12
From opposites to dimensions: filling in the gaps

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12.1 Premise

There are at least two important areas of research in Cognitive Sciences where the existence of psychological dimensions is taken for granted and dealt with as a basic, fundamental cognitive condition. On one side is the literature on opposites (e.g. *small-large*, *light-heavy*, *old-young*), with the default assumption that opposites are extremes of a common underlying dimension (respectively, "size", "weight", and "age"). On the other side is the literature on knowledge representation, in which conceptual spaces are usually modeled on a system of quality dimensions (N-dimensional spaces).

If one focuses on how dimensions are defined in both these areas, one cannot help noticing that an empirical definition, and more in general an empirical theory, of psychological dimensions is still lacking and that some important questions concerning the nature of these dimensions either remain unasked or without a satisfactory reply. These questions and answers concern *where* quality dimensions are (i.e. are they present in the information which we pick up directly from the environment or are they conceptual constructs?), *how* they are organized (i.e. in our cognitive system, is the relationship between qualities based on topological relationships, metrical relationships, similarity, or distances?), what their phylogenetic or ontogenetic *origin* is (i.e. is it evolutionary, conceptual, sensorial or phenomenal or does it involve embodied cognition?). These questions and answers also refer to *what* dimensions are. We may

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ask if they are continua identified by opposite endpoints or gradations of a single property. Or whether they are the basis of bipolar properties or, vice versa, super-ordinate structures derived from the experience of contrary properties.

In this chapter we will focus on the latter considerations concerning *what* is a dimension. In particular we will explore whether dimensions can in effect be thought of as cognitive structures *originating directly from the gradations of one and the opposite property*. This idea is implied by the concept of dimensions as linear continua, with two opposites occupying the two endpoints. In the following two sections in this chapter we will be reviewing the issue of the relationship between opposites and dimensions in the literature on opposites and on knowledge representation. We will show that the relationship between opposites and dimensions is somehow taken for granted, although it has been neither explicitly said nor empirically demonstrated how one can go from one pole to the other. This, in other words, means that it is not clear whether dimensions are cognitively coincident with bipolar structures or if they represent a different type of structure. And if this is the case, then the question of the relationship between the two still needs to be answered. At the end of this chapter we will not have an answer to all these questions. Our contribution will be to test the minimal hypothesis that dimensions are cognitive structures originating directly from the gradations of one property and its opposite and to provide theoretical arguments and experimental evidence to support the view that this hypothesis needs to be rejected.

12.2 From opposites to underlying continua

In the domain of psychological test development, the question of whether using scales which refer to opposite adjectives (or reverse-coded items) leads to the same result is an important and frequently addressed question. The chapter by Chiorri, Anselmi and Robusto, in this volume, gives an overall picture not only of the literature on the question, but also of the possible experimental methods to apply when looking for an answer.

Despite the acknowledgment of the question in this domain, the idea that two contrary properties lie on the same continuum is taken for granted in many other fields of psychological research or practice. Think for instance of the use of the semantic differential method (Osgood, Suci & Tannenbaum, 1957) where opposite adjectives are the extremes of bipolar scales divided by a midpoint (zero value), on the left and right of which two sub-sections express the gradations of one or the opposite property. And consider too the structure of the Lickert scales which are usually arranged in 5 point scales with verbal labels to express gradual contrariety: “totally in agreement”, “in agreement”, “uncertain”, “in disagreement”, “totally in disagreement”. These are consecutive, cumulative steps in a single additive dimension. And in Kelly’s Theory of Personal Constructs and the corresponding Repertory Grid interview technique (Kelly, 1955; Jankowicz, 2003) – which over the last 40 years has been applied in various areas of psychological assessment and research – constructs are by definition bipolar and scalar.

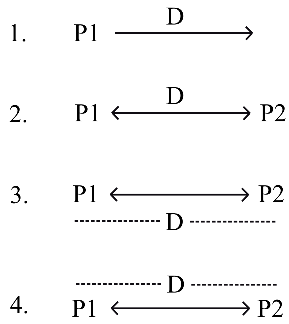

Figure 12.1 Representation of dimensions as: 1. gradations of a single property; 2. a continuum ranging between two opposite extremes; 3. a linear continuum underlying two opposites; 4. a composite construct, describing the psychophysical behavior of the two contraries and emerging from the direct phenomenal experience of both properties and their intermediates.

In the literature on semantic or linguistic theories of opposites, again the idea that opposites presuppose a corresponding continuum is an undisputed point. Since the early seventies, this has been one of the main ideas underlying the concept of markedness (Clark, 1973). According to this concept, dimensions are generated by the unmarked pole of each pair. Gradations of these unmarked poles are in fact expected to potentially cover all the variations of a given property, thus giving rise to a unidimensional counterpart of the pair. For example, in the pair *high-low*, *high* is the unmarked pole and *height* is the corresponding dimension. We might represent this idea that a dimension is formed by the gradations ranging from one property to its opposite, as in the second diagram in Figure 12.1. In spite of the difficulties encountered by researchers when operationalizing the concept of markedness (for an overview see Haspelmath, 2006), the presupposition of an implicit unidimensional continuum corresponding to the two opposite poles has persisted as a kind of default assumption.

