Chapter 12
Semantic Knowledge, Domains of Meaning and Conceptual Spaces

Peter Gärdenfors

What Is Semantic Knowledge?

What is it that you know when you know a language? Certainly, you know many words of the language (its lexicon), and you know how to put the words together in an appropriate way (the syntax). More important, you know the *meaning* of the words (the semantics of the language). If you do not master the meaning of the words you are using, there is no point in knowing the syntax (unless you are a parrot). You can communicate in a foreign language with some success just by knowing some words and without using any grammar. In this sense semantic knowledge precedes syntactic knowledge. This chapter focuses on an aspect of semantic knowledge that has not been well studied, its organization into domains.

Children learn a language without effort and completely voluntarily. They learn new words miraculously fast. Teenagers master about 60,000 words of their mother tongue by the time they finish high school. In their speech and writing they may not actively use more than a subset of the words, but they *understand* all of them. A simple calculation reveals that they have learned an average of 9–10 words *per day* during childhood. A single example of how a word is used is often sufficient for learning its meaning. No other form of learning is so obvious or so efficient.

Nevertheless, the semantic learning mechanisms show some strong asymmetries. For instance, why is it easier to explain to a 4-year-old the meaning of the color terms *chartreuse* and *mauve* than to explain monetary terms like *inflation* or *mortgage*? The difference is not a matter of word frequency: The monetary terms are more frequent, but the 4-year-old masters the semantic domain of colors and thereby knows the meaning of many color words. Adding new color terms is just a matter of learning the mapping between the new words and the color space.

P. Gärdenfors (✉)
Department of Philosophy, Lund University Cognitive Science, Lund, Sweden
e-mail: peter.gardenfors@lucs.lu.se

For example, *chartreuse* is a kind of yellowish green, and *mauve* is a pale violet. On the other hand, the child is normally not acquainted with the domain of economic transactions. To the child, money means concrete things—coins and bills—that one can exchange for other things. Abstract monetary concepts are not within a child's semantic reach. Grasping a new domain is a cognitively much more difficult step than adding new terms to an already established one. Once a domain is common to a group of potential communicators, various means (e.g., words, gestures, and icons) of referring to different regions of the domain can be developed. Conversely, if a domain is not shared, communication is hampered. The organization into domains speeds up language learning.

This chapter presents a model of such domain-oriented language learning, based on conceptual spaces. I illustrate the model with some of the semantic domains that a child acquires during the first formative years of life. I also present linguistic data supporting the hypothesis that semantics knowledge is organized into domains.

Semantics Based on Conceptual Spaces

I have proposed conceptual spaces as appropriate tools for modeling the semantics of natural language (Gärdenfors, 2000). A conceptual space is defined by a number of qualitative dimensions. Examples of perception-based qualitative dimensions are temperature, weight, brightness, and pitch, as well as the three ordinary spatial dimensions of height, width, and depth. The dimensions represent perceived similarity: The closer two points are within a space, the more similar they are judged to be. In the next section, I present a number of further dimensions that are involved in communicative processes.

I argue that properties can be represented as convex regions of conceptual spaces. For example, the color red is a convex region of the three-dimensional color space. A concept can thus be defined as a bundle of properties combined with information about how the properties are correlated (for a more precise definition see Gärdenfors, 2000, p. 105). The concept of an apple, for instance, has properties corresponding to regions of color space, shape space, taste space, nutrition space, and other spaces (see Gärdenfors, 2000, pp. 102–103, for a more detailed account of this example).

The distinction between properties and concepts is useful for analyzing the cognitive role of different word classes. In Gärdenfors (2000), I proposed that properties are typically expressed by adjectives, which describe a convex region of some domain such as color, shape, or size. Correspondingly, concepts representing a complex of properties from a number of domains are typically expressed by nouns. Gärdenfors and Warglien (2012) extended this analysis to verbs on the basis of the models of actions and events outlined in the section on Action domain, below.

Because the notion of a domain is central to my analysis, I should clarify its meaning. To do so, I draw on cognitive psychology's notions of separable and integral dimensions (see Garner, 1974; Maddox, 1992; and Melara, 1992, among others). A set of quality dimensions are said to be integral if one cannot assign an object

a value in one dimension without giving it a value in one or more others. For example, an object cannot be given a hue without also giving it a brightness, and the pitch of a sound always goes along with its loudness. Dimensions that are not integral are said to be separable, as is the case with the size and hue dimensions. This distinction allows a domain to be defined as a set of integral dimensions separable from all other dimensions.

