CHAPTER 13

Spatial language and spatial representation

Autonomy and interaction[1]

Barbara Landau and Laura Lakusta
Johns Hopkins University

In this chapter, we explore the nature of spatial language and how it engages non-linguistic spatial representational systems. We ask to what degree and in what way spatial language depends on non-linguistic spatial representation for development, and to what degree it can emerge autonomously. We focus on spatial language in people with Williams syndrome, who have severe non-linguistic spatial impairments but relatively spared language. We consider the problem of what is to be acquired when one learns spatial language, and how it might be affected when one or more aspects of non-linguistic spatial representation is impaired. Our conclusion is that it depends: Where spatial language encodes the spatial world in a coarse manner, it emerges with normal structure even in people who have other spatial impairments. Where spatial language encodes the spatial world in a more detailed (less coarse) manner, we observe impairments that echo the ones observed in non-linguistic tasks. Quite different outcomes underscore the fact that spatial language is a system with its own special properties, that it interfaces with (but does not copy) spatial non-linguistic systems, and that finding sparing or breakdown may depend largely on where we look.

Introduction

As we look around the world, we effortlessly perceive objects, spatial layouts, and events. Perhaps more remarkably, we readily and easily talk about these things, describing what we saw and where, how things happened, and how events changed over space and time. How is this accomplished? The answer to this question is of central

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importance in understanding a fundamental fact about human cognition: We can talk about what we see.

Our general purpose in this chapter is to shed light on this problem. We will do so by exploring the relationship between our spatial representations of the world and the language that encodes them, asking which aspects of spatial language depend directly on non-linguistic spatial representations of the world, and which can emerge autonomously – independent of our spatial representations. We will evaluate the possibilities by offering evidence on the nature of spatial language in children and adults with Williams syndrome – a rare genetic deficit which gives rise to a unique cognitive profile in which spatial representations are severely impaired but language is spared.

Williams syndrome (WS) raises questions of considerable general interest to scientists seeking to understand the architecture of human cognition, because dissociation across knowledge domains would support the notion that cognitive systems are highly specialized and therefore can emerge independent of each other – autonomously. There is currently much debate about the strong hypothesis of autonomy between space and language in Williams syndrome. Some have argued that there is indeed sparing of significant aspects of the language learning system, even in the face of severe spatial deficits, consistent with developmental autonomy of the two systems (Bellugi, Marks, Bihrle, & Sabo 1988; Clahsen & Almazan 1998; Zukowski 2001; Landau & Zukowski 2003). Others have argued that there is no sparing of language in Williams syndrome, nor of other cognitive systems, since genetic deficits that target one system will inevitably affect all cognitive systems (Karmiloff-Smith 1998; Thomas & Karmiloff-Smith 2002).[2]

Our chapter will address a very specific version of this broad hypothesis by asking whether, where, and to what extent language and space interact. We should say at the outset that we believe that some degree of autonomy between language and space is inevitable: In an important sense, spatial representations and language must be autonomous, since they engage quite different computational systems and serve very different functions. Thus, formal elements of language, such as noun phrase and verb phrase, do not appear as part of any known spatial computational system. And formal elements of spatial representation, such as reference systems, play no direct role in our knowledge of language. At the same time, this autonomy cannot be complete: Spatial representations and language must interact, since we must be able to talk about what we see. Yet how the brain and mind carry out this interaction is not well understood.

We believe that the case of Williams syndrome affords a unique opportunity to better understand the ways in which space and language interact, and how these interactions emerge in both normal and unusual development. In particular, the study of

2. There is much debate about use of the term "sparing" in developmental disorders. Some propose that there can be no sparing except in cases of frank lesions, which might be followed by some recovery. To be clear, in this paper, we use the term sparing to indicate the presence of normal structure, whether it occurs consequent to frank lesion or genetic/developmental disorder.

WS people – in comparison to normally developing children – allows us to identify the specific sites of interaction that might be more or less vulnerable to breakdown under severe spatial impairment. By exploring this issue, we hope to more broadly illuminate the degree of autonomy and interaction between language and spatial representation.

In the next sections, we first address the question of what is to be acquired. As in any study of language, we must be sure to understand the nature of the mature system before testing any hypotheses about sparing or breakdown. In the case of spatial language, we need to ask how – in principle – it could be affected by a severe deficit in non-linguistic spatial representation. Second, we review evidence of reported *deficits* in spatial language among children and adults with Williams syndrome. We argue that much of this evidence is ambiguous with respect to *knowledge* of spatial language because the reported deficits do not clearly distinguish between absence of knowledge and impairment in a host of performance mechanisms. Finally, we review evidence from our own lab showing that some aspects of language do indeed emerge unaffected by the spatial impairment, while others do not. Those aspects of spatial language that are negatively affected by the spatial impairment are – perhaps not surprisingly – those whose meanings call for more or less direct links to aspects of spatial representation that we know, on other grounds, are impaired in Williams syndrome. This provides evidence for the *dependence* of space and language. In contrast, those aspects of spatial language that do not require such direct links are not affected, providing evidence for *autonomy* of space and language. We conclude by arguing that the study of Williams syndrome – like other unusual perspectives on human cognition – can shed light on the normal architecture of cognition, and specifically, on the sites of interaction and non-interaction between the language faculty and the various domains of spatial representation.