This is curious since linguists and psycholinguists have spent a great deal of time trying to account for the differences between different types of opposites: complementary, gradable, reversive, directional, direct, indirect, near, good, etc. (Croft & Cruse, 2004; Cruse, 1986, 2000; Fellbaum, 1995; Jones, 2002; Lyons, 1977; Muehleisen, 1997; Murphy, 2003; Paradis, 1997, 2001; Willners, 2001). But the fact that there are various types of opposites has not caused researchers to wonder whether this might imply or indicate varying structures related to the supposed, corresponding dimensional continua. Thus, an acknowledgment of the existence of linguistically and psychologically differing species of opposites (and the efforts made to provide an exhaustive classification) has coexisted with the assumption that "antonyms name opposite sections of a single scale" (Lehrer & Lehrer, 1982, p. 484; see also Cruse, 1986; Kennedy & McNally, 2005).

12.3 From dimensions (as basic coordinates of conceptual spaces) to opposites

Another important area in Cognitive Sciences where references to dimensions are central concerns research on conceptual spaces. To discuss this point, we will concentrate on Gärdenfors' proposal (2000, 2004, 2007) which is interesting for at least two reasons, which are discussed below. He maintained that a conceptual space can be defined as a collection of one or more quality dimensions. Dimensions form the framework used to assign properties to objects and to specify the relationships between them. "The coordinates of a point within a conceptual space represent particular instances of each dimension, for example, a particular temperature, a particular weight, and so forth" (Gärdenfors, 2000, p. 6).

1. *Psychophysical measurements to define the shape of dimensions.* The interpretation of dimension that Gardenfors has in mind is certainly psychological, or phenomenal as he also calls it (2000, p.8; 2004, p. 14): "I want to make it clear that the dimensions I consider in my analysis of concepts should be given the psychological interpretation". This means that the structure of dimensions and their interrelated or independent behavior cannot be defined *a priori* in terms of one or another theory, but need to be derived from empirical, namely psychophysical, data: "when the dimensions are seen as cognitive entities, (…) their structure should not be determined by scientific theories which attempt to give a 'realistic' description of the world, but by *psychophysical* measurements that determine how our concepts are represented" (2007, p. 169). And in fact a key concept in his analysis is the perception of similarities or differences between objects or properties. Quality dimensions in his model correspond to the different ways in which stimuli are judged to be similar to or different from each other. Based on this, the distances between the instances of a property (within each individual dimension) can be determined, as well as the shape of the dimension itself.
2. *The shape of dimensions: bipolar or otherwise?* Gärdenfors did not address this question explicitly, but there are a number of cues that implicitly suggest an answer which is very different from that given, for example, by Miller (1996, p. 193) who said: "Some theorists think of attributes as dimensions. In that case, the N attributes of a given referent define an abstract N-dimensional space (a hyperspace); any particular instance can be thought of as a point in that space, its location given by its value on each dimension. (…). The size (...) of the cup, for example, can be *large or small* (modifiers), its height (...) can be *tall or short* (modifiers), and so on. Each modifier specifies the position of a referent along a particular dimension; the full set of modifiers specifies a particular location in the N-dimensional space; differences between referents are given by their different locations in that space". Miller, when modeling the psychological shape of dimensions, cannot ignore the fact that cups are perceived as *large* or *small*, or *tall* or *short*. He tries to account for a unidimensional definition of dimensions (e.g. he talks of the *size* and the *height* of a cup) and, at the same time, for a direct experience of bipolarity in the perception of qualities. In the organization of Word

Net, a project of which he was one of the founders, height was dealt with as an attribute ranging over a continuum of values, expressed by adjectives (predicative adjectives) and antonyms were defined as adjectives that express values at opposite poles of the same attribute (Miller & Fellbaum 1991; Miller, 1996; for an analysis of the connection between adjectives and qualities in WordNet, see also Karp, Savardi & Bianchi, 2007, 2008). Looking back at Figure 12.1, it is not easy to say whether the relationship between a dimension and its bipolar values that Miller assumes is better represented by diagram 2 (dimensions are formed by bipolar values, i.e. tall and short are components of the dimension height) or diagram 3 (bipolar attributes, i.e. tall and short, are experiences that map onto an underlying common dimension – height but are not components of it). What is however certain is that a strict relationship is recognized as linking the idea of dimension and the experience of opposites. Gärdenfors, on the other hand, seems to admit that dimensions *might* be bipolar – as well as admitting that some structures of dimensions are ordinal and others topological. Two of the examples of dimensions that he refers to, pitch (defined by low and high tones) and brightness (defined by two endpoints, black and white) are of this kind. But from his point of view, this remains a local solution which covers some individual quality dimensions but is not a general solution. With respect to Figure 12.1, Gärdenfors' idea of dimensions could be represented by the first or the second diagram, depending on the case. For instance, to use his examples, variations of *weight* can be conceptualized in terms of gradations of a given property, which range from "very little (weight)" to "a great deal of (weight)" – and we are therefore concerned with the condition represented in the first diagram of Figure 12.1. Conversely, when conceptualizing the variations of pitch as ranging from gradations of *low* to gradations of *high* pitch, the reference to bipolarity cannot be avoided – and in this case we turn to the condition represented in the second diagram of Figure 12.1.

12.4 The question

The observations made up to now, following one route (from opposites to dimensions) or the other (from dimensions to opposites) bring us closer to the same question, i.e. whether it is possible (and if so, on what bases) to reconcile the idea of dimensions as linear continua and the fact that opposites are clearly fundamental to the perception and cognition of properties.