The notion of a domain has been used to some extent in cognitive linguistics (e.g., Croft, 2002; Croft & Cruse, 2004; Langacker, 1986). Langacker (1986) presented his notion of a basic domain as follows:

> It is however necessary to posit a number of "basic domains," that is, cognitively irreducible representational spaces or fields of conceptual potential. Among these basic domains are the experience of time and our capacity for dealing with two- and three-dimensional spatial configurations. There are basic domains associated with various senses: color space (an array of possible color sensations), coordinated with the extension of the visual field; the pitch scale; a range of possible temperature sensations (coordinated with positions on the body); and so on. Emotive domains must also be assumed. It is possible that certain linguistic predications are characterized solely in relation to one or more basic domains, for example, time for [BEFORE], color space for [RED], or time and the pitch scale for [BEEP]. However most expressions pertain to higher levels of conceptual organization and presuppose non-basic domains for their semantic characterization. (p. 5)

Langacker's notion of domain fits well with the one I present. Besides basic domains, Langacker also talked about abstract domains, for which identifying the underlying dimensions is more difficult. In general, though, it seems that the notion of a domain within cognitive linguistics has a broader meaning than I intend (see Gärdenfors & Löhndorf, 2013, for a narrower use). Croft and Cruse (2004, chap. 2), for example, even identified domains with frames.

Semantic Domains Involved in Children's Development

Levels of Intersubjectivity

Using conceptual spaces as my framework, I now trace the development of semantic knowledge in children by identifying and describing the domains that are required for various basic forms of communication. A central hypothesis is that many of these domains are tightly connected to the development of intersubjectivity (also called *theory of mind*). In this context, I use the term *intersubjectivity* to mean the sharing and representing of others' mentality. Following Gärdenfors (2008), I break intersubjectivity down into five capacities: representing the emotions of others (empathy), representing the attention of others, representing the desires of others, representing the intentions of others, and representing the beliefs and knowledge of others, an ordering arguably supported by phylogenetic and ontogenetic evidence (see Gärdenfors, 2003, 2008). These five components are exploited so naturally in adult human communication that their importance often escapes attention.

Emotive Domain

The ability to share others' emotions is often called *empathy* (Preston & de Waal, 2002). Bodily and vocal expressions of emotion, the most obvious signals among the social animals, communicate the agent's negative or positive experiences. Preston and de Waal argue that most, if not all, mammals are endowed with empathy (at least in a basic form) as a mechanism linking perception and action.

The importance of empathy to interaction highlights the question of how emotions are represented mentally. Several competing theories on the structure of the emotive domain exist. However, most of these theories contain two basic dimensions: a value dimension on a scale from positive to negative aspects of emotions, and an arousal dimension on a scale from calm to excited emotional states (e.g., Osgood, Suci, & Tannenbaum, 1957; Russell, 1980).[1] The Cartesian product of these two dimensions allows a spatial representation of the basic emotions (see Fig. 12.1). Distances in emotive space indicate degrees of similarity between emotions.

It is well known that emotive intersubjectivity is an important aspect of mother–infant attunement interactions (Stern, 1985). The infant learns the correlation between different emotions and the corresponding facial and vocal expressions. In other words, the child learns how to map behaviors into an emotive space. Sharing an emotion means that the participants in the exchange are in emotional states that are closely located within the same emotive space. That is, the emotions are attuned. Such coordination of emotions is arguably the most fundamental way of sharing meaning.

Visual and Physical Domains

During the first months of life, the child learns to coordinate sensory input—vision, hearing, touch and smell—with motor activities (Thelen & Smith, 1994). This process generates a narrow, egocentric space that basically maps onto her or his visual field. The subsequent role of this space in intersubjective engagement is manifested, for example, by the child's ability, as of 6 months of age, to follow the gaze of the mother if she turns her head to look at an object within the visual field of the child (D'Entremont, 2000). From 12 months of age, the child can follow the mother's gaze if the mother just turns her eyes toward the object (Butterworth & Jarret, 1991).

