BEAs, given in box 8.6, another element can be added to heighten the expression of each note in the scale: shape quality. By accessing shape quality, particularly through adding deformation of the core to each gesture with the arms and limbs, the mover can further heighten the sense of each action. For actions involving light weight effort, the mover does well to perform rising (although it is not necessary to see this quality). Box 8.8 spells out these affinities between shape qualities and the three-dimensional pulls in the diagonal scale, but the expression of any spatial pull can be heightened with shape qualities (and vice versa): for example, rising and sinking are affined with “place high” and “place low,” respectively.[13]

Other affinities exist (and have yet to be discovered) in the system, which are advanced topics that we will not cover here. Likewise, we have not covered movement scales in additional spatial forms (e.g. the dodecahedron) that are being worked out in the movement studies community. Other areas of expansion and evolution of the system include the Time component—our initial treatment given in chapter 6 is sure to evolve in the coming years—and notation, which we will discuss and extend briefly in chapter 10. Both of these loci for new ideas are being pushed by work with machines.

Box 8.8
The Diagonal Scale (Right Side Leading) with the BEAs and Shape Qualities

- **Float-punch diagonal**
    - Float: right-forward-high with spreading, advancing, and rising
    - Punch: left-back-low with enclosing, retreating, and sinking
- **Glide-slash diagonal**
    - Glide: left-forward-high with enclosing, advancing, and rising
    - Slash: right-back-low with spreading, retreating, and sinking
- **Dab-wring diagonal**
    - Dab: left-back-high with enclosing, retreating, and rising
    - Wring: right-forward-low with spreading, advancing, and sinking
- **Flick-press diagonal**
    - Flick: left-back-high with spreading, retreating, and rising
    - Press: right-forward-low with enclosing, advancing, and sinking

Embodied Exercises

- **Spatial pulls in the cube (revisited):** This exercise will revisit the spatial pulls in the cube, adding in the affinities—and disaffinities—between Space with Effort and Shape.
    - Move the spatial pulls in the cube (as described in box 8.8).
        - Use affinities in effort and shape to support each expression of space.
        - Try the scale with the disaffinity in effort and shape as you move to each spatial pull.
    - Pick one spatial pull of interest to you. Practice the affinity in shape quality and effort, as well as the disaffinity. Come up with a scenario that is personally meaningful in each. What do you notice about the differences in these personal scenarios for the affinity and disaffinity?
    - Return to the last embodied exercise of section 5.3 in chapter 5, where you may have created your own scale. How does adding in shape and effort to your execution enhance your ability to feel each pull? (Note that here you may be inhabiting only states or single factors, depending on which platonic solid your scale was in.)

- **"Wring," "slash," "glide" (Revisited):** In section 8.1, we asked you to create a phrase with the BEAs "wring," "slash," and "glide," and you explored how narrative helped create a clear expression of those BEAs. Now, try the phrase again, explicitly adding support from shape qualities.
  - Wring: sinking/spreading/advancing
  - Slash: sinking/spreading/retreating
  - Glide: rising/enclosing/advancing

8.5 Application to Machines: Simulating Effort for Advertisement of Internal State

The holy grail of human-robot interaction?

Roboticists and computer vision researchers have long looked to the Effort component to help generate and recognize styles in motion quality. It helps answer the question of how a movement may vary, revealing distinct meaning in context to a particular viewer. Despite many attempts at quantifying the behavior, manufacturing or simulating Effort is an open research problem. Broadly, there is some agreement that the issue involves the temporal pattern of a given motion: changing the evolution of a movement's trajectory seems to change the motion quality (Nakata et al., 1998; Rett & Dias, 2007; Santos et al., 2009; LaViers & Egerstedt, 2012; Kim et al., 2012; Sharma et al., 2013; Knight & Simmons, 2014; Burton et al., 2016; Cui et al., 2019; Bacula & LaViers, 2021). Our presentation of Effort in this book is consistent with this broad idea, but we hope to add nuance to ideas about how humans express effort: it is not only through changing the trajectory of a given body part over time, as most of these prior publications describe. Instead, the affinities between Effort and the other components of the system describe how many aspects of the body work together to create a sense of inner attitude, intent, and motivation. Effort is fleeting and relies on every other component of movement, the body, context, and the observer to manifest.

Amy's doctoral work developed a method for style that is both generative (a library of motion primitives is sequenced via supervisory control and modulated via an optimal control framework) and interpretive (inverse optimizations can be used to classify and segment real observations of human behavior) (LaViers & Egerstedt, 2012, 2014). Simple, "one-armed" automata can be recombined via composition operators with themselves and supervisory automata to produce more complex sequences of primitives (see figure 1.3 in chapter 1). Trajectories are interpolated between these states and modulated by developing a cost function to track (more or less closely) a particular primitive, resulting in variation of trajectories over time (see figure 8.5). This variation is generated by changing weights in an optimal control problem, where each weight is associated with an effort factor: weighting deviations from a nominal, linear interpolation corresponds to space effort; weighting magnitude of overall acceleration (or input energy) corresponds to weight effort; weighting the magnitude in change of state corresponds to time effort; and weighting the match to the final end pose corresponds to flow effort. These associations may be seen as a choreographic technology, enacting a principled treatment of motion quality into an artificial system. However, they are in conflict with a principle introduced in this chapter—that effort drives are rare, fleeting moments—as the work attempts to create motion that is constantly in a drive configuration.

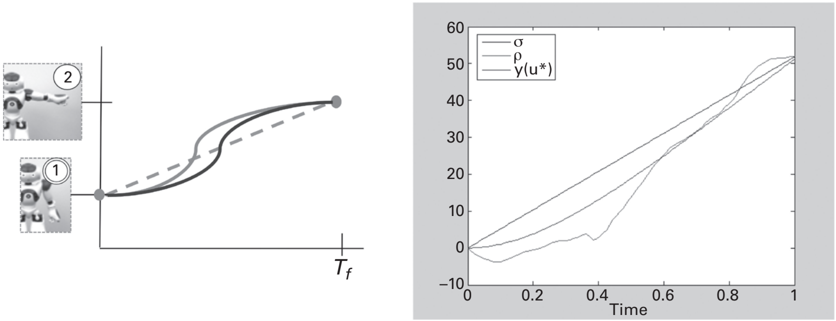


Figure 8.5
Changing movement quality through trajectory modulation. Left: A depiction of two distinct joint angle trajectories starting and ending at the same joint (here, the “shoulder” of a NAO humanoid). These poses may be sequenced as in figure 1.3 in chapter 1. As the joint opens, there are many choices of how the motion may unfold over time; two are illustrated here. Right: Mimicking a real snippet of motion-capture data through inverse optimization (here, one of the degrees of freedom modeling a human leg). The wiggly line (on the bottom at the beginning) is made up of real motion-capture data that has been smoothed; the straight line (on the top at the beginning) is a nominal linear interpolation between the starting and ending pose; the gently arched line (in the middle at the beginning) is a re-creation using inverse optimal control defined by $q=1.53$, $r=0.018$, $p=0.001$ (LaViers & Egerstedt, 2014). In other words, the motion is an artificial embodiment of direct, light, and sudden effort quality.

This work was created in the context of choreographing with and alongside contemporary dancers (LaViers et al., 2014), where it is easy to see how much is lacking in these artificial models of motion style. Namely, motion seems to change its nature on different bodies and in different contexts. A fixed mapping between motion trajectories and high-level, perceptual parameters, while a desirable theoretical idea, falls flat in practice. That is, in developing artificial embodiment for machines, close attention must be paid to the perceptual habits of a wide range of human observers across a wide range of contexts. Some research even suggests the need to consider physiological measures of human interactants, such as recordings of muscle activation (Fdili Alaoui et al., 2017). Ongoing research in this area will surely produce further insights into the complexity and nuance of quantifying the Effort component.

Embodied Exercises

- **Moving with a robot:** This exercise will invite you to find a machine—perhaps you have a robotic vacuum cleaner in your home or can find a video of a machine—and move with it, comparing and contrasting your movement quality through the lens of effort.
    - Find a robot of interest.
    - Imitate its movement quality.
    - Decide which elements of effort are present in the movement of the machine.
    - Based on that categorization, try to move *in the opposite way*. That is, if the machine is bound and direct, try movement that is free and indirect. What kind of contrast does this set up?
    - Use your movement inquiry to refine your estimate of the machine’s motion. Try a different hypothesis about the robot’s movement quality (e.g., perhaps it is strong and sudden). Try imitating that and then its opposite (e.g., light and sustained) until you are happy with your categorization.

Notice how this exercise is asking you to use your body for research about your own perception and the qualities of machine movement. Effort is one of the most difficult aspects of the BESST System to embody on command in an authentic and externally observable manner. This exercise is not as simple as it sounds and is worth repetition.

8.6 Exploring the Themes: Effort through the Lens of Inner/Outer

Expressing inner life through movement (sometimes)

Effort expression is experiencing and broadcasting an attitude or intention. Our thoughts, feelings, decisions, and sensations—which are often unknown, even to ourselves—are in large part how we know ourselves. These aspects of ourselves are visible only when the inner experience is expressed in outwardly observable movement change, including vocalization of language but also the manner in which we move. As such, the thematic duality of Inner/Outer is one way that we can understand the dynamics of expression.

We have inner experiences of emotion, feeling, attention, focus, thinking, and intuiting that may well be experienced but not necessarily observed (and vice versa). It is only when those attitudes and intentions are expressed in movement change over time that the inner becomes outer or is revealed in a way that is perceivable. It is possible to have a dynamic and rich inner life that is in fact never revealed. In addition, we often participate in forms of subterfuge where we intentionally mislead others as to how we are feeling, what we are thinking, or what our motivations are. It is through effort expression that inner life—or the inner life we want others to think we have—becomes manifest in outward dynamic qualities.

Often, effort has been applied toward the goal of "emotion" generation and recognition, a connection that has been explored but is not yet well understood by psychologists (Tsachor & Shafir, 2019). We hope that the presentation here helps highlight how none of the terms in this system correspond directly to emotion—and aims to emphasize the inaccuracy of such an approach. Assuming that the emotion of a person is visible from the external state *at all* is something that contradicts our own experience: we often work hard to hide negative feelings; many people are described as "hard to read"; and questions like "What are you thinking?" or "Are you okay?" evidence a lack of ability to understand the meaning of someone's movement patterns. Instead, the system aims to outline a coterie of movement options—a mover's palette, so to speak—that can be used, like colors of paint, in myriad ways to create various expressions. The *meaning* of movement expression is individual (on both the part of the observer and the mover) and contextual.

Furthermore, effort need not have anything to do with emotion (consider the lightness that functionally supports placing a delicate teacup high on a shelf overhead). In our application to machines, this is especially true because while machines can change motion styles, they do not have emotions. We do want to endow machines in human-facing environments with variable movement textures to create more useful tools—ones that communicate with their human counterparts either by imitating existing communication styles between humans or employing some novel, device-specific convention—but we do not aim to create life out of inorganic metal parts.

Embodied Exercises

- **Breathing:** Lie, sit, or stand in a comfortable position. Bring your attention to your breath. Focus on experiencing this through the lens of the Inner/Outer theme. Follow your breath as it literally traverses from the inside of your body to the outside and vice versa. Notice how movements happen internally as well externally.
- 🎥 **Moving with and without an audience:** Revisit the lying, sitting, standing sequence from the embodied exercises in section 6.1 in chapter 6. Go through this sequence several times on your own. Now, put on a camera to record yourself (or bring a friend into the room to observe you) and repeat the exercise. How does it feel to move when you know someone may be watching versus when you are alone? In one situation, you can focus on your inner experience; in another, you may worry about "looking stupid" and modify your experience to present an intelligent or competent persona to the audience.
- **How movement makes you feel:** Try some of the movement profiles listed in figure 8.1. How does enacting these ideas change how you feel or influence your mood? Give this internal investigation a little time to overcome the initial feelings of the awkwardness of the exercise, and notice how your body changes in response to movement.

Chapter Summary

This chapter reviews probably the most famous component of Laban's work, an area that has somehow become one of the most enticing areas of movement studies at the nexus of internal, somatic investigation and external, choreographic presentation: the matter of how inner intent translates into observable bodily changes. As such, many contradictory statements about effort have been made in the literature, and here, we aim to present a practical introduction to the topic that relies on the previously introduced categories: Body, Space, Time, and Shape. Notably, there are specific affinities between these components and Effort that reinforce one another. Moreover, we see Effort as a higher-order relationship that can emerge from a complex body moving in space and time and, crucially, *coping with its environment*. We note that movement quality—or change in movement trajectory—is not enough on its own to create a notion of intent, which relies on a complex cluster of mover, viewer, and context.

III Translating Movement to Machines

9 Deconstructing Movement: Case Studies in Expression (Answering “Why?”)

We want to mold, craft, and design the movement of machines because, as we have seen, movement communicates information. Humans naturally, and almost immediately, attempt to translate information into personal meaning. Part of what training in movement analysis offers is an ability to examine the process of how we come to meaning in order to better see alternative options. In designing robotic movement, we need to distance ourselves from our own immediate, automatic associations between movement and meaning to establish specifications that can be built into machines and broaden our possible solution space.

This chapter presents five case studies to clarify the process of movement analysis, establishing that while machines do not evince all the features of the BESST System, humans can perceive rich meaning from their motion anyway. Each case study is presented as a constellation of symbols from part II alongside qualitative analysis that utilizes the BESST System concepts and principles. In parallel, we will also review more research that has worked to create expressive machines and harmonious human relationships with them—and offer points of view of how movement studies might further dovetail with this work.

The chapter will culminate in modeling the process of communication between humans and machines, drawing a rough parallel to classical information theory. First, an artificial system is modeled as an information source, measured in terms of the number of bits needed to describe it. Then, a human observer is modeled as an information destination that depends on the decoding scheme that it uses to translate a message. Then, context (environmental and situational) is modeled as the channel through which this message is transmitted, which may change the message—for instance, through noise or other disturbances. Finally, we suggest the arts as a testbed for studying this complex process.