One may get around the question by restricting the definition of dimensions to gradations of a given property – as represented in diagram 1, Figure 12.1 – and thus avoid the question of whether and how to reconcile dimensions and contraries. By adopting this view, the dimension, for example, of weight would range from "a little weight" to "a great del of weight", that of size from "a little extension" to "a great deal of extension", that of age from "a little age" to "a great deal of age", that of altruism from "a little altruism" to "a great deal of altruism" etc. In this framework, one must disregard that an experience of "little weight" corresponds to an experience of being *light* and that "a great deal of weight" correspond to the experience of being *heavy*, or that "a little age" corresponds to the experience of being *young* and "a great deal of age" to the experience of being *old* etc.

This is a solution that is well accepted, for example, in physics, where objects are in effect neither *low* nor *high* but extend *x* centimeters and movements are neither *fast* nor *slow*, but simply cover *x* meters per second. When conceptualizing dimensions in this field, the question of bipolarity can be easily ignored and unipolar structures can be used to model dimensions. It is therefore interesting that in physics too, in the definition of some properties concerning, for instance, the state of matter, thresholds have been established in order to account for discontinuities between *solid* states, *liquid* states and *gas* states.

In psychology, however, the assumption of this view means ignoring the evidence that direct perception of the quality of an object is invariably in terms of opposite properties.This acknowledgment of the primary position of opposites in human phenomenal experience has been reached by following various paths: the widespread presence of opposites in natural languages and their robustness in the mental lexicon (Cruse, 2000; Jones, 2002); the facility of acquisition of opposites in early language acquisition (Kagan, 1984; Miller & Fellbaum, 1991; Muheleisen, 1997) and their early emergence - by 6 months of age - in preverbal cognitive schemas (Quinn, 2005; Mandler, 1996; Casasola, 2008; Casasola, Cohen, & Chiarello, 2003); the analysis of the basic dynamic laws concerning the functioning of the brain (Kelso & Engstrøm, 2006; Engstrøm & Kelso, 2008) and the perceptual foundation of opposites in human spatial experience (Savardi & Bianchi, chapter 3 in this volume; Bianchi & Savardi, 2008; Bressanelli, Bianchi, Burro & Savardi, 2008). Thus, when trying to determine the *psychological* shape of quality dimensions, the fact that the perceptual and cognitive systems give priority to this bipolar organization cannot be ignored.

We might then need to ask how these two structures are linked. We will consider two minimal hypotheses regarding the nature of this link:

1. *gradations of a given property can cover the whole dimension up to the opposite extreme* (which means, for example, that gradations of *large* can cover all the possible gradation of size, down to very small sizes). This solution is embedded in the idea that the unmarked pole of the pair can generate the corresponding dimension;
2. *gradations of one and the opposite property map inverse orderings of the same continuum.* This is a very generalized view presupposed by all the methodologies mentioned above and which makes use of bipolar scales. It is expressed well by Kennedy & McNally (2005, p. 351), who, referring to opposite gradable adjectives, stated that they "crucially make use of the same dimension and degrees (e.g. both *tall* and *short* map their arguments onto corresponding degrees of *height*) but express inverse ordering relations".

Indications of the fact that this second relationship between opposites and dimensions (bipolar adjectives refer to a single common dimension) is not always guaranteed, and thus cannot be proposed as a general rule, has emerged from research carried out in various fields of psychology. Immediately after the semantic differential method had been proposed by Osgood and colleagues in 1957, some cognitive scientists wondered whether the bipolarity of semantic space found by Osgood might be the result of the experimental procedures used and did not therefore reflect the intrinsic cognitive structure of dimensions (Atwood & Falkenberg, 1971; Bentler, 1969; Green & Goldfried, 1965). Single-adjective scale versions of the semantic differential were thus constructed and participants were asked to rate concepts separately on the two opposite scales. These studies led to contrasting conclusions, but in general the correlation between judgments made on opposite scales turned out to be weaker than might be expected if they were in fact inverse measures of the same attribute. This should have sounded an alarm, but these results were ignored in the conceptualizations of opposites and dimensions which followed.

Thirty years later the problem resurfaced. On the one hand, researchers working in the field of psychological test development found that using opposite wording or reverse-coded items – for example, using items asking for ratings of *comfort* versus *stress* – did not lead to the same (inverted) results (Conrad, Wright, McKnight, McFall, Fontana & Rosenheck, 2004; Harvey, Billings & Nilan, 1985; Hinkin, 1995; Podsakoff, MacKenzie, Lee & Podsakoff, 2003; Yorke, 2001; see also Chiorri, Anselmi & Robusto, chapter 13 in this volume). On the other hand, psychologists studying emotions, personality and social psychologists searching for an empirical validation of their theories and models (initially based on bipolar dimensions: e.g. *pleasant-unpleasant*, *relaxed-tense*, *happy-depressed*), found that some scales behave as opposite poles of a single underlying dimension – this holds, for example, for *individualism-collectivism* (Freeman & Bordia, 2001), *pleasant-unpleasant* and *happy-sad* (Watson & Tellengen, 1999) – while other scales behave as distinct scales – e.g. *masculine-feminine* (Marsh & Myers, 1986) and *optimism-pessimism* (Kubzansky, Kubzansky, & Maselko, 2004; Pinquart, Fröhlich, & Silbereisen, 2007).

These results can be considered as manifestations of methodological biases or the idiosyncratic behavior of social and emotional dimensions or may be indications of the fact that, in our cognitive system, opposites are not simply reverse properties. We believe that the latter is the case and that a systematic empirical analysis of the structure of opposites in terms of whether or not they lie on the same continuum is needed, starting from the analysis of how opposite properties behave in perceptual tasks. In the following sections of this chapter, we will provide theoretical arguments based on phenomenological observations and experimental evidence concerning the perception of spatial properties in order to test the aforementioned two minimal hypotheses regarding the relationship linking contraries to dimensions.