Representing the attention of others means that one can understand when someone is looking at some object or noticing some event. As suggested above, even very young children can understand where other people are looking. Shared attention is the result of two agents simultaneously attending to the same target. It has clearly

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[1] Of course, a representation of more nuanced emotions may involve further dimensions.

Fig. 12.1 A two-dimensional emotive space (Reprinted from Russell (1980, p. 1168) with permission from the American Psychological Association)
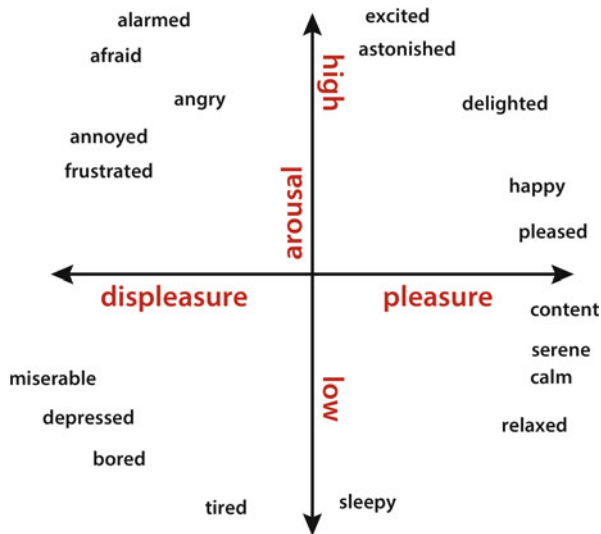
been demonstrated among the great apes (Hare, Call, Agnetta, & Tomasello, 2000). A more sophisticated version is drawing *joint* attention to an object. If I see that you are looking at an object, and you see that I see the same object, we have established joint attention.

The visual domain expands throughout the child's development. From about 18 months on, a child can follow the gaze of others even if they look at points outside its immediate visual field. This ability requires that the represented visual space extend beyond the current visual field to cover the entire physical space. The child can now comprehend references outside its visual field. It should be understood that the represented physical space is not just an extension of the visual domain but an amodal abstraction from visual, auditory, tactile, and perhaps even olfactory perceptions.

A more advanced transformation of the represented space emerges with the ability to represent an allocentric space, a space seen from the point of view of another (Piaget, 1954). This transformation involves a shift of perspective. A concrete example is the ability to direct somebody whose vision is obstructed.

More precisely, the domain of physical space should be seen as a combination of an allocentric representation of physical space and an egocentric representation provided by the visual system. This double aspect of physical space is revealed by the two linguistic codes established for referring to positions: egocentric *left* and *right*, and allocentric *west* and *east* (or *north* and *south*).

Category Domain

Objects are not only located in physical space; they are also represented in a category domain that has its own quality dimensions (Gärdenfors, 2000). If the physical domain represents where an object is, the category domain represents *what* it is.[2] The category domain is composed of a number of subdomains, such as color, size, and shape.

Although communicative coordination in the emotion and physical domains can be achieved without words, coordination in category space is, at the least, enhanced by the use of words. The first fifty or so words acquired by children are mainly category words for perceptually identifiable concrete objects: people, food, body parts, clothing, animals, vehicles, toys, and household objects (Fenson et al., 1994). They are often used in situations involving the joint attention of the child and an adult.

Hurford (2007, p. 224) has written that declarative pointing communicates only the location of an object and indicates nothing about its properties. This observation means that pointing may function without a shared category space having been established. Parents often scaffold children with words, in a situation of joint attention, to provide information about a category domain. As Goldin-Meadow (2007) and others have demonstrated, children combine pointing with words long before they rely on words alone. The words complement pointing or gaze-sharing and thus expand the possibilities for shared meaning domains in the communicative situation. The minds of the communicators meet in two ways: in the visual domain and in the category domain. Only later does the child learn words for abstract category domains such as kinship relations or money.

It is not well known how category space develops in children. Some cues can be obtained from children's ability to learn nonsense words for new things (Bloom, 2000; Smith, 2009). There seems to be a shape bias in that the shape of objects seems to be the most important property in determining category membership for small children (Smith & Samuelson, 2006). Children also overgeneralize concepts (Bloom, 2000; MacWhinney, 1987).