9.1 The Duality between Embodiment and Intelligence

The interdependence of movement and thought

The nature of intelligence has been debated for centuries. As discussed in chapter 1, scholars are also grappling with understanding human embodiment. Learning from these scholars, we have used the term "embodiment" to refer to the physical expertise (or "intelligence") displayed by dancers in their studio-based work, by potters in a sculpting course, by singers in a performance of opera, or by football players in their field-based work—to name only a few. All of these "physical" practitioners also benefit from studying strategies and deploying technology to aid their work. This constitutes a concrete way that *embodiment* and *intelligence* are two inherently interrelated aspects of human capability.

In the fields of robotics and artificial intelligence (AI), artificial agents are designed to imitate aspects of human intelligence, although there is a robust and fascinating debate about whether they do: AIs typically excel at things that humans struggle with (e.g., multiplying large numbers and classifying millions of files quickly) and struggle with things that humans excel at (e.g., contextual analysis and making someone feel cared for). In the same vein, sometimes the field of robotics is described as developing "embodied intelligence" (analogous to "artificial intelligence"), but this confounds a key feature of human capability with machine capability and obfuscates the role of embodiment in human behavior. Instead, we characterize work in robotics as developing *artificial embodiment.* Just as the field of artificial intelligence aims to create systems that perform "intelligent" actions, researchers in the field of artificial embodiment (i.e., in the field of robotics) aim to create systems that take "embodied" actions. Such a delineation better describes the inability of machines to reproduce human behavior and sets guidelines for the use of words like "embodiment," "embodied," "intelligence," and "intelligent."

This is not to say that robots do not have interesting movement patterns. In fact, we believe working with robots, along with puppets, kinetic sculptures, animated avatars, and the like, actually sharpens movement studies—just as working with and developing new instruments sharpens music studies. Singers, who create music with their own vocal cords, benefit from this understanding, whether they sing with or play instruments themselves. (We also would do well to remember that all musicians *make music with their own bodies*, even when playing instruments or using computational tools; the division between dancers and musicians is academic.) Likewise, human movers can learn a lot about their own functional strategies and expressive capacities by closely observing the movement of robots and other artificial bodies.

For example, watching the humanoid Boston Dynamics Atlas robot perform a backflip wowed the internet when the video was released in 2017. The viral clip contained the robot jumping on several boxes in series and then rotating itself 180 degrees, parallel to the ground, in order to jump off the last, highest block while rotating 360 degrees in the air, perpendicular to the ground. The device launches itself with stark power before forming a contracted ball that was compared to how human gymnasts tuck to perform complex aerial tricks. In the end, after taking a moment to find stability on both its “feet,” the robot lifts both “arms” into the sky in a clear imitation of a gymnast dismount. The move was lauded as Olympics-ready, stunning, and above all, creepily humanlike in various media outlets.

And yet, was it humanlike? How do humans perform backflips? Both acts reduce the moment of inertia of the body, but notice two things that may be initially overlooked but are revealed by movement analysis. Functionally, the robot’s flip is not initiated like a human backflip, which is propelled by our hips whipping through space at the end of our flexible spines; Atlas does not have an articulated spine and initiates the movement from its distal “ankle” joints. Expressively, the machine’s ending arm raise is notably deadpan and flat, and there is little sense of the jubilance, amazement, and pride that frequently accompany a gymnast’s dismount through the carriage of posture (often a performative projection itself, meant to leave a good impression on human judges); Atlas lifts its arms with a stilted, one-note sharpness that is a notable departure from the seeming grace of the in-air, dynamic jumping and rotation.

We see many things that are *not actually there* in a demonstration like this. The idea that it is a humanlike act is in direct contradiction of the single, common feature of all living, lucid humans: breath. Even humans using a mechanical ventilator to live express themselves in the environment through an ongoing deformation of the core, but Atlas does not deploy *any* deformation in the core. Yes, the robot rotates successfully—as does a quarter flipping through the air (though we do not see this as a reasonable approximation of a human backflip)—but what is more intriguing is how it does so in such a different, dissimilar manner to human gymnasts, despite morphological similarities in features described in chapter 4 (see especially box 4.1), such as bilateral symmetry and two "upper" and "lower" limbs.

The moment of raising the arms to finish taps into an expectation that we have about physical performance: we see success and celebration because we have seen it in so many previous scenarios, and we are wowed by the physical triumph of the team of engineers who programmed that action. Likewise, people who own robotic vacuum cleaners often attribute personality and narrative to these remarkably simple devices (which have no such intentional design). Video gamers celebrate the increasing lifelikeness of virtual avatars that, in fact, look very little like real humans—lacking body hair, sweat, breath, and consistent foot traction in their environments, among other differences. How is this perceptual feat accomplished? What are the aspects of movement that need to be present to create this trick? How do we name them? And how do we notice these distinct modes with more regularity and nuance?

This chapter begins to share how the taxonomy introduced in part II can help answer these questions by presenting analyses in a form supported by that taxonomy. Each case study will include a **component constellation,** shown in figure 9.1, highlighting the terms used and displaying each symbol. These constellations are simply ways of gathering symbols together, organized by component, but viewing each symbol shows relationships between the terms (e.g., arc-like and spoke-like directional shape change share all but one feature between their symbols). Chapter 10 explains how these symbols can be used to notate movement using different notational structures to add temporal information and refine the relationships between the concepts and their symbols.

9.2 Expressive Moving Bodies

Movement analysis reveals and enables expression across bodies

Consider a scene from the movie *Star Wars: A New Hope*. A gold, clunky humanoid, C3PO, angles its upper torso toward a young man, Luke Skywalker. Outstretched from the right side of the body is a curled pair of

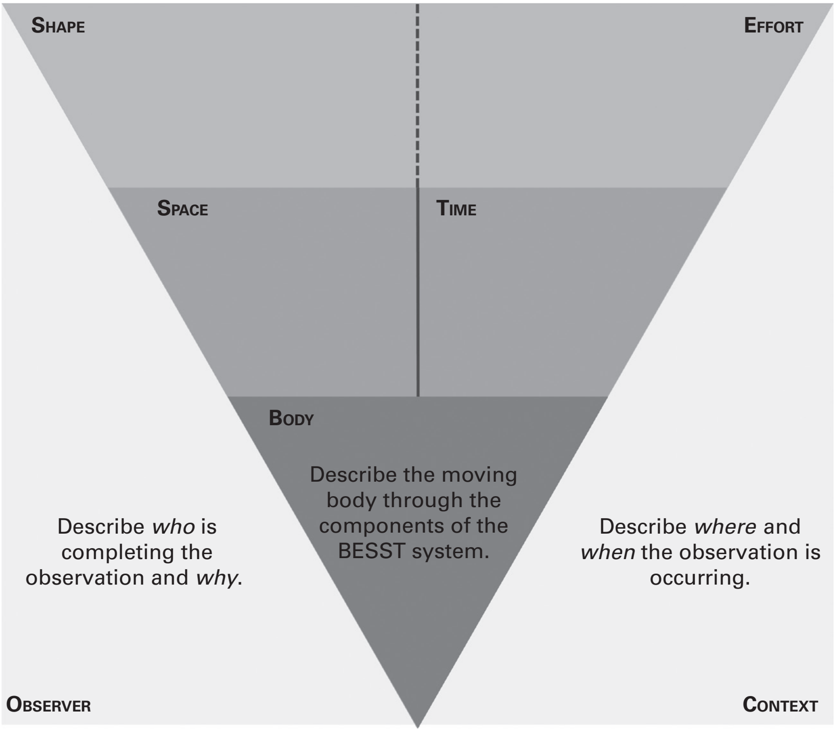


Figure 9.1
Anatomy of a component constellation. These diagrams offer a template for organizing the concepts inside the BESST System applied to a particular observation or case study. The structure reflects Body as the basis, moving in Space and Time, with higher-order ideas of Shape and Effort emerging from complex interactions of the other components. The areas on both sides of the inverted triangle offer space to acknowledge the role of observer and context in the analysis.

"fingers," with one extended at eye level. The two static "eyes" seem to be looking past the end of this extended "finger." C3PO's human counterpart is gazing similarly and leaning into the device, opening the vulnerable, fleshy part of his abdomen to contact the side of the machine. What is going on in this scene? *Why is the robot moving like that?*

Perhaps you would answer along the lines of "The human and the robot are collaborating," "The pair is trying to figure out where to go next," or "The robot is helping the human." All three of these are reasonable interpretations of the scene. But all of these interpretations (and indeed any others you came up with) are assertions that require evidence to back them up. Why is the typical interpretation that they are collaborating and not competing? What in the scene lends itself to being an important piece of evidence to support a conclusion about the relationship between the two agents? (And, for later: what elements in your own, personal past experience, as well as the environment, make you interpret this evidence in this way? We will discuss these questions in sections 9.3 and 9.4.)

So we ask: what in the scene makes you draw that conclusion? This requires a pause, as you have already assessed the scene in some sense, and now you must go back to before you made that assessment to really *observe* what is going on. This takes practice and expertise. Training in the taxonomy presented in part II is one piece of this, but experts in movement studies further develop the skill to describe what is observed, for example, over many hours in the studio rehearsing a new piece and giving detailed corrections to dancers. Such corrections are most effective—that is, able to be implemented by a dancer—when they are qualitative (commands like "Create a 38.2-degree angle between your forearm and upper arm" are not very effective with human dancers) and objective (dancers cannot fix an aspect of movement that was not actually present and cannot create a new behavior without clear bodily instruction). Likewise, as we will summarize at the end of section 10.4 in chapter 10, movement analysis suggests a similar design process for robots that relies on evidence-based observation and notation, driven by the BESST System's taxonomy, and iterative ideation rooted in understanding the personal and contextual nature of meaning.

In this spirit, let us begin to practice that type of process. Less interpretive descriptions of the scene that we may offer are the following:

- The robot and the human share a common gaze.
- The human is standing close to the robot, craning his neck.
- The robot is *pointing instructively* at something in the distance.
- The robot is *leaning casually* into its human cohort.

These last two descriptions are essential because they identify concrete verbs and adverbs that the robot *seems* to be performing that build up to the larger, higher-level assertions—or *interpretations*—that come more naturally or immediately to a lay observer.

By describing bodily posture, the relationship between the two bodies, and the context of the scene, we are already *performing movement analysis*.

But so far, this analysis is weak. The assertion that the robot character is "pointing" is fully reliant on the contextual and situational features of the scene. Consider how you can confound the "pointing" classification: add a panel of buttons within the reach of C3PO's outstretched finger. Now this static snapshot suggests a different adverb and verb entirely: *carefully pushing* a button.

The taxonomy in part II provides some defense against this issue: it describes the movement rather than classifying or evaluating it. Armed with this type of language, descriptions of the scene can become at once more detailed and less reliant on context. An analysis of this scene, using the BESST System and formatted in a component constellation, is presented in box 9.1.[1]

The case study in box 9.1 demonstrates how the taxonomy enables unpacking of the lay descriptions previously given, which were laden with interpretation, to a description that is less embedded in a particular context or observation. The BESST System facilitates a more granular analysis that organizes itself along particular components with associated principles and uses. For example, the Effort component is used to analyze motivation and intent, while Body helps us understand the physical experience of being a moving body in gravity.

Note that this analysis is not unique or singular: many possible constellations are equally valid. It is simply the process of writing down what seems essential for a particular application. Initially, our analysis included more about the shape of Luke's neck and the relationship of the two bodies side by side (Luke at C3PO's left and C3PO at Luke's right), but upon further discussion, we realized that the meaning of this particular scene in this particular narrative would be the same if these elements shifted. For example, it does not matter if we switch the positions of Luke and C3PO, putting the robot actor into Luke's right side zone instead of his left. The resulting scene could still communicate the idea of collaborating on something that is at a shared point in the distance.

This scene represents many of the aspirations of roboticists today: seamless, harmonious human-robot collaboration. But it is important to remind ourselves that both the robot and the human counterpart are actors reading from a script, supported by directors and other crew members who work hard to make every moment in the movie meaningful to the audience. They are constantly reading the scene, adjusting the set design and reactions of

Box 9.1

Case Study 1: C3PO Helps Luke

- The robot and human share direct space effort, attending to a direction left-forward-middle with their focus, posture, and gesture.
- The human shares an overlapping kinesphere, in mid-reach space, with the robot, engaging in the basic body action of touch, as well as rotation and expansion of the neck, creating emphasis on his focus.
- The robot is bridging to the environment with a spoke-like directional mode of shape change, with all the distal digits of its arm extended in a relaxed gesture.

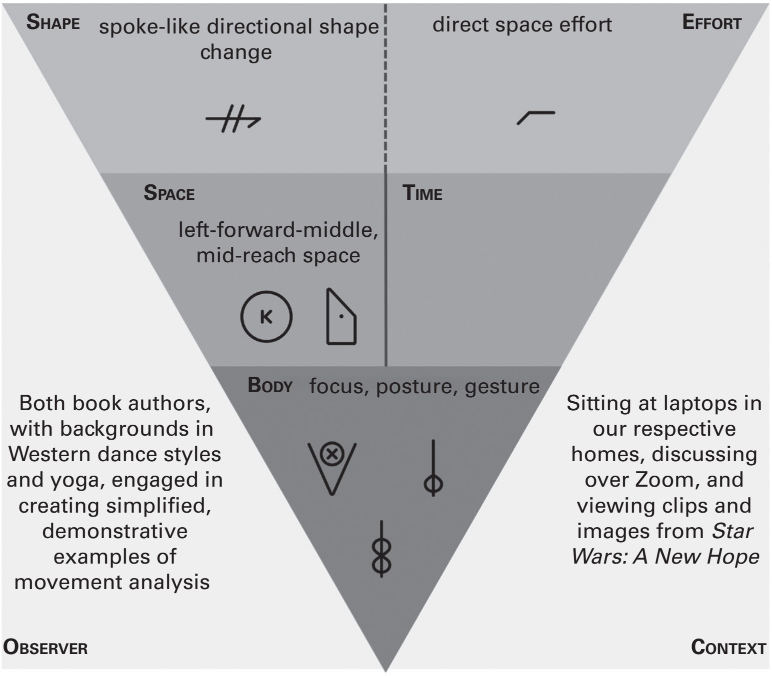


Figure 9.2

Component constellation for Case Study 1.

fellow actors to ensure that a coherent story of relationship is told. It is a galaxy far, far away from reality—it is powered by the performing arts!