12.5 Intersections and symmetric differences between two sets of properties

Some concepts from the set theory (and some Eulero-Venn diagrams) will help us to begin to develop an argument in support of the hypothesis that there are discontinuities between two opposites that the idea of a single common continuum cannot account for.

Let us consider two sets of properties, P1 and P2 (Figure 12.2). Let us say, for example, that P1 is the set of phenomenal values manifesting the property *shiny* and P2 the set of phenomenal values manifesting the property *wide.* The intersection between P1 and P2 (P1∩P2) represents the instances where the two properties *wide* and *shiny* are co-present.

When P1 and P2 are not contrary properties, it is always possible to find, in P1∩P2 objects that both *maximally* manifest the property P1 and the property P2. For example an object can be simultaneaously *maximally wide* and *maximally shiny,* in the same space and at the same time.

This condition does not hold when P1 and P2 are contrary properties. In fact, it is never possible to find an object that is at the same time *maximally wide* (P1) and *maximally narrow* (P2), with respect to the same space and time.

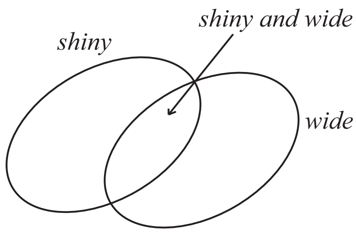

Figure 12.2 Venn diagram of the domain of the sets of properties P1 and P2. P1 is the set of phenomenal values of the property *shiny* and P2 the set of phenomenal values of the property *wide.* The intersection represent the instances that manifest both properties. The non-overlapping areas of P1 and P2 are known as the "symmetric difference".

In terms of set theory, the idea can be expressed by saying that given P1 as the set of gradations of the property, e.g. *wide,* and given P2 as the set of gradations of the opposite property, e.g. *narrow*, the intersection between P1 and P2 cannot consist of a full overlap: $P1 \cap P2 \neq P1 \cup P2$. The portions of P1 and P2 that are excluded by the intersection define the "symmetric difference" of the sets ($P1 \Delta P2$). When P1 and P2 are contrary properties, the symmetric difference can never be an empty set. This can be expressed as:

$$P1 \Delta P2 = (P1 \cup P2) - (P1 \cap P2) \neq \emptyset \tag{12.1}$$

This law makes it therefore impossible to accept the first minimal hypothesis of reduction of opposites to a dimension: *gradations of a given property can cover the whole dimension up to the opposite extreme.* In fact, the condition of there not being a total overlap guarantees that there is always at least one element of P1 that cannot be expressed in terms of gradations of P2 and vice versa.

We will see in section 12.7, where we look at some experimental data, that the capacity of covering all the gradations of P1, starting from P2 (or vice versa), is variously compromised, depending on the specific structure of the contraries in question. For some pairs of contraries, in fact, we cannot cover any portion of P1 starting from P2 and for other contraries this is partially (but never completely) possible. But in the latter case, there are further difficulties caused by the potential non-unidimensionality of the two opposite ratings.

However, to deal with this we need to take a step further and enrich the basic condition stated in this section (Formula 12.1) with other considerations concerning the cardinality of the symmetric difference and of the intersection.

12.6 The cardinality of the symmetric difference and of the intersection gives rise to different types of opposites

Let's consider the necessary condition for the symmetric difference between two sets referring to two contrary properties not to be an empty set (formula 12.1). Different conditions regarding the cardinality of the symmetric difference can be defined – the cardinality of a set A is a measure of the number of elements in the set and is indicated by $|A|$. To be more precise, when P1 and P2 are two contrary properties, the cardinality of their symmetric difference can range from 2, as represented in the diagram on the left in Figure 12.3, to $(P1 \cup P2)$, as represented by the diagram on the right in Figure 12.3.

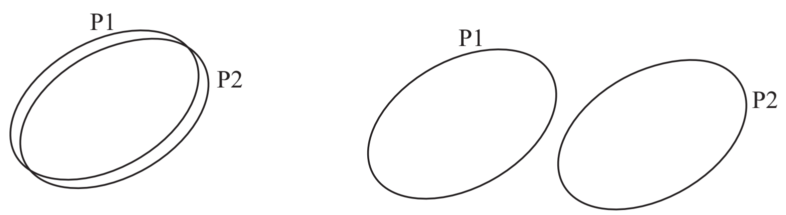

Figure 12.3 On the left, the lowest cardinality possible of the symmetric difference: $|P1\Delta P2|=2$; on the right the highest cardinality possible of the symmetric difference: $|P1\Delta P2|=|P1\cup P2|$.

Now let us apply three different cardinalities (1, >1, ∅) to the parts of P1 and P2 that, added together, give the symmetric difference and to the intersection between the two sets P1 and P2.