From 18 through 24 months of age, children undergo what might be called a naming spurt, acquiring a substantial number of nouns for representing objects. Evidence suggests that, during this period, they also learn to extract the general shape of objects and that this abstraction helps in category learning (Smith, 2009; Son, Smith, & Goldstone, 2008). One interpretation is that the development of the shape domain, as a region of the category domain, strongly facilitates the learning of names for object categories.

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[2] This distinction mirrors the products of the dorsal and ventral streams of visual processing in the brain.

Value Domain

Understanding that others may not have the same desires as oneself requires a representation of value space, one that is detached from other domains. This capacity develops before the ability to represent the beliefs of others (see Flavell, Flavell, Green, & Moses, 1990; Wellman & Liu, 2004), emerging as a separable domain somewhere between 14 and 18 months of age (Repacholi & Gopnik, 1997). A reasonable hypothesis given the empirical data is that children initially consider the value of an object to be intrinsic to the object, in other words, a dimension of the category domain, such as color or size. Only later is the value domain separated from the category domain so that different individuals may be understood as assigning different values to the same object.

Whereas emotions express how an individual feels, desires express an individual's attitudes toward objects, events, and other agents. Because desires are relational, representing the desires of others is cognitively more demanding than representing their emotions is. One way to represent an individual's value domain is with a utility function that assigns values appropriately. Other representations exist. However, I do not discuss the structure of the value domain in this chapter.

Action Domain

Experiments on how one perceives the movement of persons and other objects (e.g., Giese & Lappe, 2002; Giese & Poggio, 2003; Johansson, 1973) have suggested that the kinematics of movement contain sufficient information to identify the underlying dynamic force patterns. Runeson (1994, pp. 386–387) has gone further, claiming that one can directly perceive the forces that control different kinds of motion. The process is automatic; one cannot help but see the forces. This capacity seems to develop early in infancy (White, 1995). Thus, the force domain can be understood as a shared domain for purposes of communication.

In Gärdenfors (2007b) and Gärdenfors and Warglien (2012), that analysis was extended to actions and the forces involved in generating those actions. The basic premise is that an action can be represented as a pattern of force vectors. The force pattern for running is different from the force pattern for walking; the force pattern for saluting is different from that of throwing (Vaina & Bennour, 1985). Note that forces as represented by the brain are psychological constructs and not Newton's scientific concept.

Similarities between actions should be studied in order to identify the structure of the action space. This investigation can be done with the same basic methods as those used for objects. Walking is more similar to running than it is to throwing. Little is known about the geometrical structure of action space. I make the rather weak assumption that the concept of betweenness remains meaningful. An action concept can then be characterized, like other concepts, as a convex region, in this

case of force patterns. Unlike other ways of modeling action, this form of representation does not require explicit representation of the time domain. Explicit representations of time appear to develop comparatively late in childhood.

Like other basic domains, forces can be understood metaphorically. Language often describes applications of mental force, as when one person threatens or persuades another. In such cases the term *power* is often substituted for that of *force* (Gärdenfors, 2007a; Winter & Gärdenfors, 1995).

Goal Domain

Even though one can interpret another's behavior as goal-directed, doing so need not mean that one represents the other's intention. It is sufficient to represent the action's goal. Because the human cognitive system takes self-induced motion as a cue for goal-directedness, intentions to act are inferred from observed behavior. Gergely and Csibra (2003) argued that infants do not primarily interpret instrumental actions as intentional actions. Instead, they judge them by their efficiency in reaching a goal, perceiving them as a function of the physical constraints of the agent's situation, that is, as obstacles, visual conditions, and so forth. Only later do children adopt a mentalistic stance, learning to attribute intentions to the actor.

Therefore, any representation of intentions requires that goals already be represented. The goal domain is primary and must be described first. When the agent is located at a certain physical distance from a desired object, the goal domain can be read from the physical domain. Reaching the goal is reaching the location. The difference is that, in the physical domain, the locations of the agents and objects are in focus, whereas in the goal domain, the focus is on the distances between them. In this example the goal domain is the space of force vectors that extend from the initial to the desired location. When the goal is represented in this way, two principal ways of obtaining the goal arise. One is that the agent moves to the goal location and grasps the object. The other is that the agent uses imperative pointing, so that another individual brings the object to the agent.