The example of two actors casually leaning into one another does not feel like "dancing" or even seem particularly "expressive." It is a rather pedestrian, neutral moment plucked from an action-packed, propulsive plot. But the same taxonomy that describes this moment captures the behavior of social dancing. Using the BESST System to describe casual dancing or bouncing to a rhythmic tune, as in the case study in box 9.2, can capture a distilled essence of this kind of activity in order to explain how simple robotic platforms, such as the squishy yellow BeatBots Keepon or the DreamWorks *Trolls World Tour* dancing Branch doll, achieve a robust imitation of complex activity.

The imitation between bodies described and diagrammed in box 9.2 is a baseline capability in human-robot interaction (HRI): to create social confederates whose changes in posture, gesture, and other expressive elements communicate meaningfully to and from their human counterparts, an ability to imitate the actions that humans make well enough to be perceived as similar is needed. As such, imitation[2] is used as a baseline performance measure in many HRI experiments (e.g., see Gielniak et al., 2011; Simmons & Knight, 2017), and the similar, often unconscious, process of mimicry may be a foundation of human-to-human nonverbal interaction as well (Ashenfelter et al., 2009). Imitation is considered in more depth in chapter 10, which uses notation to clarify imitation across human and machine bodies.

9.3 Expressive Sensing and Perceiving Bodies

We see elements of ourselves in the world

Reading an excerpt from a childhood book aloud, which we can describe as a series of basic body actions of vocalization modified with various Effort configurations, will mean something different to people based on their prior experience (or lack thereof) with the same book. Prior experience will change a person's experience of the information, writ large on the page but digested with nuance by their bodies. A similar process occurs when viewing a piece of art, feeling an unusual texture, tasting an earthy wine, hearing a familiar melody, smelling an exotic perfume, or observing a moving body—a process that is accomplished through a combination of the senses. Sometimes you are drinking wine and sometimes you are not, but

Box 9.2

Case Study 2: Dancing across Bodies

Justin Timberlake (top component constellation)

- The performer Justin Timberlake singing his 2020 collaboration with Anderson .Paak, *Don't Slack,* bouncing to the beat of the song in a social setting (in our particular place and time) utilizes a combination of rotation in the proximal joints (e.g., hips and shoulders), bouncing up and down in space along his axis of length, parallel to his relationship with gravity, which enhances his experience of weight-sensing.
- He will typically try to match the tempo of this repetition with the tempo of the beat of the music, creating a satisfying experience of synchrony of kinespheres with other bodies sharing the space.
- Often he may begin bridging to these other bodies, using arc-like and spoke-like modes of shape change to indicate his awareness of his social counterparts. In addition, changing the dynamic quality—or effort configuration—of his motion quality can match mood to music and further communicate socially. In the music video for *Don't Slack,* Timberlake inhabits states associated with passion drive: rhythm, mobile, and dream states.

Keepon (lower left constellation)

- The simple Keepon robot is made of a soft, squishy yellow shell made of two conjoined spheres and affixed to a few linear actuators that telescope up and down in series, pinching the yellow form into various bends that mimic articulation. A popular video of the device shows it moving up and down along the vertical axis matched with the beat of a popular pop song. The subtle folds in the device's soft exterior shell suggest the kind of core deformation associated with shape qualities; we see rising and sinking in this action of the Keepon. Rising and sinking are also supported by the movement to high and low, respectively, reflecting affinities between Shape and Space. Although there is no true rotation or spine available to the device, it successfully imitates a human mover and can encourage shared movement in a social setting (Michalowski, Šabanović, & Kozima, 2007; Michalowski, Simmons, & Kozima, 2009).

Branch Troll Doll (lower right constellation)

- Beyond a mess of passively waving purple hair, the Branch troll doll (created as a unit of merchandise for the *Trolls World Tour* movie that featured the song *Don't Slack*) has only one or two actuated degrees of freedom to generate motion: a joint in the center of the doll's torso to which two lower and two upper limbs are affixed. As the motor rotates, it induces a weight shift related to the rotation of a proximally located joint. This action is matched to the beat and meter of *Don't Slack* that plays when the doll is in motion. Although there is no up and down translation in space, the device successfully imitates a human mover enough to create an entertaining doll.

Box 9.2 (continued)

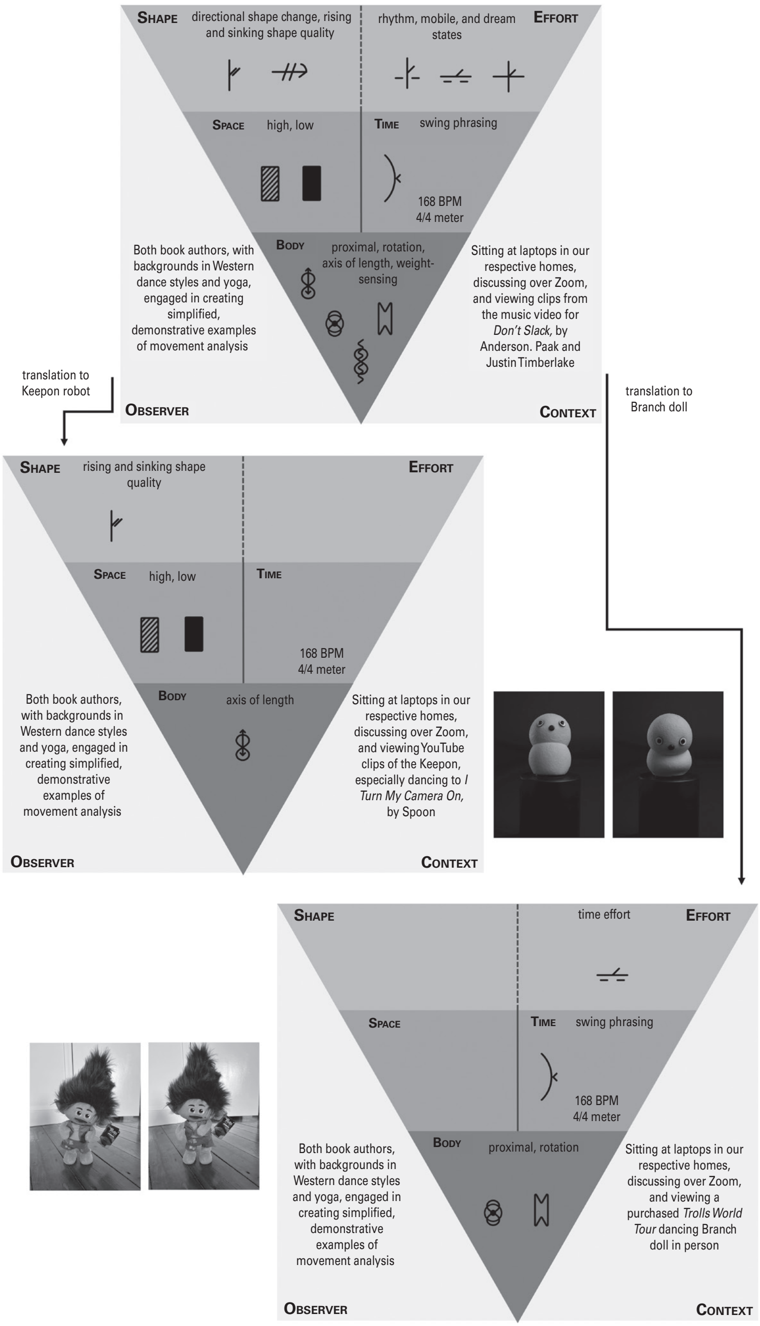


Figure 9.3

Component constellation for Case Study 2. Images of Keepon by BeatBots, LLC/Hideki Kozima/Marek Michalowski, used with permission.

you are *always* moving. It can be hard to consciously observe movement because of its constancy. Notice it right now: authors writing (fingers flying quickly across the keyboard, lips pursing and brows furrowing in concentration, ribs expanding with a dissatisfied exhale) and readers reading (eyes skimming lines of text, sit bones shifting weight in chairs, hands and arms reaching out to turn pages). Both require bodily movement.

Beyond bringing awareness to our constant motion, differences (and inaccuracies) exist in our individual perceptions. In 2015, an image of a striped dress went viral as people realized that two entirely different color profiles (white/gold and blue/black) were seen by viewers of the image of the dress online. Or consider the process of copy editing. Copy editing is a notoriously difficult process, as our sensory systems often see what we want to see, not what is actually on the page, allowing typos to slip by unnoticed. Thus, people do not always notice the environment accurately.

Even more, the conclusions that we draw from the same stimulus are often quite varied. Our cultural and societal context, as well as our personal preferences and experiences, inform this. Consider a close call under consideration by a sports referee. In American football, a "catch" is often characterized as requiring the player to have control of the ball. Sometimes referees make wildly unpopular decisions (e.g., they saw control where others did not, or vice versa); sometimes a play is genuinely divisive, with players, pundits, referees, and announcers in sincere consternation over what transpired (despite extensive replays and multiple camera angles). Such opinions may also be influenced by which team we are rooting for. *How do we know if a football player made a successful catch? How do we know if what we are observing is real?*

9.3.1 Human Senses and Sensing

There are many ways of "knowing" the world, and in movement studies, the body is considered the basis for knowing. We know because we move: we sense the world through our movement (from tiny saccades to larger changes in position to get a better vantage point), and we make sense of sensory information based on our unique, lived bodily experience. Developing our conscious attunement to these senses deepens our capacities not only as movers, but as perceivers:

> The more developed and thorough our capacities for receiving and responding to sensory information, the more choices we have about movement coordinations and body functioning. (Olsen & McHose, 2004, p. 16)

Traditionally, five senses (sight, sound, smell, taste, and touch) are recognized as the primary vehicles by which humans perceive the world; however, the "sixth sense" is that of proprioception, or kinesthetic sensing. Like the other senses, proprioception is another way that we decode and code information—not only through receptors in the skin, but the muscles, tendons, and joints as well. The word comes from the Latin word *proprius*, meaning "own," combined with "receptive"; it is a way that we sense through our own bodies "where" we are in space and in relationship to the environment. Movement is also perceived with sight, sound, and touch (and to a lesser extent smell and taste), all of which are explicitly utilized in somatic practice.

Many robots communicate through more than the visual channel. Researchers in HRI have proposed systems that use sound mirroring workspace tasks for improved localization during collaboration (Cha et al., 2018) and simulating various states of effort (Dahl et al., 2017). A measure comparing systems across several factors, including movement and sound, has also been proposed (Frederiksen & Stoy, 2019). Sound and movement, as well as a soft, cuddly exterior, engaging the haptic channel, were all used in the PARO device, a robotic stuffed animal shaped like a seal that has generated some of the most significant results in experimental treatments with human subjects of any therapeutic or "social" robot (Šabanović et al., 2013; Geva et al., 2020). Temperature is another modality that has been explored, where adding warmth has been shown to increase connection between human and machine (Park & Lee, 2014).

The Theragun is a handheld machine that delivers percussive therapy via a pumping action on the surface of the user's body. It is applied in varying speeds and pressures by the user or a massage therapist. Its purpose is to release muscle tension; help break down scar tissue and "sticky" fascia surrounding the muscles, enhance blood flow and lymphatic circulation, delay the onset of muscle soreness, and improve flexibility after vigorous physical activity. Its design allows it to be easily held and manipulated, and it becomes an extension of the arm/hand of the mover itself, increasing the pressure that is available to be applied to the body greater than the human hand alone could provide.

Through the haptic engagement of the machine with the body surface that it is being used on, the Theragun uses touch to increase kinesthetic awareness. This awareness brings the user into attunement with muscles, bones, and viscera—essentially, the inner contents of the body. This effect mimics foam rolling (where a user presses a part of the body that needs therapy into the sharply rounded surface of a foam cylinder), but with a very different energetic method. The device creates a distinct, strong sense of energy (which can be overwhelming to bring close to the body), which is part of the therapy: users can feel this energy, creating release and a heightened combination of pleasant and unpleasant sensations. Considering the somatic experience of massage with an artificial aid, as done in the case study in box 9.3, which is an example of leveraging a somatic strategy, can aid in designing and testing such a device.

The context of dance, and even the figures in this book, can emphasize a visual absorption of information through movement, but we experience movement through haptic channels as well (as the Theragun example demonstrates). Both the vibration and motion in our own body, as well as bodies in shared space, stimulate our sense of touch. In our own bodies, the skin forms a boundary between the motion of our internal organs and tissues and the motion manifest in the environment. This layer also provides a site for connection to other bodies in the environment. Likewise, all the senses are part of the observation of movement and contribute to our perception of meaning.

9.3.2 Perceptual Habits and Creating Narrative

What happens when a more intelligent agent meets a less intelligent agent? What happens when a more embodied creature meets a less embodied creature? For example, what happens when adults meet a tiny baby? The intelligent, embodied adult makes up a story about what the baby is doing (e.g., “Aww, she’s reaching for her mother” or “How sweet, she wants to play with her big sister”). Science offers little evidence that a newborn could have such complex intentions, and yet such a narrative is commonly ascribed to their behavior by playful and loving adults. A tiny reach toward any given individual can have a myriad of possible meanings, most of which fit a desired narrative of familial bliss.