This makes it possible to account for the distinction between contrary poles consisting of a gradable series of values (e.g. *large-small* or *young-old*) and contrary poles referring to a single value for each pole (e.g. *dead-alive* or *full-empty*). This difference is at the basis of the traditional distinction between complementary pairs (also known as bounded antonyms) or binary pairs and gradable antonyms (or unbounded antonyms) and it is also one of the elements considered in the proposal regarding a psychophysical definition of dimensions (Savardi & Bianchi, 2003; Bianchi & Savardi, 2008, ch.3; Savardi, Bianchi & Kubovy, submitted). According to this last approach, the structure of the two poles and of the intermediate region can be defined based on the observer's phenomenal experience and can be expressed in terms of two types of indexes: metrical indexes (the symmetrical or asymmetrical extension of the two poles and the extension of the intermediate region) and topological indexes (the fact that the poles are intervals or points, i.e. do they refer, respectively, to a range of values or to only one value? And if they are a range, are they bounded or unbounded? And for intermediates: do they exist and, if so, are they a point or a range?). We will leave aside here the distinction between bounded and unbounded ranges and simply focus on the basic distinction between P1s and P2s that consist of ranges of elements (e.g. large, hot, open, irregular...) versus single elements (e.g. full, empty, closed, female, dead...).

If we apply the three levels of cardinality (1, >1, ∅) to the two parts of P1 and P2 that are excluded from the intersection (i.e. |P1-P2| and |P2-P1|) and to the intersection itself (|P1∩P2|), we come out with the theoretical 3x3x3 combinations presented in Table 12.1. For simplicity, p (i.e. point) indicates cardinality = 1, r (i.e. range) indicates cardinality > 1 and n (i.e. no elements) indicates cardinality = ∅.

Table 12.1 Results when the three different cardinalities (1, >1, ∅) are combined for the three elements |P1-P2|, |P1∩P2|, |P2-P1|. For the explanation see text.

		|P2-P1|=1 (p)	**|P2-P1|>1 (r)**	**|P2-P1|=∅ (n)**
|P1-P2|=1 (p)	**|P1∩P2|=1 (p)**	ppp	[ppr]	(ppn)
|P1-P2|=1 (p)	**|P1∩P2|>1 (r)**	prp	[prr]	(prn)
|P1-P2|=1 (p)	**|P1∩P2|=∅ (n)**	pnp	[pnr]	(pnn)
|P1-P2|>1 (r)	**|P1∩P2|=1 (p)**	rpp	rpr	(rpn)
|P1-P2|>1 (r)	**|P1∩P2|>1 (r)**	rrp	rrr	(rrn)
|P1-P2|>1 (r)	**|P1∩P2|=∅ (n)**	rnp	rnr	(rnn)
|P1-P2|=∅ (n)	**|P1∩P2|=1 (p)**	(npp)	(npr)	(npn)
|P1-P2|=∅ (n)	**|P1∩P2|>1 (r)**	(nrp)	(nrr)	(nrn)
|P1-P2|=∅ (n)	**|P1∩P2|=∅ (n)**	(nnp)	(nnr)	(nnn)

We have said that, when P1 and P2 are not just any two properties chosen randomly but are properties which are exact opposites of each other, it is not possible to achieve a complete overlap. In this sense, the area of P1 and the area of P2 that is outside the intersection is not empty: P1-P2≠∅; P2-P1≠∅. Therefore, 15 out of the 27 theoretical combinations represented in Table 12.1 are impossible when the sets P1 and P2 refer to contrary properties (these are the cases in round parentheses, in which P1-P2 or P2-P1 or both have cardinality n). Moreover, since the order of P1 and P2, in this analysis, is completely arbitrary, we can also eliminate from Table 12.1 the cases that have an inverse structure (i.e. those in square parentheses). The remaining 9 combinations (those out of parentheses) describe the 9 possible structures of contraries, as shown in Figure 12.4.

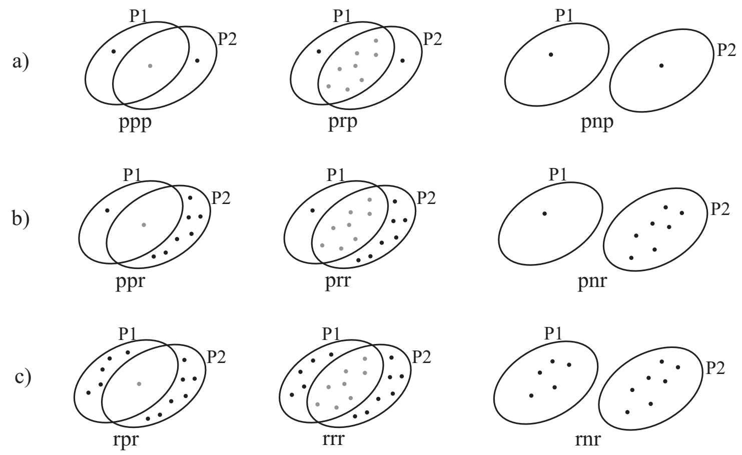

Figure 12.4 Venn diagrams with sets showing the representation of the 9 combinations in table 12.1, corresponding to the 9 basic possible structures of contraries.

Bearing in mind that:

1. non-overlapping properties indicate those that cannot be identified in terms of gradations of the opposite set;
2. the properties that manifest both P1 and P2 fall in the intersection, Figure 12.4 represents, by row:
   - contrary properties comprising two single non-overlapping properties (one for each set) and one (ppp), a range (prp) or no properties (pnp) in the intersection between the sets;
   - contrary properties comprising a single non-overlapping property in one set, and a range of non-overlapping properties in the other set, with one (ppr), a range (prr) or no properties (pnr) in the intersection;
   - contrary properties comprising a range of non-overlapping properties for each set, with one (rpr), a range (rrr) or no properties (rnr) in the intersection.