1. Spatial language: What is to be acquired and how might it break down?

Many theorists have assumed that talking about objects and events in the world depends, in part, on our non-linguistic representations of the world. Because we can talk about aspects of our spatial experience, there must be some elements of linguistic and non-linguistic representation that are shared. This idea has been explored extensively by cognitive scientists including psychologists, computer scientists and linguists (H. Clark 1973; Fillmore 1997; Landau & Jackendoff 1993; Hayward & Tarr 1995; Herskovits 1986; Jackendoff 1983; Miller & Johnson-Laird 1976; Regier 1996; Talmy 1983; see Bloom, Peterson, Nadel, & Garrett 1996, for recent views).

But the connection between space and language is not a simple one. For example, one might suppose that the relationship between language and space is like a one-way entailment: Whatever is encoded in space is also encoded in language. This hypothesis is easily falsified by examining the general character of spatial language. Consider object names, which typically encode categories (e.g., *dog*, *house*, *table*). Each name encodes the object's membership in a category, regardless of the many distinctions that can be made by the spatial- perceptual systems – distinctions such as variation in size, color, and other surface properties. Language is essentially "blind" to these distinctions in its basic vocabulary, probably because of a basic design feature of language: Lexical items encode categories at a level of detail coarser than that available to perception (Landau & Jackendoff 1993).

The same is true for words that encode spatial relationships. Terms such as *above*, *below*, *in*, *out*, etc. encode a subset of spatial properties that are represented by other spatial systems. For example, when we reach for or grasp an object, our perceptual-motor system must encode metric information about the object, viewer, grasping hand, etc., and this information must be updated as the action is carried out. However, languages do not have a stock of basic spatial terms that encode absolute metric distance or orientation (Talmy 1983). Rather, English prepositions such as *above* or *below*, *near* or *far* (and equivalent terms in other languages) encode relationships that are blind to absolute distance. Of course, one can use language to describe metric relations, but this is usually accomplished by recruiting measure terms and number words, which make up the language's stock of metric terms. These, and many other examples, show that the basic terms of a language are highly selective in the properties they choose to encode and that these constitute only a subset of the properties available to the human spatial representational systems.

Given this, testing hypotheses of language-space autonomy and interaction will require that we understand which spatial properties language regularly encodes. The answer to this question will depend on what aspect of spatial language we consider. In our chapter, we will consider the linguistic encoding of objects, motions through space, and spatial relationships. Using Jackendoff's (1983) framework, these notions correspond to ontological categories <OBJECT>, <ACTION> and <PLACE> OR <PATH>, respectively. The representation of each lexical item will specify its relevant ontological category, phonological form, syntactic category, and where relevant, the item's link to a spatial representation. The latter will provide information crucial to picking out instances of DOG, RUN, INTO, etc. in the world. The nature of the spatial component will prove to be critical in making predictions about the impairment of spatial language in the context of severely impaired non-linguistic spatial representations.

Figure 1 shows an example, using the word "cat", adapted from Jackendoff (1996). This lexical item specifies that the word "cat" is pronounced /kæt/, that it corresponds to an OBJECT (animate), and that it is encoded syntactically as a Count Noun. Furthermore, the representation is linked to a spatial representation that specifies the object's geometric structure, along with parameters suitable to variation in size, color, etc. Note that this spatial representation is not generated internally to language, but rather, comes from within the perceptual system, which can specify many different properties. The spatial part of the lexical representation "points to" the spatial representation, which can then allow the speaker/hearer to recognize that some object is, in fact, a cat. Note also that the spatial representation does not encode any particular value of the parameters that specify colors, sizes, etc.; that is, it is "blind" to specific values. As another example, the lexical item "skip" is pronounced /skɪp/, corresponds to