This can mirror what happens when humans meet robots. Regardless of what ideas science fiction (and engineers working in the field) may create about the promise of robotics, human capacity outpaces that of artificial devices today—and probably at least for a very long time into the future—in terms of *both* intelligence and embodiment: our creativity, problem-solving ability, and effective improvisation in the face of dynamic, changing environmental conditions are unmatched and not even particularly well

Box 9.3

Case Study 3: Using a Theragun to Tap into the Haptic Channel

- The theme of Exertion/Recuperation is a way into understanding Theragun's popularity, particularly among athletes, as it enhances the recuperation phase needed after extensive exertion.
- The haptic disturbances created by the Theragun promote bodily healing, shortening the time required to rest and improving performance. In this regard, the machine mimics the basic body action of touch (kneading sore muscles, rubbing areas in pain), bodily behaviors that humans engage in and experience. Operators respond to their own sensations, partly (unconsciously) in a state of shape-flow and partly (consciously) invigorating their musculature, in order to guide the device. In some sense, the device is a mechanical solution for many of the hands-on practices of somatics, which encourage using massage and touch to develop a clearer relationship between mind and body, intention and action. In doing so, the machine allows the user to have increased access to the baseline of weight-sensing and flow-sensing.
- This difference in energetic methods can be analyzed through the Time and Effort components. The vibratory phrasing of the device-user pair creates a rhythmic structure within which the flow of the mover is released in response to the condensing, controlling action of the "hammer" head. In terms of Effort, these energetic changes most often live in configurations of rhythm state: combinations of weight and time effort.

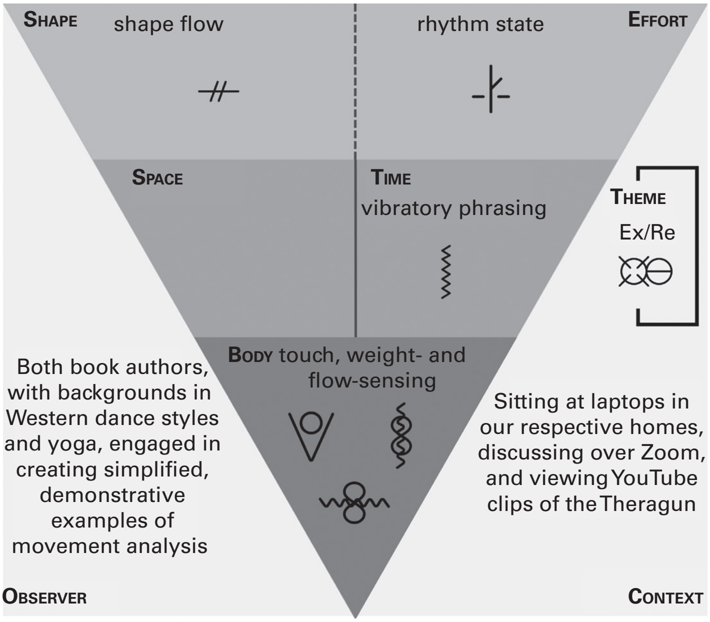


Figure 9.4

Component constellation for Case Study 3.

understood. And yet, when we see machines in the environment, we make up stories just as we do with babies (e.g., "Oh dear, what a pathetic little guy, running into the wall like that" or "How funny, it's waving at me" or "Oh no, it's going to kill us all!"). Each of these narratives may have nothing to do with the design of the device in question but instead reflects the narratives, perceptions, hopes, and fears of the observer. Thus, even robots that are not particularly complex machines may be quite expressive to humans. Or, as the French-Cuban-American essayist, diarist, and author Anaïs Nin (1961, p. 124) wrote: "We see things not as they are, but as we are."

This idea explains some of the impressions that users have of the simple robots that are slowly but surely making their way into consumers' hands. One of the most prolific in-home robot devices is the automated vacuum cleaner, the iRobot Roomba. While other companies have subsequently developed versions of this robot, such as Xiaomi, LG, Husqvarna, Dyson, Samsung, Neato, and Aztech, to name a few, this kind of device is colloquially often still identified as a Roomba, regardless of the developer's name. This commonly used robot, and the user's relationship with it, offer another example where it is possible to illuminate the influence of experience on perception—and how a simple, functional device can be quite expressive.

The Roomba is an autonomous robot designed to vacuum/clean the surfaces it moves over. It is essentially a disc with brushes and a suction capacity that allow it to stir up and remove debris. Some Roombas also have a mopping function that introduces the use of liquid to wipe the surface that it is in contact with. It utilizes lasers and cameras to achieve navigation and obstacle avoidance. In essence, it is designed to clean a floor, alleviating a tedious human chore. Even nearly twenty years after its introduction, the Roomba remains one of the few robots inhabiting many human-facing scenarios, leading to many interpretations of the device's motion by human observers.

What if C3PO, in the example in box 9.1, is replaced by the Roomba? Can this robot "point instructively" or "lean casually"? Probably not. From a mechanical standpoint, it accomplishes the function of moving across indoor terrain remarkably well; but from an information-theoretic point of view, the device has only its heading (angle of travel relative to the environment) to advertise anything about its internal state. Yes, this robot lacks human form, but even with a tail or ears, it might have a chance of indicating changes in internal state through visible movement, but it was not designed for expression.

Forgetting to use the lens of expression when designing a robot has meaningful consequences. For example, soon after deploying mobile grocery store inventory monitor robots, Badger Technologies found that customers preferred its Marty robot model (which has a similar expressive form as the Roomba: it can drive around and change heading, albeit in a larger, narrower form, a pin still shape form) when it had a large pair of plastic "googly eyes" affixed to it (King, 2020). Surprisingly, affixing a cheap, plastic, off-the-shelf decoration to these devices allows a more successful interaction and suggests that a better solution could exist if the lens of expression had been considered by engineers in the design of Marty.

Without the googly eyes, the Marty robot is a large gray monolith that glides in and around grocery store aisles. Due to the placement of its primary collision detection sensor (a mounted scanner), the robot moves with a consistent facing but can rotate with differential drive wheels, allowing it to navigate narrow spaces. However, to the lay human, there is little to differentiate one of its four sides from another: each is flat and gray, differing only slightly in terms of dimensions. Thus, without a clear visual fiducial, it can look like the robot does not keep a consistent direction of travel relative to its body. This ambiguity—or lack of spatial intent—can create an ominous presence for shoppers, who have reported it as "following them around the store" (even though it is not). Thus, the added googly eyes use a familiar visual signal (rather than an unfamiliar red line, say) and, with that simple augmentation, it is easy for shoppers to recognize and identify one side of the machine from another. Now, the robot becomes more expressive to (and more harmonious with) the human interactant as a consistent direction of travel is discernible.

A similar experience occurred for the robotics company Sphero, which made a ball-shaped robot—with perfect radial symmetry—that rolled around nimbly and could be controlled by human operators through a phone app. This initial product struggled to find widespread interest, but when Disney approached the company about making a mock-up of a new *Star Wars* character, BB-8, comprised of two balls, one that rolled on the floor and one that balanced atop this spherical "wheel," the company had a hit device on their hands. As with Marty, Disney's design provided the device with a physical form that identified its body, creating a consistent sense of top-bottom, left-right, and front-back through the asymmetrical decoration that now balanced atop the device. Box 9.4 provides analysis of these three robots: the Roomba, Marty, and BB-8.

Box 9.4

Case Study 4: Mobile Robots in Human Spaces

- From the lens of the Function/Expression theme, the Roomba and Marty provide a service (function) but many users who interface with them ascribe expression to the devices (largely through the way that the devices navigate the environment). This theme highlights the inseparability of function and expression: even devices designed only for functional ends express ideas through their movement.
- For example, when the Roomba is observed in users' homes, the path of travel (locomotion) of the machine can be observed, and its response to obstacles reveals its ability to redirect its pathway to continue on its way. Because it appears to be navigating and coping with the environment, albeit in the most simple and rudimentary of ways, the projection of human action on the part of the observer becomes possible. Moreover, the beeping noises the robot makes (a form of vocalization) when it gets stuck also reveal its inner state—a "cry for help" that allows the human to respond to the machine and further ascribe a narrative or personality to the robot.
- The simple augmentation of the googly eyes to Marty allowed it to take an identifiable form—a face (or a preferred direction for action and sensing) that creates a sense of front, back, right, and left, the spatial zones that the original design lacked. Now, the robot looks like it is *moving sideways to its right*, a much more salient, if odd, movement design that highlights the consistency in the device's operation, helping shoppers feel more at ease with, and a bit entertained by, the machine. The augmentation of the BB-8 with the second ball achieved a similar outcome. The form is now identifiable as having a face, and as such, zones of movement in space that are salient to human viewers.
- To consider the differences between the three robots, look at the still shape forms associated with each: Marty takes the form of a pin, while BB-8 and (to some extent) Roomba are ball still shape forms (Roomba could also be considered tetrahedral because of its stable base).

(*continued*)

Box 9.4 (continued)

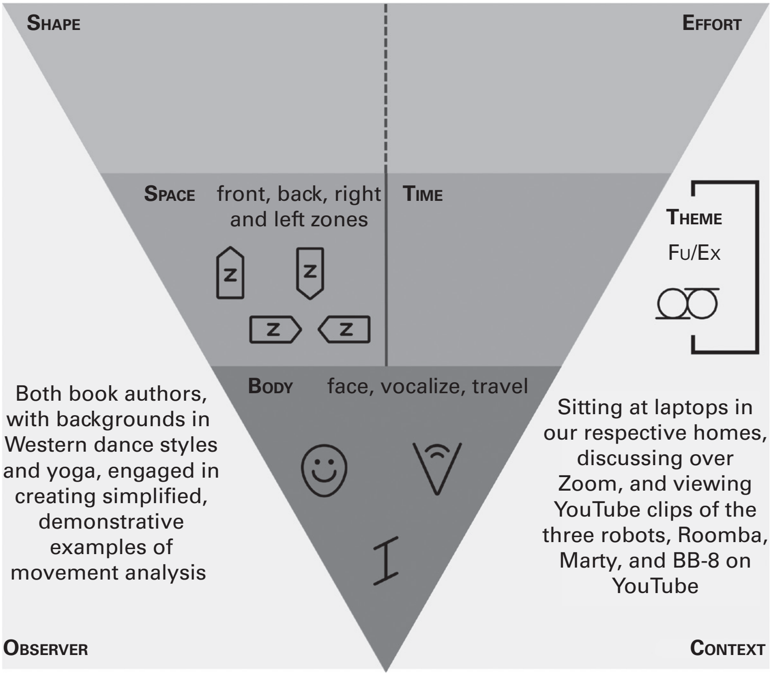


Figure 9.5
Component constellation for Case Study 4.

In addition to the features discussed in box 9.4, Disney's design gave BB-8 a back story and an array of characters (played by actors in the movie) that revealed a personality, narrative, and sense of animacy for the device through their reactions to its scripted behavior. Likewise, we worked with collaborators to affix simple augmentations to the iRobot Create (an open-source, reprogrammable version of a Roomba) to embed the device in a theatrical setting, as shown in figure 6.2 in chapter 6, eliciting reactions from audience members that were made possible by the more perceptible configuration space of the device and the human performers' reactions to it (Pakrasi et al., 2018; Berl et al., 2019). Similar work uses the frame of an animal to inspire mechanical augmentation (Singh & Young, 2012). Bacula and Knight (2019) use both animal inspiration and a theatrical embedding to develop expression with mobile robots. In all three cases, we may say that the new hardware designs employ a choreographic technology and a theatrical embedding to establish a perceptible and consistent orientation in the environment.

Just like the Roomba embedded in a theatrical setting, the scene with C3PO relies on the expertise of artists to make any sense. While it may not be effective at imitating any arbitrary idea, a Roomba, in real life, does not come equipped with a director, cinematographer, scriptwriter, or internal human actor to ensure that the scene reads with clarity. And yet, the Roomba is undeniably expressive to human counterparts (Fink et al., 2012)—even if not *as* expressive as other bodies (per the model presented alongside figure 7.5 in chapter 7). This example demonstrates how it is possible to perceive ideas of "intent," personality, and decision-making that are more complex than the device, which is powered by technology developed in the 1990s, actually employs. This speaks to the notion that wildly distinct bodies different from the human form can be perceived as expressive. The observer perceives the robot making decisions, mapping the space, and negotiating in a way that resonates with the human experience of movement in space. These three robots and the human come into communication through locomotion, navigation, and sound—and, most critically, *the complexity of the human's prior experiences with those modes of movement.*

9.4 Expression in the Environment

How context manipulates meaning

Consider an agent "moving from point A to point B"—a classic task in robotics. Without any additional objectives defined, such as minimum energy, the agent is free to traverse in many, many ways. We may say that the agent *moves freely*. Now, add one complicating factor to the task: the presence of a friend or an observer, which implies a social constraint. To solve this task, the agent should traverse from point A to B in a way that might look reasonable to or even entertain the observer or friend. You might say that the agent now *tries not to look stupid*.

Give the task an environmental context: see two examples in figure 9.6. First, consider that the agent needs to safely traverse a living room environment (right side) in the presence of a friend. Now the task imparts the functional element of avoiding the obstacles in the environment—continuing to have the expressive, social task of looking reasonable to the friend. Turn up the potency of that expressive task, requiring that the agent also communicate "anger" to a friend. Now, a solution might be for the agent to

Figure 9.6

Two distinct environments for movement. At left, a wooded, natural space with thick undergrowth and chaotic obstacles, and at right, a designed, interior space with distinct obstacles. Both inspire different movements and create different contexts for analyzing those movements. Two movers in this space will have kinespheres and dynamospheres joined by the shared context that become part of the environment itself.

stomp with heavy, sure-footed steps and *slash arms wildly in the air*. Such a pattern of behavior would likely alert a friend to a turbulent inner state.