Before considering if there is empirical evidence for these varying structures of contraries, let us consider what the implications are in terms of the two hypotheses that we are testing here, starting with the first one: *gradations of a given property can cover the whole dimension up to the opposite extreme.*

According to the diagrams in Figure 12.4, the greater the cardinality of the symmetric difference, the higher the number of elements of P1 or P2 that can only be described in terms of gradations of one, but not the opposite, property.

With respect to the hypothesis, this means that in the case of ppr for example:

1. there is an instance of P1 that does not correspond to any instances in terms of P2 and if the dimension is constructed in terms of gradations of P2, one element is therefore missing;

2. there are many instances of P2 that do not correspond to any instances of P1 and if the dimension is constructed in terms of gradations of P1, only two elements are covered and there is only place for one of the instances of P2 (i.e. that in the intersection).

Therefore, whatever the starting point, a dimension generated as an extension of one pole cannot cover *all* the instances of the two opposites properties ($P1 \cup P2$). A similar discourse holds for all the other types of contraries represented in Figure 12.4: what changes is the number of experiences that cannot be "reached" by this definition of dimension.

Let us now consider the second hypothesis: *gradations of one property and its opposite map inverse orderings of the same continuum.*

In this case too, the diagrams represented in Figure 12.4 make it clear that some difficulties arise. The potentiality to be inverse measures of the same continuum only holds, if in fact it holds, for the members of the sets P1 and P2 that are in the intersection. These instances in fact manifest both P1 and P2 and there is therefore a theoretical chance that they refer to corresponding degrees of the same attribute, but express inverse ordering relations. In any case this needs to be empirically verified. The potentiality to fall into the same continuum is however certainly precluded in the case of all the instances of P1 and P2 not falling in the intersection. Since they manifest only one but not the other property, they cannot lie on a common continuum.

12.7 Empirical evidence

Let's now see if the arguments discussed thus far find corroboration in empirical analyses of the experiential structure of opposites. We will refer to the results from two series of studies.

12.7.1 Various types of contraries

An analysis of the psychophysical structure of 37 basic spatial opposites has revealed that there are in fact various different structures of contraries that can be distinguished based on metrical and topological measurements (Bianchi & Savardi, 2008, chapter 3; Savardi & Bianchi, 2000a; Savardi, Bianchi & Kubovy, submitted; see also Savardi & Bianchi, chapter 3, in this volume). If we reconsider the data concerning in particular the topological descriptions of the two poles and the intermediate region in the light of the nine diagrams in Figure 12.4, we can say that (despite the sample of opposites being limited to 37 pairs) representatives of each combinations were found. The percentages in Figure 12.5, below each diagram, refer to the number of times that participants described one or the other of the 37 pairs in terms of the structure represented in the corresponding diagram. As the percentages reveal, some of the 9 structures were described more frequently than the others, but it is important here to observe that each structure has been used by at least one participant to describe at least one pair of the sample.

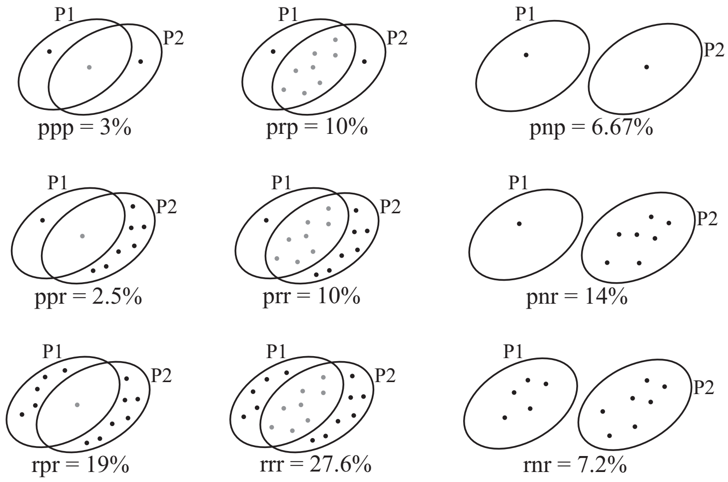

Figure 12.5 Distribution of the descriptions of 37 spatial opposites in terms of the diagrams represented in Figure 12.4 (percentages are calculated from Savardi Bianchi and Kubovy, submitted).

12.7.2 How far the gradations of each pole go

In order to test whether bipolar judgments (that is ratings given in terms of the two opposite properties) could in effect give rise to a common continuum, we presented participants with a series of pictures showing various different gradations of two opposites target properties. For instance, when testing the pair *long-short*, we presented participants with a set of distances marked in the ground and going from 20 cm to 12 meters (in random order) and asked them to observe the distance and to rate to what extent it manifested the property *long* using a 6 point scale, with 0 meaning “not at all”, and 6 “maximally”. Similarly, we presented them with various inclinations of a bar, from perfectly horizontal to perfectly vertical, going though 21 intermediate inclinations and asked them to rate the extent to which each stimulus manifested the property *vertical* (Savardi, Bianchi, Burro, submitted; Savardi, Bianchi, Burro & Karp, in preparation).