Goal domains can be more abstract than force vectors in the physical domain. In principle, goal vectors can be defined in all kinds of semantic domains. If I want the wall to be painted purple, my goal is to change its color from the current location in the green part of the color domain to the desired location in the purple region. Goal spaces are represented as abstract spaces in economics, cognitive science, and artificial intelligence. The classic example from artificial intelligence is Newell and Simon's (1972) General Problem Solver. I suggest that these spaces are generated by metaphorical extensions from the original physical space and thus always maintain the key notion of distance. This hypothesis is supported by the pervasiveness of spatial metaphors in relation to goals, as in "he *reached* his goal," "the goal was *unattainable*," "the target was set *too high*" (see also Lakoff & Johnson, 1980).

Consider next the problem of representing intentions. The basic premise is that the intention domain can be seen as a product of the goal domain and the action

domain.[3] An intention is thus a combination of a goal and a planned action conceived of as leading toward that goal. Take the difference between *blink* and *wink*. A blink is an often unintentional action, a pattern of forces exerted on the muscles around the eye. By contrast, a wink is an *intentional* action combining the action of blinking in order "to awaken the attention of or convey private intimation to [a] person" (*Concise Dictionary*, 1911).[4]

Event Domain

The most advanced test for intersubjectivity in humans or other animals is designed to find out whether they can represent what others believe or know. The most common method for evaluating this capacity is the false-belief test (e.g., Gopnik & Astington, 1988; Mitchell, 1997; Perner, Leekam, & Wimmer, 1987). It is generally accepted that this capacity develops in children during their fourth year.

Wellman and Liu (2004) have argued that children can represent other persons' diverse beliefs before they can judge false beliefs. They found that many 3-year-olds who cannot pass false-belief tests can still correctly answer a target question concerning an agent's belief that is opposite from their own; it seems they understand that people's actions are influenced by diverse beliefs. Language proficiency in children is correlated with their ability to pass the false-belief test (Astington & Jenkins, 1999). In particular, parental use of mental predicates in their child-directed speech is correlated with their children's performance in false-belief tests (de Villiers & Pyers, 1997).

What is involved semantically in representing the beliefs of others, as in knowing that somebody has a false belief? Beliefs are normally expressed as propositions. So, how is the meaning of propositions related to semantic domains?[5] One possibility is that most simple propositions express events. In Gärdenfors and Warglien (2012), we modeled an event in terms of two vectors: a force *vector*, which typically represents an action performed by an agent, and a result vector, which describes a change in the location or properties of a patient.[6] Consequently, the event domain is cognitively more complex than other domains.

Given this model, one may reasonably speculate that understanding the beliefs of others requires understanding their representation of events. If this conjecture is

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[3] *Product* is meant in the mathematical sense. The intention domain is that product space generated from the goal domain (a vector space) and the action space (derived from the space of forces).

[4] As I show in the following section, this model of intentions is the same as the model of events—except that the action involved in an intention is only planned. This analysis fits well with Gergely and Csibra's (2003) proposal that one infers the intentions of a person from the beliefs and desires one attributes to that person.

[5] Cognitive semantics has traditionally not handled propositions well.

[6] The event domain can thus be expressed as the product space of the action domain and either the physical or the category domain (see intentions).

correct, it is no wonder that understanding the beliefs of others develops rather late in childhood. Consider Nelson (1996), who showed how the use of the word *know* develops over time in children and does not achieve its ordinary meaning until after children can pass the false-belief test.

This section has identified a number of semantic domains needed for children's communication. Several are based on the different possible levels of intersubjectivity. I have outlined how these domains can be represented with the aid of conceptual spaces. Because independent semantic evidence suggests that the domains are necessary for modeling basic meanings, their connection to intersubjectivity can be used as a stepping stone to an analysis of the development of semantic knowledge.

Some Linguistic Evidence of Semantic Domain Knowledge

A central thesis of this chapter is that the semantic domains, as structured by conceptual spaces, form an important part of semantic knowledge. In this section I present linguistic evidence that the development of semantic knowledge can appropriately be described as the development of separable semantic domains.