Now return to the original task, getting from point A to point B in an isolated (not social) context in a new environment: a forest, covered in thick overgrowth (left side of figure 9.6). In order to move effectively through this thickly wooded environment, the agent must *stomp with heavy, sure-footed steps* and *slash arms wildly in the air*. Add the observer back to the scene. Does the observer perceive "anger" from the movement pattern? Likely not. Now, the movement takes on a functional lens and likely communicates something like "competency," or maybe "urgency," to the onlooker. The new environment changes the meaning of the motion.

To be complete, note that "the environment" can contain many factors not related to the flora of the biosphere or interior design of the building. People in the environment change what movements mean; the series of events preceding the current event changes what movements mean; and the culture and country in which the movement occurs—which carry their own conventions and politics—change what the movements mean. Thus, we describe all of this as *context*.

Interpreting the meaning of movement as this example has simulated is the goal of a growing area of research in AI. Explicitly modeling context can improve performance (Heimerdinger & LaViers, 2019), but the examples presented in this chapter hopefully highlight how the meaning assigned to any given movement is not fixed. Changes in context (human-facing environments are *dynamic*, the context is always changing), viewer (every human brings a different corpus of experience), and the mover itself (a rich, expressive body) create a moving target for artificial systems.

Yet there is some way that humans are frequently able to come to salience based on the actions of others in the environment, and thus it is a goal of the field of AI to replicate this. We would argue that this is also a problem of artificial embodiment. As we have seen in this book, knowing or interpreting the movements of others is rooted in our own experience. Thus, it is not just a matter of decision-making to determine the state of our counterparts, but actually our physical experience and expression of movement in context inform how we achieve this. That is, we do not observe movements and then come to a decision about what they mean. We experience movements inside complex environments and react to them in order to tease out more information through interaction.

Take, for example, the following movement: *clenched fist to chest, resulting in a concave core shape change around the sternum, and a flexion of the neck, essentially a bowing of the head*. This movement could have multiple meanings in different contexts. For example, it could mean:

- I am so angry that I am pulling my energy in before I explode.
- I am so joyful that I am taking in what I have just received before I open up to the world.
- I am surrendering to subjection and feel powerless to respond.
- I am so tired . . . I just want to hold my heart.
- I have really bad heartburn and am trying to mitigate it.
- I am choking on a piece of chicken.
- I have a stiff neck and upper back today and need to stretch.

Upon seeing the prescribed movement, we may not consciously have any of these possibilities in mind, but our body has experienced many of them, so they are part of our physical experience—our embodiment.

Being aware of this embodiment arises in applications such as using the motion of pedestrians to improve the sensing systems of autonomous vehicles. For example, detecting alarm in a pedestrian could alert the system to an unseen obstacle that is occluded by another car (Afolabi et al., 2018). We will see the same problem in chapter 10: many movement sequences can express the same idea, and many ideas can explain the same movement sequence. This creates technical challenges that so far are intractable. Gathering data to model human movement is one of the biggest challenges in this area. Some researchers have looked to YouTube, television, and the movies for "natural," "in situ," and "unconstrained" movement examples (Luo et al., 2020). Yet, as we discussed in the analysis of Luke Skywalker and C3PO in section 9.2, these samples of movement are highly edited, curated, and selective to develop media that is entertaining, and meaningful, for audiences.

Take, for example, the chore of cooking. Cooking is a daily activity required for human survival; as such, humans have extensive experience of engaging in this movement behavior. The context of cooking and meal preparation often is the kitchen, and most cooking involves imparting flavor through the use of spices to enhance the taste or nutrition of the food that the cook is creating. One famous chef, Emeril Lagasse, developed a particular movement phrase that became an important stylistic feature of his cooking style and helped to bolster his popularity: he would add ingredients with physical flair and punchy ingredient delivery, exclaiming "Bam!" as he added key spices to his food. Part of what makes this movement phrase (a sharp moment of condensing effort quality accompanied by the vocalization "Bam!") so attractive to so many is its play on dynamics and phrasing, which is *unexpected* in the context of cooking.

Lagasse's signature moment involved a pursed, contracted hand directed at the food that he was currently making, a dramatic pause, which included holding his breath, and then an exuberant, even careless, explosion of spice, as well as his breath, as he yells "Bam!" and his fingers flay out into an expanded, released state. The musculature that was holding in his viscera as he pulled in and paused his breath is released along with the spices. This arc is common to many moments designed to create drama: tension building, pausing at a climax, and a quick resolution. Lagasse, who was not a trained mover, expertly created this moment multiple times each show using his own expressive body, as analyzed in the case study in box 9.5.

Lagasse's signature "Bam!" phrase on his cooking shows becomes a salient moment largely through the context in which it occurs. Because he makes this

Box 9.5

Case Study 5: A Profile of Emeril Lagasse

- The “Bam!” moment, which is achieved both with vocalization and breath support, utilizing a held breath and a forceful exhale, generally is employed when adding spices to the dishes being prepared. He dispenses the spices with an impactive phrase that is simultaneously performed through a gesture and a postural shift. The left hand comes up, palm facing the audience, in front of his forehead while his right hand condenses with speed and force to impart the spices into the dish being prepared.
- The Effort component in relationship to the context in which the action is performed is one way of understanding the heightened impact of this movement moment. Through flow effort fluctuations coupled with constellations of awake state (space and time effort), the phrase unfolds and becomes impactive as the heightened moment of the punch (condensed expression of action drive) occurs at the end of the phrase.
- Cooking is often methodical and measured, but Lagasse turns that idea on its head by introducing a movement phrase that surprises the observer. Considering the component constellation here, it is also worth noting what is “not” there: for example, the lack of bridging to the environment using a spoke-like mode of directional shape change, a more typical method of carefully bridging to the environment and adding spices with more decorum that one might expect to see when cooking and using tools. Thus, in designing a cooking robot meant to entertain human observers (e.g., the one currently being developed by Moley Robotics), designers might consider this type of analysis. It is not intuitive, but by using less precise spatial focus—also called “legibility” and “predictability” in some HRI research (Dragan et al., 2013)—a more engaging and “humanlike” robot might be created.

(*continued*)

Box 9.5 (continued)

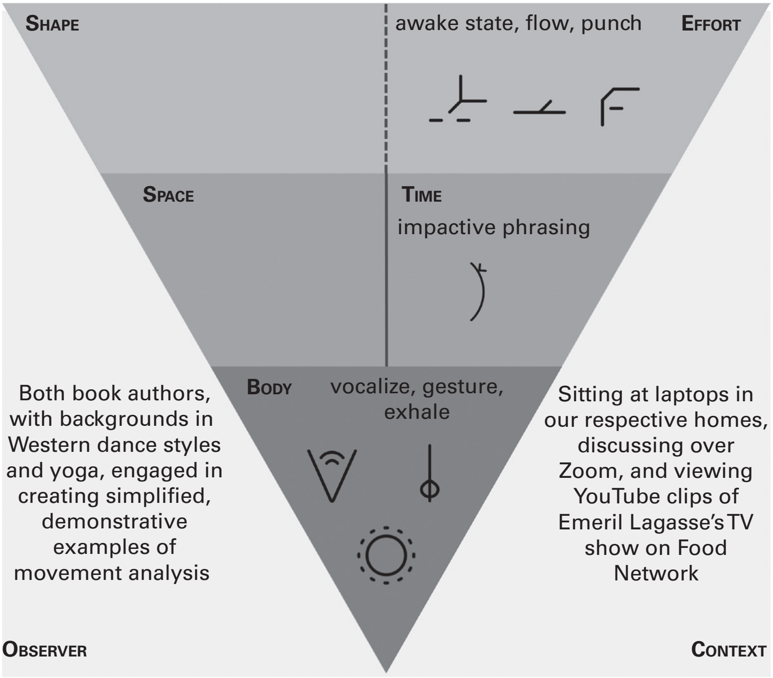


Figure 9.7
Component constellation for Case Study 5.

moment so much about energy, body, and time—but not space—his dynamic quality is different, producing a contrast to his other activities in the kitchen, which require more measured control and menial performance: chopping, wrapping, or tying. To create a moment of entertainment, he essentially "punches" the spices into the dish—with the heightened dynamic moment at the end of a phrase of less punctuated actions. This "surprise" moment becomes salient because it is unexpected in the context in which it occurs.

Lagasse's popularity is not purely a function of the amount of energy or movement he enacted; it has to do with *what* and *how* he communicated. We need a model that allows us to understand that this communication is personal, unique, and contextual. The next section aims to provide such a model to an engineering audience, looking away from traditional motion models and toward traditional communication theory.

9.5 A Model for Expression and Meaning-making

Information theory and the arts

Isaac Newton's laws have long been used by mechanical engineers to describe, model, and predict the motion of moving bodies. Here, motion is measured in meters (displacement), meters per second (velocity), or meters per second per second (acceleration). And yet these measures do not immediately relate to the informative aspect of motion. Imagine a hand outstretched to another human; if that extension of the hand takes one or five seconds, it likely relays the same *amount* of information (though requiring different amounts of energy) to a human viewer but may convey a different *message*. How should we resolve this as engineers?

Turning away from Newton's laws, because we are, all of a sudden, less concerned with the forces, torques, velocities, and displacements of a body, we look to the canonical model of *communication* set forth by Shannon (1948), loosely abstracted and adapted for our purposes in figure 9.8. This model enumerates three components to account for in the process of successful communication: the source, from which a message is broadcast by a transmitter; the destination, where a receiver decodes the message; and the channel, which may introduce variable amounts of noise that may alter the message at its destination. This theoretical model has been used to govern successful message transmission in the field of telecommunications. Shannon does not tell us how to come to meaning (Hidalgo, 2015), but coding/decoding are an apt analog to construction/deconstruction, as discussed in part I.

Consider that the source broadcasts a particular behavior. One way to quantify this behavior is using information, measuring, say, the number of bits needed to describe the message. Bits correspond to how many physical elements with an on and off state (e.g., a transistor or a light-emitting diode) are needed to encode the source's current state. This is an objective measure that models the complexity of the source's behavior: if the source can do only two things, we need only one light-emitting diode, or 1 bit ($\log_2(2)=1$) to indicate which state it is in, but if the source can do 100 things, we need 7 bits ($\log_2(100)=6.6$) and seven diodes. A model for describing not only the internal state of a robot with bits, but also its external state, was introduced in section 7.4 of chapter 7.

From the moment it is broadcast, this source message may then be decoded by a receiver with a different decoding scheme than the source

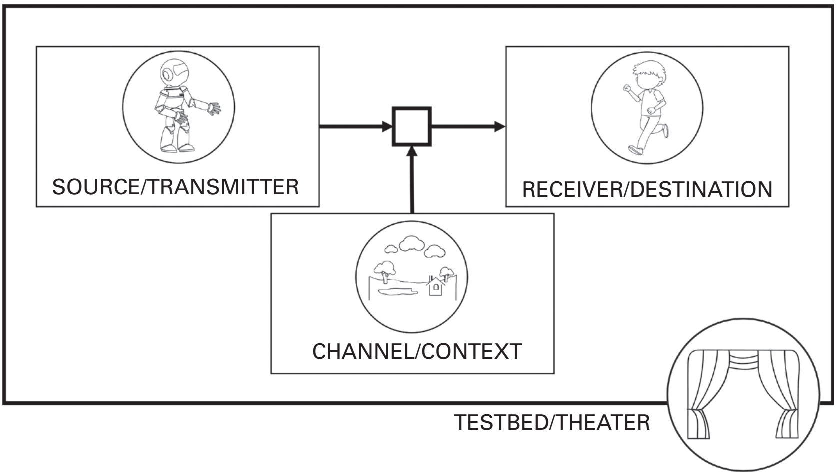


Figure 9.8
An information-theoretic model for understanding communication through movement. This model is based on the model for communication in (Shannon, 1948), which divides the process into a source, encoded by a transmitter that broadcasts across a channel (of varying "noisiness") and decoded by a receiver to get the message to a destination. As seen in this book, the performing arts is a perfect testbed to better understand this picture. This is also a useful frame for engineers to understand and systematize the methodologies used in this book.

used to encode the message, resulting in a different interpretation at the destination than was intended at the source. Moreover, the channel may introduce changes to the signal that is broadcast, again resulting in a message at the destination that is distinct from the one that was created at the source. But, when these models are aligned and dynamic error-checking schemes are successful, the message reaches its destination.

We can apply this abstract model—that has already helped develop robust mechanical and electrical systems for communication—to constrain the expected success of robots in creating and interpreting movement behavior, factoring in differences in perception across individuals as well as contextual measurements. If the source is simple and impoverished, there is a fundamental limit on how much can be communicated. On the other hand, the source can be as complex and rich as imaginable, but if the receiver does not have the correct decoding scheme, the intended message will never reach its destination. And, to extend the metaphor, humans should be modeled as destinations having their own unique, unknown, and constantly changing decoding schemes; therefore, each will make its own unique, transient meaning. These issues occur in every presentation of art. This is a core motivation that suggests to us that the arts—especially dance, with its focus on categorizing, classifying, and creating gross bodily movement profiles—constitute an essential resource of expertise for the field of robotics (Herath et al., 2016), artificial intelligence (Stark & Crawford, 2019), and human-machine interaction (Jeon et al., 2019).

In particular, the performing arts provide a natural testbed for teasing apart the complex interactions between human and machine counterparts. Jochum et al. (2016) applies this paradigm in the theater to better understand how caregiving robots might be understood by humans, positioning applied theater as an important tool in this long-term societal goal. Cuan et al. provide a model (2018) for embedding HRI experiments into live dance performance both on a proscenium stage (2019a) and in an interactive installation (2019b). Fallatah et al. (2019) discuss the challenges of handling machine failures in live performance, creating a taxonomy of four error types with distinct fixes. This type of work guides research in broader, public contexts as well (see Herath et al., 2017; Cuan et al., 2020).