After a series of trials testing other properties, participants were again presented with the set of stimuli which they had used to judge *long*, asking participants this time to rate the opposite property (e.g. *short* and *horizontal*). The set of stimuli was identified starting from two extreme conditions that the experimenters agreed clearly manifested the two opposite properties (e.g. a distance that was clearly *long* vs a distance that was clearly *short*; a clearly *vertical* and a clearly *horizontal* bar, etc.). The stimuli in between were regular increments (in cm or angle of inclination, in the two examples) of a property towards its opposite. The decision to use photographs was taken after finding that similar results emerged when testing the unidimensionality of spatial characteristics using photographs of objects or real-life objects (Savardi, Bianchi & Burro, submitted). For each series of stimuli two series of ratings were thus obtained which expressed, respectively, the perception of one property (e.g. *closed, high, full*) and its opposite (e.g. *open, low, empty*) each time for the same set of objects. By comparing the two series of ratings, we verified whether participants were in fact expressing inverse measurements of the *same characteristic* or if they were rating two separate characteristics. In other words, we were able to verify whether there was a single common construct (a dimension) underlying the two series of judgments. The pairs of contrary properties chosen were characterized by four different structures in terms of phenomenological psychophysics. This made it possible to test the hypothesis regarding the unidimensionality or non-unidimensionality of contrary properties, taking into account various different phenomenal types of P1 and P2. Specifically, in terms of the diagrams in Figures 12.4/12.5, the contraries studied corresponded to the diagrams with higher frequency: rrr, rpr, pnr, prp.

The results are shown in Figure 12.6. There are 4 pairs of graphs (1a, 1b; 2a, 2b; 3a, 3b; 4a, 4b) which refer respectively to pairs of contraries which have been found, in previous studies, to have the same psychophysical structure. Each pair, with the exception of the bottom pair (*full-empty* and *vertical-horizontal*), shows poles which behave in a similar way.

In contrast, much greater differences emerged when making a comparison between the pairs. This revealed that *the distance that the gradations of each pole go* varies sometimes even significantly.

For the contraries *divergent-convergent* and *left-right* (two examples of rpr in Figure 12.4), the series of stimuli seems to be divided into two parts. Gradations of P1 cover only one of these parts, and gradations of P2 cover only the other part (see Figure 12.6, 1a and 1b). For one of the stimuli, neither one nor the other property applies – this means that, for these contraries, diagram rpr should be modified so that what is now the intersection is a new independent set. It is therefore not possible, for these contraries, to refer to an underlying common dimension. For these pairs, an answer to our initial question regarding how far the gradations of each pole go, would be that they do not reach the midpoint of the hypothesized continuum.

For *open-closed* and *straight-curved* (two examples of pnr contraries in Figure 12.4), there is a small area of overlap between the domains of application of these two qualities (see Figure 12.6, 2a and 2b). For these pairs, and given the type of task, the pnr diagram should be modified so that the intersection is not an empty set but comprises some instances (i.e. doors which are very slightly *open* and ropes which are only lightly curved)[1]. If there is an overlapping area, for each of the two poles

[1] It has to be noted that, in general, in the task where people were asked to *rate* the extent to which a certain property was present, qualities that in a different task had been described as consisting of a single precise state, were now said to be potentially applicable to a range of instances (with different degrees). To give an example, participants reported that they experienced a door as "being *closed*", in the strict sense, only in the absence of even the slightest opening; in all other cases, the door was perceived as being *open*, at various degrees). Similarly they recognized that, when going to the petrol pump, the experience of the tank being *full* meant precisely only one thing: that it is full to the brim, and a cinema is experienced as being *full* only when there are

there is also one stimuli in P1 and many stimuli in P2 (from stimulus 13 to 23 in the case of *closed* and from stimulus 8 to 23 in the case of *straight*), where only one of the properties can be perceived. So we consider once more the question of how far gradations of each pole go. For these pairs, quite far if we start from P2 (but one instance of P1 remains excluded), and only a very short distance if we start from the gradations of P1. In any case, neither P1 nor P2 covers the whole continuum.

For *long-short* and *wide-narrow* (two examples of the contraries rrr in Figure 12.4), the area where P1 and P2 overlap is greatly extended and only in the case of extreme stimuli could participants perceive one property but not the opposite one (see Figure 12.6, 3a and 3b). That is to say that they couldn't see any degree of being *short* in stimuli numbers 22 and 23 and they couldn't see any degree of being *long* in stimulus number 1; similarly they couldn't see any degree of being *narrow* in stimulus number 23 nor any degree of being *wide* in stimulus number 1. For both these pairs, the gradations extend relatively far for both P1 and P2, although there is in any case at least one extreme instance for each set that cannot be reached starting from the opposite set.

With *vertical-horizontal* (an example of prp contraries) the story is different again: in this case there is a quite large subset of stimuli (from 8 to 18) in which participants could not recognize either P1 or P2 (see Figure 12.6, 4b). Not only is there thus a big gap in between the areas of application of the two opposite properties, but the domain of the two properties is also completely disjointed, or in other words the intersection is empty. For this pair, in fact, diagram rpr in Figure12.4 should be modified and a new independent set should replace the intersection.

Full-empty, in terms of phenomenological psychophysics (i.e. in terms of metric and topological characteristics) turned out to belong to the same class as *vertical-horizontal*. However, with this type of task, this pair manifested behavior that was more similar to that of *long-short* and *wide-narrow* (see Figure 12.6, 4a). There is in fact a large intersection between P1 and P2[2]. In this case too, as in the case of *long-short* and *wide-narrow*, there is at least one element of P1 and one element of P2 that cannot be perceived as constituting gradations of the opposite property. Thus although gradations of both poles can cover large areas of the opposite set, they cannot cover it all.

no more seats available. These poles were described as "points", that is they referred to single experiences (see Savardi & Bianchi 2000a; Savardi, Bianchi & Kubovy submitted). However, when the task was to evaluate "how much" of a property was recognizable in a series of states, participants shifted from focusing on the qualitative instances that fit the property exactly, to evaluating its clear or even partial presence. Going back to the example of the door, when participants were looking at doors that were only slightly open, they described this experience not only in terms of low-medium degrees of being *open* but also in terms of the presence of a certain degree of being *closed* ("a bit closed"; "too closed to pass through"). So, in general "point" properties acquired, with this task, a more extended range of application.