In the analysis of child language data, the establishment of a word in the vocabulary of children is often analyzed for the average frequency of the word's usage at a certain age.[7] Typically, the frequency of a word's usage starts at or close to zero, increases rapidly, then levels off once the word is established in the vocabulary.[8] The resulting curve thus has an *S* shape. I hereafter call the interval during which usage increases rapidly the *establishment period* for a word.

I can now formulate a general hypothesis concerning semantic domains: *If one word from a domain is learned during a certain establishment period, then other (common) words from the same domain tend to be learned during roughly the same period.* In order to test this hypothesis, I have analyzed data from the Child Language Data Exchange System (CHILDES) corpus and have used the publicly available web-based ChildFreq application, a highly efficient tool for such investigations.[9] In this chapter I can present only a few examples from my analysis.

For most of the domains discussed in the previous section, words are established during the language spurt that takes place between 12 and 24 months of age. This observation holds in particular for the different regions of the category domain. For example, consider the region of fruits, part of the category domain. Figure 12.2 shows the frequency curves for the names of several of the most common fruits: *apple*, *banana*, *pear*, *grape*, and *orange*. These words have an establishment period

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[7] An alternative to using age as the independent variable is to consider the general linguistic competence of the children, often measured in terms of an utterance's mean length (number of words).

[8] In fact, a word's usage usually shows a slow decline, in part because the need for any particular word decreases as more words are learned.

[9] ChildFreq was developed by Rasmus Bååth. It is available at http://childfreq.sumsar.net/
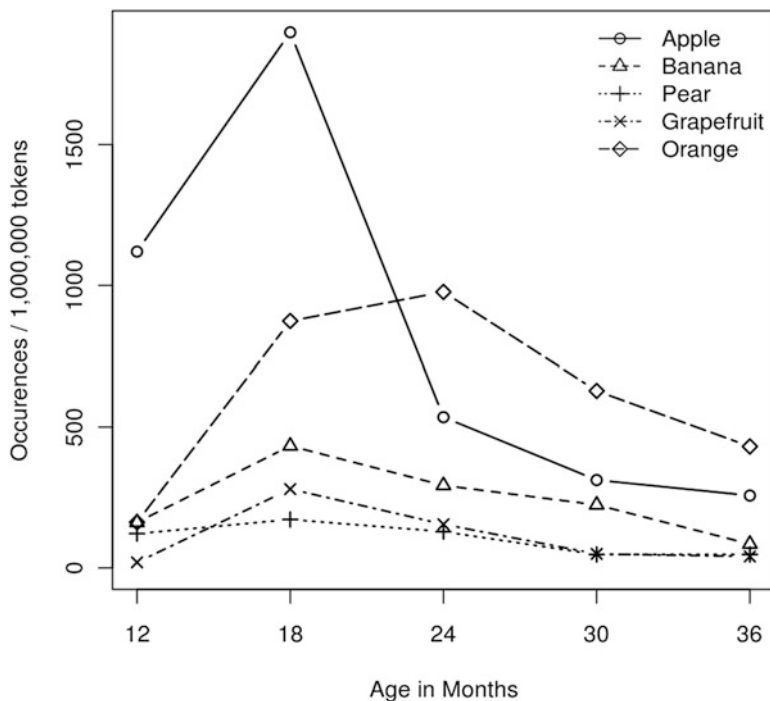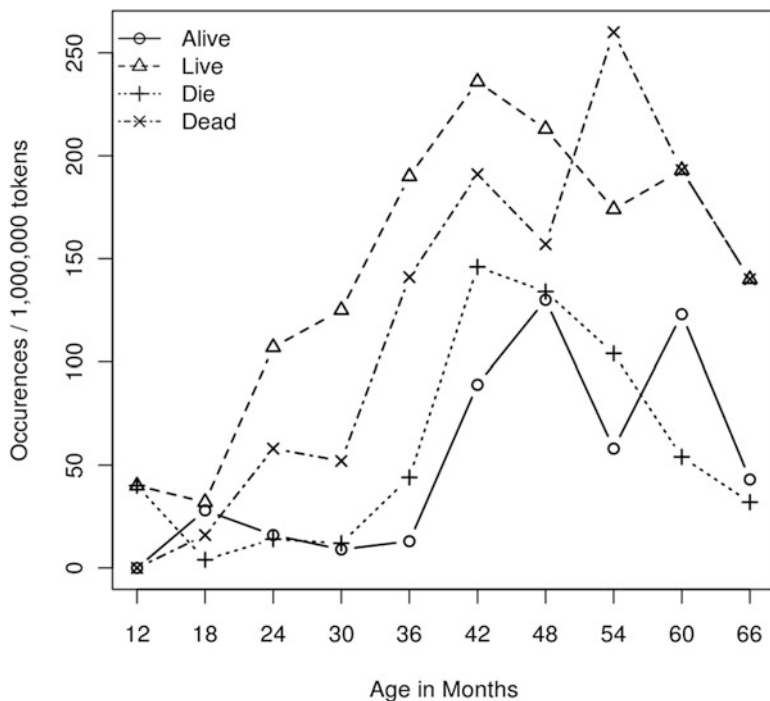
Fig. 12.2 The establishment periods for some common fruit words (Reprinted from Gärdenfors (2014, p. 67) with permission from MIT Press)