9.5.1 Revisiting the Uncanny Valley

This way of viewing robots—as expressive devices whose internal states can be transmitted via a quantifiable number of bits—can reframe the commonly cited uncanny valley, in which researchers predict a dip in evaluations of likability after a certain point of lifelikeness in bodies. In the model of Mori et al. (2012), for instance, plotting likability as a function of realism, this feature (or valley) is even more prominent for agents that move, like robots, than for static sculptures or dolls. Put another way, machines in the uncanny valley have the wrong amount of "human likeness": if they were simpler devices or more convincing replications of real humans, the devices would become acceptable again. Jochum and Goldberg (2016) describe this result:

> Mori maps the relationship between affinity and human likeness on a graph, where the horizontal axis is the degree of an object's similarity to a living human and the vertical axis is the degree of affinity humans have for the object. Mori posits a non-linear function with a sharp negative extreme (loss of affinity) as likeness increases beyond a critical point (where phenomena start to appear "too close for comfort"). (p. 161)

They also describe how it is informed by art:

> This interest [in creating realistic humanoid robots] coincides with a renewed interest in mimesis and figural sculpture in the 1960s and 1970s that raised the threshold for the representational uncanny in visual art. Sculptures by George Segal (*The Dinner Table*, 1962), Frank Gallo (*Walking Nude*, 1967) and John D'Andrea (*Couple*, 1971) are human-scale statues that reproduce human anatomy in precise detail, provoking aesthetic defamiliarization that renders the human body simultaneously both familiar and unfamiliar. (p. 163)

In a broad sense, robot designers might understand the lesson as "Don't make your robot too lifelike." But in trying to understand the mechanisms at play in creating this challenge for robot designers, Jochum and Goldberg (2016, p. 165) highlight the role of the ever-evolving presentations in the visual arts in forming human impressions and opinions, creating a "shifting ground of the uncanny."

Further complicating Mori et al.'s model, we can consider the phenomenon's edge cases, remembering that the model aims to predict averages over a large subject pool. For example, the robot Sophia, built by Hanson Robotics, is a robot commonly cited as having an uncanny effect on viewers (Männistö-Funk & Sihvonen, 2018). Among other things, its eerily stretched rubbery surface that barely accommodates the motion of a mechanical hinge (meant to be re-creations of skin and a jaw) can leave a creepy impression with interactants. However, it is unlikely that David Hanson, Sophia's inventor, would consider the device creepy—he is proud of and familiar with the impressive device that he and his team have built! In fact, writing about the uncanny valley more broadly, he argues that simple (very unlifelike) robots can leave a similar impression (Hanson, 2005).

Robots judged to be "uncanny" may be seen as defying the media equation suggested by Reeves and Nass (1996). Although these devices are artificial, mediated, or symbolic representations of agency, they do not seem real. Likewise, Bartneck et al. (2020) stress the complexity of anthropomorphism, describing it as a phenomenon that relies on multiple factors, including culture. That is, the arrangement of the axes in Mori's plots trying to understand the uncanny is difficult to create in a repeatable fashion because what one person considers realistic or likable may be different for another subject.

The measure presented in this section (as well as section 7.4 in chapter 7), using bits to arrange different bodies against a single coordinate, might be a more repeatable characterization of moving platforms. Likewise, the BESST System establishes a middle ground between lay descriptions and measured quantities on which to evaluate a robot's movement: Does it have a consistent relationship to gravity (axis of length)? Does it exhibit an affinity between light motion quality and the vertical (high) dimension? Does it create a consistent sense of phrasing in its motion that allows observers to understand how many different actions it is performing?

Upon seeing the component pieces of movement, as described in the BESST System, we have found many possible interpretations for the same scene. Consequently, there is no universal measure of likability or effectiveness for any single device. So we argue that building robots with embodied movements that are meaningful to human viewers or creating systems that interpret the action of human interactants correctly are processes that will require extensive hands-on design from human engineers *and* artists.

9.5.2 Revisiting Movement Primitives

If indeed some sort of communication model can be used to understand human movement, what, then, are the symbols used in this correspondence? The typical way that researchers try to answer that question is with the notion of movement primitives (Bregler, 1997; Fanti, 2008). In chapter 1, we highlighted the pioneering work of Del Vecchio et al. (2003), who used motion primitives to describe human behavior. That chapter included the observation that "the same movement model used to generate robotic behavior through actuation can also be used to interpret the behavior of counterparts through sensing." This, then, is another way of phrasing the problem of understanding human movement, either for interpretation (as in AI, designing computer vision algorithms for human settings) or generation (as in artificial embodiment, manufacturing expressive robots): can we find a set of movement primitives that describe human movement?

This chapter has presented the usage of the BESST System to characterize movement somewhere in between "low-level" descriptions (e.g., the joint rotates 45 degrees) and "high-level" descriptions (e.g., the robot and human are friendly collaborators planning a trip together). This practice parallels progress in computer vision. For example, Saenko et al. (2012, p. 2) use "mid-level primitives" to capture "the structure of interactive verbs" and improve overall recognition of human movement. Researchers like this team and Del Vecchio's team are left to align these primitives with verbs from an English dictionary. As highlighted in the example of Luke and C3PO, however, the descriptive power and observational approach of lay human language are more contextual and personal than the BESST System's taxonomy as employed by Luo et al. (2020).

Motion primitives have also been used to generate robotic movement (Nakaoka et al., 2004; Belta et al., 2007; LaViers & Egerstedt, 2012; Lagriffoul et al., 2018). In these examples, as in the case of computer vision, there is a fuzzy line between researcher-defined primitives, based on their own somatic experiences, and mathematical descriptions, including those extracted from data. In Amy's own doctoral work, much of the design of a finite state machine came from a careful study of classical ballet and social dance forms that was both limited by her own bodily experience and also inextricably mixed with her understanding of what could be captured in a particular model. For example, warm-up exercises from the ballet *barre*, studied in a particular weekly course at the Atlanta Ballet, were simplified to create an "interesting enough" finite state machine (LaViers & Egerstedt, 2011). Disco dancing was similarly modeled, using observations of disco dance on YouTube in the early 2010s made by a person (Amy) trained in Western proscenium-based dance (not disco) using poses that were tacitly designed to read clearly on a Softbank NAO humanoid robot (LaViers & Egerstedt, 2012). We do not see how any purely objective and quantitative (e.g., mathematical) model could ever capture these aspects of experience that were embedded in the work to produce models of motion primitives. Likewise, in prior work using Labanotation as part of a scheme to specify robotic action (Abe et al., 2017), there is a large area where research and notator intelligence has to fill in the gaps in a way that is often tacit (and unacknowledged) in the work—and thus impossible to recreate.

Returning to the comparison between movement notation and music notation presented in section 2.3 of chapter 2, we need to acknowledge that the search for a set of motion primitives that explains human motion robustly still continues. This chapter aims to help illuminate why: meaning and salience in movement are not just about a mechanical structure in action but rely on many other factors. Even pitch—the mathematical description of which was not understood for hundreds of years after its invention—is an imperfect way of capturing the full phenomenon of music (Kelly, 2014). In this light, we encourage the subjective, qualitative analysis in the five case studies presented in this chapter, which use the whole BESST

System as a tool, as another approach for identifying motion primitives: the basic ideas in the Body component (e.g., basic body actions) are primitives that get modified by higher-order concepts of motion (e.g., phrasing and effort) that are represented farther up the inverted triangle shown in figure 3.4 in chapter 3 as well as the component constellations presented in this chapter.

What if we created a data classifier (see, for examples, Saenko et al. 2012; Peng et al. 2018; Wang et al. 2018) based on Lagasse's action? While researchers have made significant progress in object and movement recognition, open problems are highlighted through the lens of somatics and choreography (and revealed by our inability to robustly notate such movement). Specifically, the simplicity of extracted models and the confounding nature of context leave many open challenges in this domain, which may be helped by movement analysis.

First, note that these systems do not extract all the information about Lagasse's movement from the scene (not even all the information discussed in our simple analysis here): even state-of-the-art computer vision algorithms extract rigid, linklike skeletons (see figure 10.2 in chapter 10) that look more like robots than humans. These models ignore our fleshy viscera and rarely model breathing. Yet, as we have seen, our perception of Lagasse's breathing is part of how we identify the pattern of his movements—and relate it to our own somatic experiences. This demonstrates an important principle: the label set—or notational abstraction—that we use to describe the data impacts what can be classified.

A second problem is that Lagasse's behavior is filmed because of how *unusual* it is, not how *normal* it is. Thus, using classifiers built on his behavior will likely mischaracterize moments of cooking in real kitchens. Moreover, Lagasse's focus on a particular style of cuisine (e.g., Cajun and Creole), due to his own cultural context, creates a limited repertoire of actions: he is not folding dumplings, frying collard greens, or flattening flour into tortillas. This marginalizes communities with cooking styles that may not be prevalent—or even represented—in the training data.

The central design challenge for machines that will move with us (or observe our movements) is that unique embodied experiences create individual points of view for humans. When building a pedestrian bridge or designing a vegetable peeler, knowing the range of human weights or the widths of human hands is enough to create specifications that enable successful design. By contrast, creating movement on a robot that means the same thing to a wide variety of people requires understanding more than the physical measurements of their bodies. This design challenge requires an understanding of a myriad of complexities, including users' shared culture, distinct experiences, current environment, social context, and changing moods. In other words, designing a successful robot that functions correctly in a human-facing environment shares all the challenges of writing a best-selling novel, painting a masterpiece, and, perhaps most of all, choreographing a dance.

Chapter Summary

This chapter has presented examples of rich movement behaviors on both natural and artificial bodies. We have also used this space to consider research horizons in movement: challenging open problems and goals and how these can be reframed through the lens of movement theory. Finally, we described a model for understanding how information is transmitted through motion and contextually made into meaning by human viewers—a pair of distinct but interconnected processes that will help guide us as we work to broaden the expressive capacity of robotic systems to interpret and generate complex movement profiles. To this end, in the next chapter, we introduce notation that serves as a tool for identifying distinct movement styles and analyzing the meaning of movement.

10 Notating Movement: Advanced Analysis through Symbolic Representation

What does it mean for two distinct bodies to "do the same thing"? The answer depends on your representation—that is, on your *notational abstraction*. This chapter will compare and contrast various forms of movement representation. In so doing, it creates an opportunity for the reader to more deeply observe motion and provides tools for translating movement ideas between distinct bodies. It also reinforces the notion that training and context affect what we observe about movement.

Chapters 1 and 2 both ended with attempts at grappling with notation, and the chapters in part II introduced symbols for the taxonomy presented. In chapter 1, we painted two distinct pictures of noticing movement: one as a quantitative, objective record (section 1.2) and one as a qualitative, subjective record (section 1.3). In wrapping up the chapter (section 1.4), we offered readers an immediate, intuitive inroad to notation, kinesthetically attuning to movement through unstructured line drawings, motivating that this act of recording was a bridge between the two approaches: the line drawings were certainly subjective (being given very little structure or convention), but they also reflected objective features that were observed (like a change of direction or increase in pace). In chapter 2, we shared the plight of choreographers like JaQuel Knight, who have little ability to protect their intellectual property due to the lack of abstract, reproducible record keeping associated with human movement.

While Knight turned to the system of Labanotation as a tool in his quest to record his choreography, in this chapter we turn to *motif*, a system that aims to be more abstract than Labanotation—and therefore reproducible across bodies (as leveraged in the research described in section 5.4 of chapter 5). We even suggest that a motif of Knight's choreography could provide greater protection to his intellectual property because its abstraction applies better across distinct bodies. Thus, if an eight-legged robot was performing

Knight's work, a motif would reveal this similarity. However, as we know it today, motif is too broad and flexible to be applied in this way. Thus, we suggest a series of new conventions for the form that could aid in this task. This chapter ends with opportunities for the reader to practice notation for themselves.

10.1 Types of Movement Recording and Systematic Notation

Technology for capturing movement events and experience

Technology enables us to record aspects of movement events, but notational systems have a higher calling, requiring symbolic abstractions that record ideas with enough specificity to translate to another instance of performance. Musicians have such a tool and therefore can use a largely agreed-upon notational system to document their creations. Dancers and movement practitioners have many tools that attempt to capture movement abstractly, but none with the same level of success or widespread adoption. This is not because dancers have not been working on the problem for as long, but because the problem is much harder. The space for exploration is bigger and more complex in the human body than in a given human-built instrument. This section reviews technological and notational systems for representing human movement.

10.1.1 Recording Systems

Movement analysis led to an invention with widespread application in many creative and scientific pursuits: motion-picture recording. Eadweard Muybridge was curious about whether a horse maintained one hoof in contact with the ground throughout its gait cycle. As a horse runs faster and faster, this becomes harder to discern with certainty; so Muybridge (1887) used an existing recording method, still photography, and took many, many pictures very close together in time, resulting in a strip of images that when laid left to right (showing time progressing to the right) revealed new insights into animal gait. From there, the idea of rapidly spinning these closely shot photos in sequence, creating the illusion of movement (as in figure 10.1), evolved into what we now know as video recordings (Laurier, 2013).

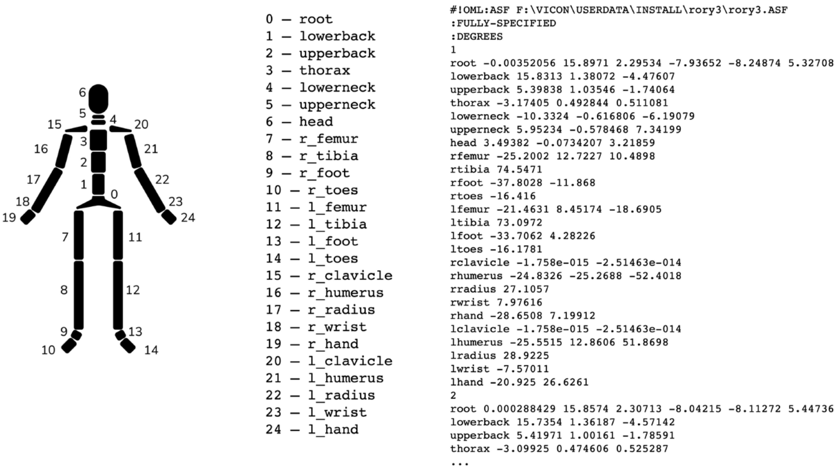
Today, video remains the best and most used format for recording, sharing, and preserving choreography and other movement phenomena. Dancers use the medium to keep track of rehearsals, and biologists use it to

Figure 10.1

Exhibits in the Science Museum of Virginia. These exhibits explain how a series of still pictures can be used to record movement. Left: Muybridge's famous experiment, studying horse gait with rapid succession photography, is used to create a wheel that allows the participant to manipulate a series of static horse images into a sense of a running horse by spinning the wheel. Right: A participant controls the frame rate in video playback via a mounted dial; slowing the frame rate allows the participant to notice details of movement not evident in real time.

record and study animal behavior. Video has also become a rich format for the arts, with movies, television shows, and documentaries used to express all sorts of ideas native to the two-dimensional format of video. All these formats are possible since video gives us information that photos do not—namely, how the subject is moving and changing over time.