2 Again, if one considers the kind of stimuli studied (a transparent vase containing a blue liquid, ranging from completely empty to full to the brim) and the questions asked ("How full is this?" and "How empty is this?") it becomes clear that participants were rating in one case how much of the container was filled with liquid and in the other case, how much of the container was not filled with liquid. It is interesting that a similar interpretation could also potentially apply to *horizontal* and *vertical*. However participants' responses revealed that they still perceived a certain degree of *verticality* for few states of obliquity beyond the exact *vertical* position, and the same went for *horizontal*. But for most oblique positions, the perception of verticality or horizontality did not hold anymore.

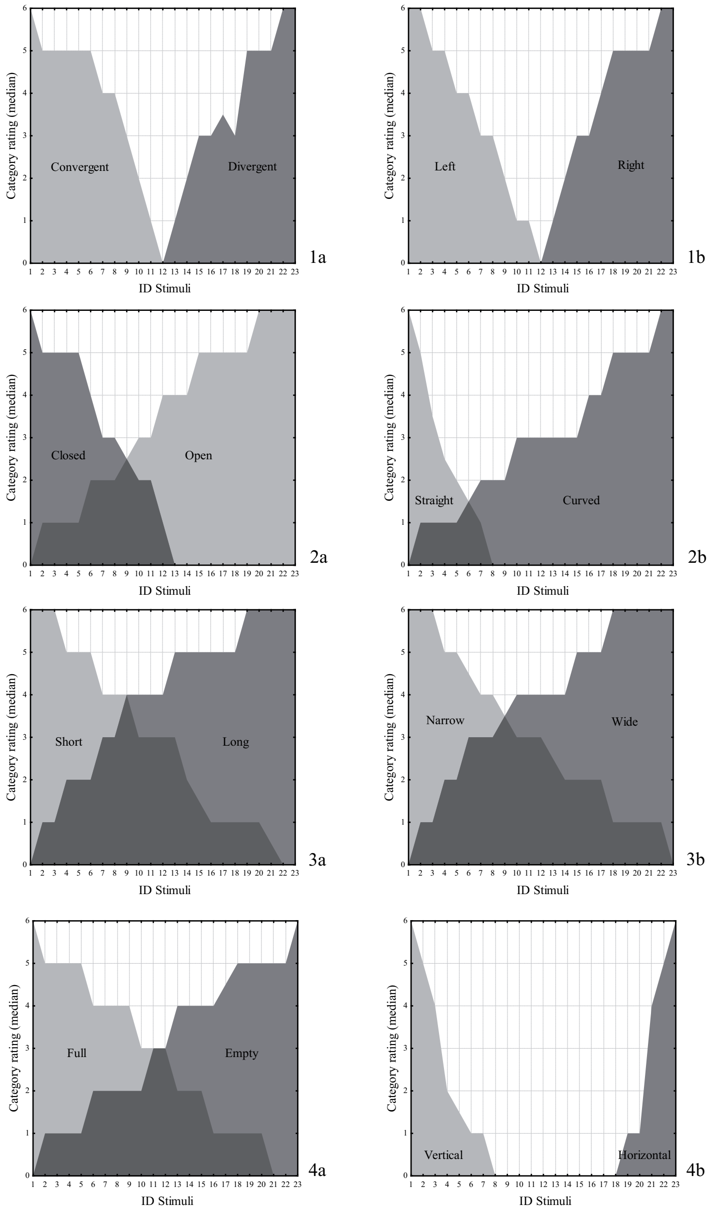

Figure 12.6 Along the x axis, each graph represents 23 different stimuli displaying the properties in question, which are manifested in increasing gradations. On the y axis the median ratings attributed by participants to the corresponding stimuli are reported. The gray areas show the amount of the x axis which is covered by the gradations of one property and its opposite, and the stimuli, if any, in which both properties are perceived (the areas of overlap).

In conclusion, in agreement with what one expect would be predicted based on the argument developed in sections 12.5 and 12.6, these results show that there are more or less extended "gaps" in the supposed common continuum that remain unfilled if one tries to model the corresponding dimension directly from the gradations of the two poles.

Moreover, it has to be said that when an overlap is present, this does not necessarily guarantee that P1 and P2 map the same dimension and degrees, but with inverse orderings.

An analysis of *long-short*, *high-low*, *large-small* and *wide-narrow* demonstrated that ratings of each individual property given when observing a sample of objects which significantly vary in terms of extensional characteristics, in effect fall along the same continuum. For example, judgments of *high* given when looking at a set of objects ranging from a die to the nave of a cathedral, were in effect distributed along the same continuum. But when the series of ratings (or the two opposite continua, e.g. *high* and *low*) were compared, it turned out that they were not distributed along the same continuum (for details see Savardi, Bianchi & Burro, submitted).

These observations, taken as a whole, contribute towards revealing the inadequacy of the two first solutions represented in Figure 12.1 as a possible link between opposites and dimensions and, if anything, suggest turning to one of the two solutions represented in the third and fourth diagrams of the figure. Experimental data are anyway required to test the validity of both of them. Research in this direction is however a necessary step if a corroborated psychological theory of dimension is to be established.

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