between 12 and 18 months of age. *Orange* is something of an exception, probably because it is also used within the color domain.

There are some domains for which the words are clearly established later. One such domain is that relating to life and death. Figure 12.3 shows that the establishment of the words *live*, *die*, *alive*, and *dead* occurs mostly between 30 and 42 months of age.

Another example is the domain relating to knowledge and memory. Figure 12.4 shows the frequency curves for the words *believe*, *remember*, *forget*, and *guess*. In this case the establishment period occurs between 36 and 54 months of age. Note that these words concern an individual's relation to facts and thereby relate to the event domain (see the immediately preceding section). Furthermore, the period coincides with the one during which children learn to pass the false-belief tests.

A final example from ChildFreq concerns the levels of intersubjectivity (see the section on Levels of Intersubjectivity, above). It is difficult to find a clear correspondence between these levels and the learning of particular words. However, I have chosen the verb *look* as an indicator of understanding the attention of others; and the verbs *want to* and *wanna* as indicators of understanding desires; *going to* and *gonna* as indicators of understanding intentions; and *know*, *think*, and *believe* (the latter
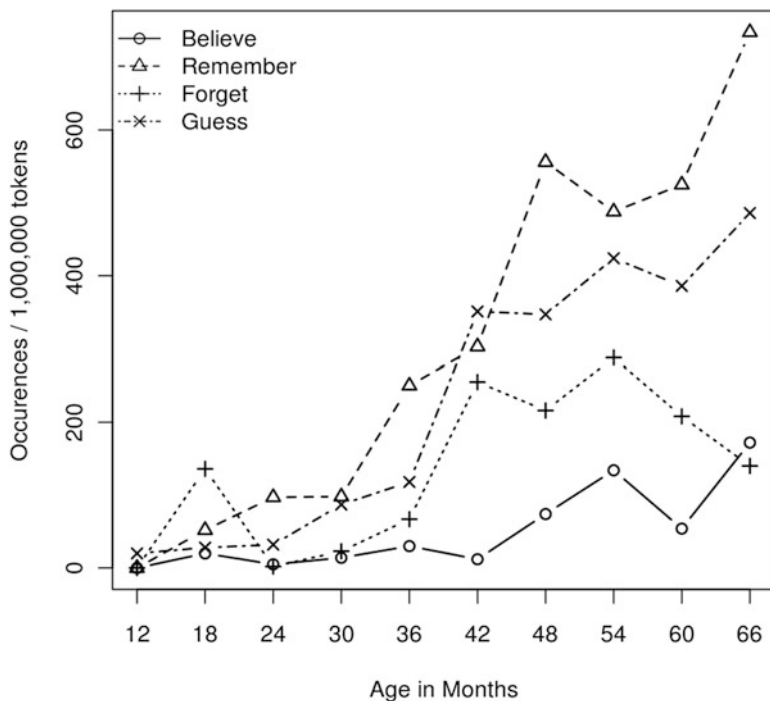
Fig. 12.3 The establishment periods for some words from the "live" domain (Reprinted from Gärdenfors (2014, p. 68) with permission from MIT Press)

two combined into one category) as indicators of understanding belief and knowledge (see Fig. 12.5).[10]

Figure 12.5 suggests that the sequence of the establishment periods conforms to the one I proposed in Gärdenfors (2008). An analysis of the uses of these words in different contexts is required in order to establish the connection with intersubjectivity more clearly than I have in this chapter. Note that *know*, *think*, and *believe* do not quite follow the usual *S* shape. Their trajectories may partly be explained by the many idiomatic uses of these words, which make their frequencies increase at a rate more constant than that of other words. Although I can present only a limited number of examples in these pages, it should be clear that my hypothesis on establishment periods is rich in empirically testable predictions. I invite corpus linguists and child development researchers to continue testing it.