Motion-capture systems used by research labs and movie production studios (figure 1.2 in chapter 1 and figure 10.2) allow us to expand beyond the limits of two-dimensional recording, capturing a three-dimensional recording of a movement event. These systems use passive, reflective markers or active, instrumented markers worn on the body of the subject to capture its movement. Then, the systems use a redundancy of cameras or other sensors to capture movement from multiple angles for three-dimensional re-creation. Sometimes these systems are paired with traditional video to reveal further depth of detail, (e.g., Carnegie Mellon's "panoptic" studio (Joo et al., 2015)), fusing data from multiple sources; or they are used alongside the BESST System (e.g., by leveraging shape qualities to improve the



```
0 — root
1 — lowerback
2 — upperback
3 — thorax
4 — lowerneck
5 — upperneck
6 — head
7 — r_femur
8 — r_tibia
9 — r_foot
10 — r_toes
11 — l_femur
12 — l_tibia
13 — l_foot
14 — l_toes
15 — r_clavicle
16 — r_humerus
17 — r_radius
18 — r_wrist
19 — r_hand
20 — l_clavicle
21 — l_humerus
22 — l_radius
23 — l_wrist
24 — l_hand
```

```
#!OML:ASF F:\VICON\USERDATA\INSTALL\rory3\rory3.ASF
:FULLY-SPECIFIED
:DEGREES
1
root -0.00352056 15.8971 2.29534 -7.93652 -8.24874 5.32708
lowerback 15.8313 1.38072 -4.47607
upperback 5.39838 1.03546 -1.74064
thorax -3.17405 0.492844 0.511081
lowerneck -10.3324 -0.616806 -6.19079
upperneck 5.95234 -0.578468 7.34199
head 3.49382 -0.0734207 3.21859
rfemur -25.2002 12.7227 10.4898
rtibia 74.5471
rfoot -37.8028 -11.868
rtoes -16.416
lfemur -21.4631 8.45174 -18.6905
ltibia 73.0972
lfoot -33.7062 4.28226
ltoes -16.1781
rclavicle -1.758e-015 -2.51463e-014
rhumerus -24.8326 -25.2688 -52.4018
rradius 27.1057
rwrist 7.97616
rhand -28.6508 7.19912
lclavicle -1.758e-015 -2.51463e-014
lhumerus -25.5515 12.8606 51.8698
lradius 28.9225
lwrist -7.57011
lhand -20.925 26.6261
2
root 0.000288429 15.8574 2.30713 -8.04215 -8.11272 5.44736
lowerback 15.7354 1.36187 -4.57142
upperback 5.41971 1.00161 -1.78591
thorax -3.09925 0.474606 0.525287
...
```

Figure 10.2

Example of a motion-capture data structure. This data structure is used in multiple types of capture systems, including three-dimensional capture with active and passive markers (e.g., Natural Point's OptiTrack, seen in figure 1.2 of chapter 1), as well as skeleton extraction from depth cameras (e.g., Microsoft's Kinect Azure). Typical skeletons extracted have tens of degrees of freedom to model human motion, although some specialized applications use more detailed designs. Each joint (left) is given an anatomically inspired name, as listed in the skeleton file (center). Then these joints are animated with a data file (right) that determines the angles over discretized time steps with a very high frame rate. The right side of figure 8.5 in chapter 8 shows an example of motion-capture data. *Note*: this model leaves out many known joints (e.g., the vertebrae), and actual human joints are not accurately described by a simple single degree of freedom with fixed axes of rotation, as modeled in this data format.

immersive experience (Swaminathan et al., 2009)). However, even these formats are limited by the level of detail in the motion models used to explain the data. Most use a rough model that focuses on distal skeletal action, leaving out the fleshy expansion and sound of breath, the familiar twitch of skin over excited muscles, and the smell of perspiration—all of which may affect how a human notator represents the same movement—producing a highly repeatable but simplified recording system.

10.1.2 Notational Systems

Since as early as the 1700s, movement notation systems aimed at gross bodily action (as distinct from music notation which began thousands of years prior) have been developed for various purposes. Often, notation systems are linked to musical scores and are primarily concerned with noting a singular event for the purposes of recording, preserving, and reconstructing choreography. The goal has been to document actual and specific movements for reproduction of artistic work on able-bodied human performers. For example, *Afternoon of a Faun*, a famous ballet choreographed and performed by Vaslav Nijinsky in 1912, before video recording, is often recreated from notational scores made of Nijinksy's performance of the work (Guest & Jeschke, 1991). Moreover, several types of movement notation have been used to program robot motion (Laumond & Abe, 2016). Several systems of notation are listed and briefly described in box 10.1.

As described in chapter 2, we can even consider the first forms of music notation, which were hugely important technological innovations of their time, as forms of movement notation. Tablature told musicians where to pluck instruments as a way of recording song (Kelly, 2014). This system is found on early cuneiform tablets dating to around 2,000 BC (The Schoyen Collection, 2022). This was before more abstract concepts (e.g., the neume and note, developed by monks working to record the performance of religious songs and chants in the Middle Ages) led to modern notation. The mature notation that we know today records enough information about the song that a trained expert who has never heard it can reproduce it well simply by reading the score. Moreover, it can be used across instruments, including with the human voice, and in this sense, we have described it as being *platform-invariant*.

This notation requires an abstraction away from the physical performance of the act (as the way to make a C note on any number of instruments requires a different movement) and emphasizes pitch and rhythm over things like emphasis and performance—areas where modern performers can distinguish their own versions of the work. In such a sense, we can consider modern music notation having a singular goal in sound, but a wide multiplicity of possible prescriptions in movement. Likewise, when we ask a machine to imitate a feature of human movement, we need a relaxation of how the movement can be performed due to the distinct anatomies of the movement platforms. While Labanotation and similar systems work to allow someone who has never seen a dance understand what it is, they do not afford executions on bodies of distinct morphologies in the same way (thus we can say that they are *platform-specific*). The notation relies on a

Box 10.1

Types of Movement Notation

- **Beauchamp-Feuillet:** Beauchamp-Feuillet notation was published in the early 1700s and was created to notate Baroque dances of the period so that courtiers could learn the dance sequences and perform them well when visiting the royal court. This system notates the steps of the mover along a floor pattern that the dance utilizes. In addition, the musical score is written across the top of the page and linked to the steps happening at specific points in the music.
- **Zorn:** In the mid- to late 1800s, Friedrich Zorn created a notation system, also linked to musical scores, which consisted of columns of figure drawings under each bar of music, showing the floor pattern and the progression of the dancers' form. Zorn's primary goal was to record dances that had already been made to preserve and reconstruct them.
- **Labanotation:** Labanotation was developed, initially by Rudolf Laban in the 1920s and further codified by many others, most notably Ann Hutchinson Guest (2013), to record the body moving in space. While created primarily as a means of recording choreography, it has been used to record human movement in other contexts as well—and even used to program robot motion (Abe et al., 2017). It is organized as a vertical staff, with the center line indicating weight support through the legs, and it is read from bottom to top (i.e., time moves up the page instead of left to right). Each subsequent staff line, extending right and left from the center line, organizes actions of body parts from proximal joints out to distal limbs, reflecting the bilateral symmetry of the human form. It is focused on recording already created and/or observed movement (see figure 10.3 for an example). Many Labanotated scores also reveal the progression of accompanying music alongside the movement notation. It is also used in documenting intellectual property for choreographers like JaQuel Knight, as described in chapter 2 and in (Milzoff, 2020).
- **Benesh:** Developed by Joan and Rudolf Benesh in the 1940s, this notation system was developed particularly for recording ballet choreography. The notation appears and is read similarly to music notation: that is, five lines on a staff read left to right. Each line on the staff represents a part of the body (from the floor and the bottom of the staff: foot position, knees, waist, shoulder, and head). Each "frame" (analogous to a musical note) records the dancer's positions in sequence. This structure creates compatibility between the movement and musical score, allowing Benesh notation to be written directly below and read alongside the musical accompaniment.

(*continued*)

Box 10.1 (continued)

- **Eshkol-Wachman:** In the late 1950s, a team out of Israel developed what is known as the "Eshkol-Wachman notation system." This is the first notation system that was created to be used both on paper and in the computer. Concerned primarily with joint angles and rotation, the system utilizes geometric models with a spherical system of coordinates. It has been used to study nonhuman movement and has no specific relationship to music as the previously mentioned systems do.
- **Motif:** Emerging out of Labanotation and using many overlapping symbols, motif developed inside the evolution of Laban/Bartenieff Movement Studies (LBMS), with a focus on capturing salient and essential aspects of movement and movement patterns. It can be used to create, record, and clarify movement action and intent. Many symbols have been added as active practitioners find needs for new symbols that support their particular application. It has also been used to specify robotic motion, across distinct platforms, as described in section 5.4 of chapter 5 and in (Jang Sher et al., 2019).

one-to-one correspondence between bodies, as used in methods that translate Labanotation scores for robotic movement (Salaris et al., 2017). This is an aspect of ableism—assuming that everybody has two arms, two legs, a wide range of motion, etc.—that limits our extant notation systems (our technology) for translating movement between distinct bodies.

In other words, we do not know (or don't agree on) what "middle C" is for moving bodies. On the one hand, motif will not give us the level of specificity and detail of the movement notation schemes described here. On the other hand, it will not require the same physical features of the body implied by these systems. Notice that the free-form wiggles introduced in section 1.4 of chapter 1, which did a surprisingly good job of recording movement, do not imply a specific platform on which the movement needs to be performed. For this reason, we have found motif to be a useful tool for translating movement ideas across bodies compared to more formalized types of notation. We will also propose some new conventions (in section 10.4) that improve the consistency with which motif may be used, attempting to bring it closer to something like the powerful abstractions of music notation.

Figure 10.3

An example of a Labanotation score. Left: The mover (Cat) starts by standing with her legs underneath her hips in a neutral stance while her arms are relaxed alongside the body. The mover then bends her knees, or *pliés*, while her arms shift. The mover then rises to *relevé* while both arms shift asymmetrically. The mover takes two steps forward, and her arms widen symmetrically and then she takes two steps to the side while her arms form an asymmetric frame around the mover. Then, the mover steps her feet together with a final flourish of her arms. Right: The score is read as if the mover is walking on it (bottom to top). It begins with place middle for the right and left legs (the lowest position of the center columns) and indicates right-low and left-low for the arms (the lowest position of the outside right and left columns, respectively). Next, the leg columns indicate place low to represent the *plié*, and the arm columns describe side-middle to place high (for the right arm) and forward-middle to place high (for the left arm). For the *relevé*, the score indicates both legs in place high, with the arms returning to side low (right and left, respectively). Next, the legs begin stepping; this breaks the phrase into two symbols three different times: first the two steps forward (right leg forward-middle, followed by left leg forward-middle in the center right and left columns, respectively), then the two steps to the side (right leg side-middle, left leg side-middle), and finally stepping together (right leg back-middle followed by left leg place middle). During the stepping pattern (the last half of the score), the arms are given various spatial directions, both symmetric and asymmetric, which is reflected in the symmetry and asymmetry of the score. The column corresponding to the right arm reads: right-forward-middle, right-side-middle, back-low, and then right-side-low. The column notating the left arm reads: left-forward-middle, place high, back-low, and then left-side-low. Here, the spatial symbols (the same ones presented in figure 5.2 in chapter 5) are analogous to musical notes. The lengthy description in this caption belies the richness of even a very simple score. At the same time, the score represents only part of what the human mover did. For example, the focus on spatial directions leaves out aspects of motion quality, demonstrating how training, taxonomy, and symbolic representation create a bias in what is observed and what can be transferred to other bodies. At the same time, the authors' training (e.g., in ballet) biases how we use the elements of the score (in both reading and writing).

10.2 Introduction to Motif

Notation for determining the essence of a phrase of movements

The symbols utilized in motif derive in large part from those used in Labanotation, but as the BESST System has evolved, new symbols have been created to reflect the evolution of the system and better capture essence in movement expression. Throughout part II, we introduced our own preferred set of symbols in the context of technology design. Books and practitioners working in different applications use slightly different symbols and conventions that we have used and also edited, leaning heavily on the symbols in Guest (2000) and Studd & Cox (2013/2020).

Motif is used to both create new movement phrases and discover new patterns, or to capture the essence of an already created movement event. The goal is to understand new movement experiences, as well as to clarify and communicate intent and expression of movement. The idea is to find what is essential, recognize patterns, establish context for, and identify the intent of the movement expression (see box 10.2 for a detailed list).

The idea of motif is not to record the details of a singular, reproducible movement event, but rather to discover patterns that express what is crucial to the event, both as perceived by the observer and experienced by the mover (noting these may be different). Thus, there is a many-to-many relationship between any given movement sequence and any given motif. This creates an opportunity for translation between bodies, for creative transformation and genesis, and for a finding of the essence (or meaning) of a particular sequence for a particular observer. That is, many, many movement sequences can be said to be described by the same motif, and many motifs can be said to describe any given movement sequence. Similar to the scribbling exercises shown in figure 1.4 in chapter 1, this creates a broader opportunity for using notation for reflection, learning, refinement, and the creative process.