Further evidence of the domain called organization of semantic knowledge is the way that metaphors do not come alone. Lakoff and Johnson (1980) convincingly argued that metaphors are organized around schemas such as "argument is war," "time is a resource," and "more is up." I have proposed that a metaphor expresses an

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[10] It is difficult to identify any expression that corresponds to understanding emotions (empathy), for this capacity develops well before words are learned.
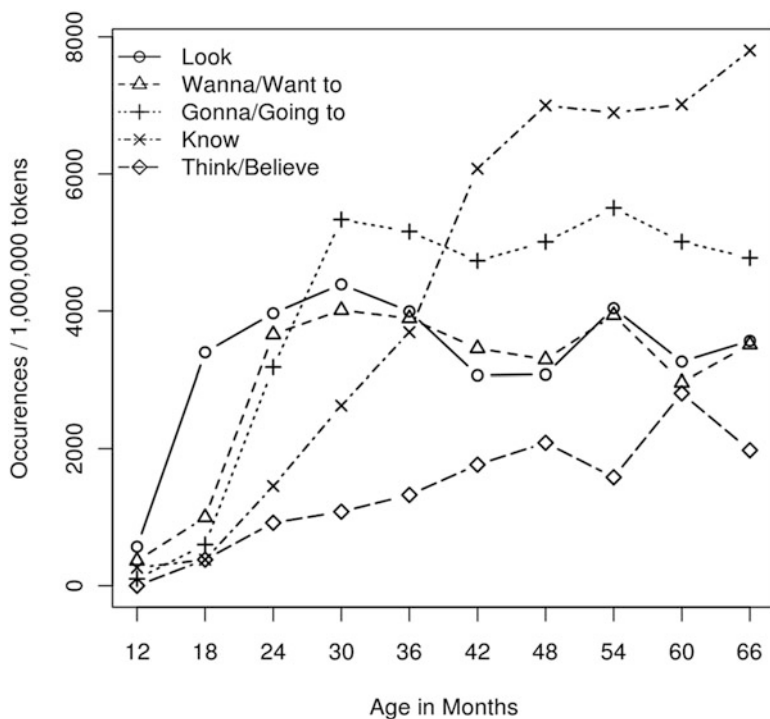
Fig. 12.4 The establishment periods for some words from the "knowledge" domain (Reprinted from Gärdenfors (2014, p. 69) with permission from MIT Press)

"identity in topological or geometrical structure between different domains" (Gärdenfors, 2000, p. 176). That is, a word that represents a particular structure in one domain can be used as a metaphor to express the same structure in another domain. Once a metaphor has established such a mapping, it can be exploited to provide other metaphors from the same domain.

An example of such a mapping is the designation of certain computer programs as *viruses*. This metaphor drawing on the biological domain has created a new way of looking at this class of programs. It has suddenly opened up possibilities for expressions like *invasive* viruses, *vaccination* programs, and hard-disk *disinfection*.

Conclusion

In the tradition of Chomskian linguistics, learning a language is learning its syntax. By the same token, one does not know a language unless one knows the meanings of the words that one uses. In this chapter I have illustrated some key aspects of how cognitive structure constrains the learning of semantic knowledge. The central

Fig. 12.5 The establishment periods for some verbs related to stages of intersubjectivity (Reprinted from Gärdenfors (2014, p. 70) with permission from MIT Press)

thesis is that semantic knowledge is structured by domains defined as sets of integral dimensions. This understanding of domains can be used to analyze semantic development in children. I have presented the central domains involved in children's cognitive development, in particular with respect to their development of intersubjectivity. I have offered some linguistic evidence supporting the hypothesis that it becomes easier to learn new words within a domain once it has been established.

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