10.2.1 Types of Motif

There are different styles of writing motif—or three types of *staffs* onto which symbols may be placed to create the notated score (see box 10.3 and figure 10.4). Different contexts befit different staffs depending on what needs to be revealed, communicated, and understood. The component constellations used in the case studies in chapter 9 are examples of motif as

Box 10.2
Uses of Motif

Notate and notice movement

- Capture, or visually represent, movement patterns and sequences, with a focus on the core essence rather than every detail
- Deepen awareness of a particular movement event
- Create a tangible, concrete artifact of the ephemeral, fleeting movement phenomenon

Construct and design movement

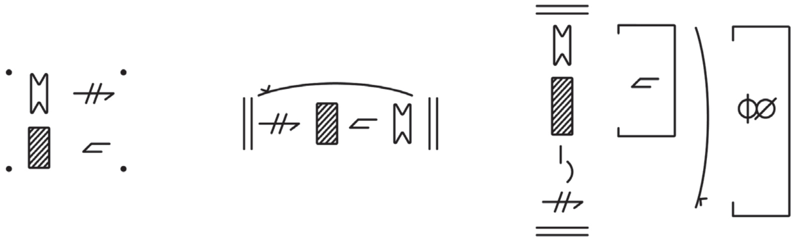
- Help to find, create, and iteratively design new patterns of movement, including developing a more refined physical performance of the sequence, bringing experience and expression into closer alignment
- Illustrate the contextual relationship between movement elements (i.e., foreground what is the core action and background what is a modifier)
- Clarify the relationship of parts to whole by recognizing large, overarching patterns, despite the more minute patterns within, that support the whole expression

Interpret and share movement

- Reflect choice (both of the mover and of the observer/notator of the movement)
- Assist with coming to a shared perspective, across multiple observers, in the process of observation
- Transfer the same movement sequence across distinct (human and machine) bodies

well; we say that they use a **triangle staff.** There are three additional styles commonly in use by Certified Movement Analysts (CMAs) today.

The **constellation motif,** which uses the **constellation staff** (see the left side of figure 10.4), is a group of "ingredients" that are present in the movement event. It reveals elements essential to the movement, but it does not reveal order, frequency, or duration. It simply notes that all these things must be present. It can be understood as the list of ingredients needed to prepare a recipe, but it is not the recipe itself. As such, all listed elements are equally important to revealing the movement event. Any symbol can be used in a constellation motif to indicate an idea that is present. The



Constellation motif Horizontal motif Vertical motif

Figure 10.4
Three types of motif. Types of motif using symbols for rotation, high, an impulsive phrasing bow, spoke-like directional mode of shape change, bound and direct effort quality, and, in the vertical motif only, the Stability/Mobility theme. Left: a constellation motif. Center: a horizontal motif. Right: a vertical motif.

component constellations used in the case studies in chapter 9 are similar to this more traditional type of motif, adding in the structure of the BESST System outlined in figure 3.4 in chapter 3.

The **horizontal motif,** which uses the **horizontal staff** (see the center of figure 10.4), indicates essential elements and adds information about the order in which the actions occur. It can be useful when the central action is the primary expression and does not necessarily require additional details to be understood. While some modification support is possible (e.g., phrasing bows that reveal segmentation of parts that belong together inside the larger expression), it can be cumbersome in this format. The horizontal staff also allows understanding of the beginning, middle, and end, but it does not give any information about the duration of those parts of the phrase. It is written from left to right across the page, bounded by double bars on either end. As in the constellation motif, all elements are equally important, but the order in which they occur (in time) is delineated.

Finally, the **vertical motif,** which uses the **vertical staff** (see the right side of figure 10.4), reveals essential elements, the order of occurrence, and the relative duration of actions and events. It also allows the modification of primary actions (in the central column) with other things that are supportive in adding richness to the essential action (columns may be added to either the right side, the left side, or both). Most notably, in the vertical motif format, multiple modifiers and phrasing bows can be used to reveal emphasis, tone, thematic information, and more. It is written from the bottom of the page to the top.

Thus, the three types of motif commonly used in the LBMS community are listed in box 10.3 and illustrated in figure 10.4 using symbols from the BESST System introduced in part II: rotation from Body, the high spatial pull from Space, an impulsive phrasing bow from Time, spoke-like directional mode of shape change from Shape, and bound and direct effort quality (along with an added layer of thematic information, Stability/Mobility in the vertical staff).

Motif can be rudimentary or complex, general or detailed; the notator has complete control over deeming what is essential. This is what is beautiful and befitting about motif, especially for our purposes of technology development. Rather than trying to write all the details of a specific movement instance (on a specific mover), as Labanotation and similar systems do, motif encourages the notator to make choices about what is essential to the core idea of the phrase. This is true in all three formats of motif, but the inclusion of relative duration in vertical motif makes it appealing as a potential format for a detailed and sufficiently abstract system of notation for translating movement phrases between natural and artificial bodies.

Box 10.3
Types of Motif

- **Constellation motif:** The constellation staff uses the form of four dots in the corners of a square with elements contained within. It is useful for capturing the mood and tone of a cluster of movement ideas; there is no specificity of temporal relationships.
- **Horizontal motif:** The horizontal staff uses two bars at the beginning, then a sequence of symbols left to right in time, and finally two bars at the end. It is useful for capturing sequence; there is no specificity of relative duration or ability to modify the main action.
- **Vertical motif:** The vertical staff uses two bars at the bottom (the start) and the top (the end). A sequence of symbols is written up the page between these two pairs of bars. Modifying symbols may be placed to the right or left of this central column containing the “main action” (or most important ideas about the movement expression). Single bars can be used to indicate the start and end of phrases within the longer sequence. It is useful for capturing more details of a sequence; it is more laborious to create than the other two motifs.

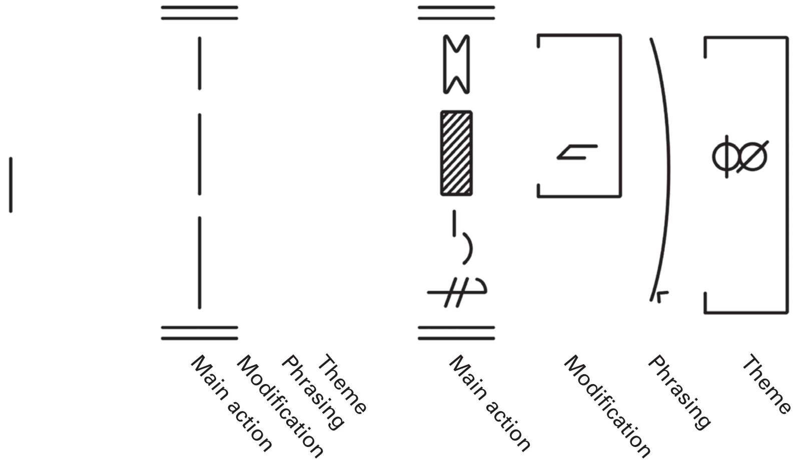
We do not yet know how to notate movement as we notate music; that is, how to create an abstract score that communicates a dance to a dancer who has never seen it—and may not even share the same bodily configuration as the dance's choreographer. Whereas the same piece of music can be played on any number of instruments, movement scores and robotics programs tend to be platform-specific, just like early forms of music notation (like tablature) were. Somewhat relatedly, these tools bear less formality and established convention than modern music notation. In this book, we take liberty with this openness and propose some new conventions for motif (see section 10.4) that we feel better align with the corpus of theory presented here and are particularly useful in our work with machines.

10.2.2 Vertical Motif: Action Stroke and Its Replacements

Constellation and horizontal motifs can be created rather straightforwardly from the symbols given over the course of part II, but vertical motif, which offers the deepest level of detail, needs a longer discussion. The easiest way to begin practicing vertical motif is to begin with the **action stroke** (illustrated on the left side of figure 10.5). There starts the essential designation and the first step in revealing a *perceptual* pattern: the differentiation between *action* and *no action*. Action is indicated by a line and no action is indicated by empty space. These simple notations offer a great deal of information about the movement event by identifying the number of actions and by segmenting how they unfold over time in a given movement event.

When writing vertical motifs, the option to replace and modify the action stroke with more specific symbols is available. Action strokes can be replaced by or modified by the set of symbols that were introduced throughout part II of this text. Themes, as well as phrasing, can be represented symbolically, but these symbols do not replace an action stroke; rather, they modify it (as they are not actions unto themselves). These concepts are listed in box 10.4, and their spatial arrangement in a vertical motif is diagrammed in the center of figure 10.5.

For example, if the main action is primarily about the space of forward high, that symbol would replace the action stroke. Further, it might be important to recognize that space is being revealed with a great sense of delicacy, which we could decide to notate as light weight effort, in which case an effort symbol modifier could be added. The opposite is also the case: if the primary action is about an expression (or a series of expressions) of



An action stroke

Vertical motif with action stroke

Vertical motif with symbols, pre-signs, and modifiers

Figure 10.5
Examples of a vertical motif using only action strokes and using additional symbols and modifiers. Left: An action stroke. Center: An action stroke motif with the anatomy of “lanes” labeled: main action, modification, phrasing, and theme. Right: A more complex vertical motif using symbols from the taxonomy in part II. Symbols that elongate (high and rotate, in this example) replace action strokes, while symbols that do not elongate (spoke-like directional shape change) are used as pre-signs for action strokes. This motif also uses modifiers (bound and direct effort in this example), phrasing (impulsive phrasing bow), and theme (Stability/Mobility).

effort that unfolds in the space of forward high, then the effort symbols would be in the central column and the space symbols would modify it. This model follows the tetrahedral model of BESST, where every component of the system can be seen as the central basis for viewing motion.

This way of approaching vertical motif writing adopts the idea that the central column of the motif represents what is most important, or salient, to the understanding of the movement expression. The adjacent columns then reveal aspects that support the main expression and help illuminate layers of information to enhance the richness of the representation. In this approach, the effort and shape symbols (as well as certain other symbols that do not “elongate” to reveal relative duration) are **pre-signs** that are attached to an action stroke when they are used in the central column in a vertical motif, but stand alone in a horizontal or constellation motif. The

Box 10.4

Rules for Motif on the Vertical Staff

Symbols that replace action strokes

- Time component
    - Relative duration (embedded in the length of a symbol in a vertical motif)
- Symbols that expand/elongate to reveal relative duration
    - Body component
        - Basic body actions
            - Posture
            - Gesture
            - Locomotion
            - Rotation
            - Condense
            - Expand
            - Hold
            - Jump
    - Space component
        - Spatial direction
    - Shape component
        - Primary shape patterns
            - Gather/scatter
- Symbols that are used as a pre-sign and need an action stroke to reveal relative duration
    - Body component
        - Basic body actions
            - Change of support
            - Vocalize
            - Focus
            - Touch
        - Body parts[2]

(*continued*)

Box 10.4 (continued)

  - Space component
    - Level
    - Zone
    - Reach space
    - Pathway
  - Effort component
    - All effort symbols are a pre-sign and need an action stroke to indicate duration.[3]
  - Shape component
    - Primary shape patterns
      - Concave/convex
    - Still shape forms
    - Modes of shape change
    - Shape quality

Symbols that modify action strokes

- Any symbol that can replace an action stroke
- Body component
  - Patterns of body organization
- Time component
  - Phrasing
- Thematic duality

length of the action stroke it is connected to reveals the relative duration of this symbol.[1] These concepts are summarized in box 10.4, and an example is provided on the right side of figure 10.5.

10.3 What Is Up with Imitation?

A framework for translation—and, therefore, communication—between distinct bodies

How is it that any character that is unlike a human can be expressive? We have claimed that not all robots can express the exact same physical actions as others, noting the comparison between a humanoid, with its armlike extensions enabling gestures with low dynamic constraint, and a quadruped, with a dynamic requirement for stability that at least three extensions (or "limbs") must contact the ground for static stability. In this section, we will turn that idea on its head and note how unlike bodies can imitate one another—even very, very simple movement systems can seem to imitate more complex ones from a *perceptual* point of view. In fact, having a symbolic system for notating movement becomes a point of transfer for how ideas on one body can be expressed on another—and thus a starting point for design.

Several notable examples provide evidence that this sort of abstract imitation is possible. The perception of consistent narrative in the experiments in Heider and Simmel (1944) suggest that human actors can replace (or be replaced by) abstract shapes used to create a narrative cartoon—results that surprised researchers in the consistency of the interpretation by human observers. Figure 4.2 in chapter 4 also shows examples of a variety of forms that have been used in expressive contexts, often alongside humans, to communicate consistent ideas (as human actors might). These examples show how shared experience (e.g., having the same social upbringing), can produce similar responses to the same stimulus, but they should be contextualized by the common act of comparing thoughts and opinions about art, beautiful vistas in nature, or other stimuli. For example, after watching a film, moviegoers will compare their perceptions of the work, often disagreeing about its quality or message.

In representing motion of and with machines, we can see similar feats. For example, if you ask someone to imitate an airplane, the response will likely be to hold out both arms horizontally to evoke the wings of the plane. This consistent use of our bilateral symmetry and alignment to direction of travel can be explained through the Body component of the BESST System. This same idea of imitation has been posed in reverse (a robot imitating a human instead of a human imitating a machine) in human-robot interaction (HRI) research (Jang Sher et al., 2019; Kaushik & LaViers, 2019), where human subjects were asked to determine whether a robot was doing the same thing as a human. Kaushik et al. (2018) imitated a human motion-capture skeleton using a metric derived from analyzing human motion alongside the contemporary dancer and scholar Ilya Vidrin. In this case, the device's motion was driven via a lower-dimensional signal derived from the motion-capture skeleton, and the other was driven via an uncorrelated signal. In this case,