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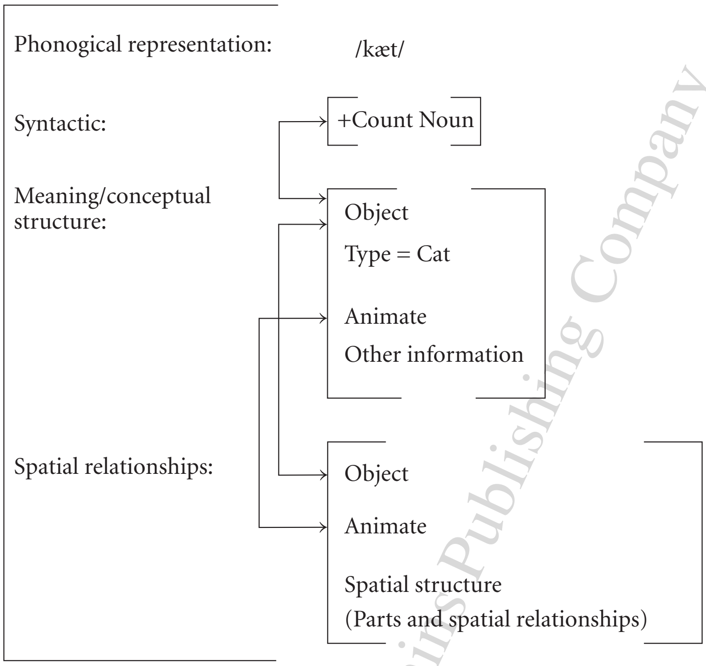

Figure 1. Different levels of representation for the lexical item "cat". Each level contains information specific to itself but commonalities across levels permit binding for a unified representation of the word. Our discussion emphasizes the inclusion of spatial information in the representation of some lexical items. (adapted from Jackendoff 1966).

the ontological category <ACTION>, and is encoded syntactically as a Verb that has a single obligatory argument (the Actor). Additional arguments, such as <PATH> (e.g., "She skipped *into the room*") can be added, but are not obligatory. Other categories of verbs may specify two or more obligatory arguments, (e.g., "She put *the spoon in the dish*"). The representation of "skip" will also contain a link to a spatial representation that specifies the geometric structure of skipping, along with parameters that can specify, perhaps, the speed of the skip. Again, the geometric structure of skipping is determined by computational systems outside of language – plausibly, the motor system, which generates commands for skipping. The perceptual system will have access to these descriptions as well, in order to allow us to recognize the action of skipping.

As a final example, the expression of PLACES and PATHS, in English, is accomplished by lexical items such as *above*, *on*, *in*, *into*, etc., which express a spatial function designating the relevant spatial region of a specified reference object. This results in a phrase that specifies the spatial relationship, e.g., *in the dish* or *into the room*. The lexical items include phonological specification and relevant ontological category (e.g., PLACE-function or PATH-function). Because they usually represent relationships, these terms take arguments; that is, they will need to specify the Place or Path function and the Reference object upon which it operates. These two items are then expressed syntactically as a Prepositional Phrase, with the Place/Path function expressed as a Preposition, and the Reference object as a Noun Phrase. The spatial component will specify the geometric content of the spatial relationship. For example, for the term *above*, the spatial representation will specify a reference system comprised of orthogonal axes whose origin is centered on the Reference object; within the reference system, the relevant region for "above" the Reference object will be indicated. As a contrast case, the term *into* need not specify a set of axes. Rather, it will need to specify the direction of the Path relative to the Reference object (e.g., "*into* the room" rather than "*away from* the room") and the geometry of the Reference object that is required to match this Path function (e.g., for the term *into*, any object that can be conceptualized as a "container").

Given these representations, we can make some predictions about the extent to which impaired spatial representations will result in impaired spatial language. Simply put, if the corresponding spatial representation is impaired, so should the use of the spatial term. For example, if there is impairment in the representation of axial reference systems, then we might expect corresponding impairment in the capacity to accurately describe Places or Paths that engage such reference systems. As another example, if there is impairment in the capacity to perceive actions, we would expect difficulty in using or understanding the word "walk" to refer to walking. Notice that these predictions apply to *referential* functions of language – that is, the ability to accurately and truthfully produce or comprehend spatial terms to name spatial relationships and actions as they occur in the real world.

However, the complete representations of these terms contain much more than their links to spatial representations, and the functions or uses of these terms are not just referential. The *non-spatial* aspects of the lexical representations should not be compromised by spatial impairment. For example, both verbs and prepositions take one or more arguments; these vary in number and type depending on the verb/ preposition's meaning. The verb *walk* takes just one NP argument but *give* takes three; the preposition *in* takes one NP argument but *between* takes two. Verbs also vary in the type of argument they can take, including NPs (for verbs like *give*) and Sentential complements (for verbs like *think*). The number and type of arguments that a Verb or Preposition takes should not be affected by spatial impairment, since this is a separate aspect of the lexical representation that does not require any spatial information. Research has shown that the argument structure of verbs and prepositions can be inferred from syntactic context alone (Landau & Gleitman 1985; Fisher, Hall, Rakowitz, & Gleitman 1994; Landau & Stecker 1990; Fisher 2002).

Other aspects of the lexical representation should also remain unaffected by impaired spatial representations. These include the phonological representation of the word and other aspects of meaning that can be induced from evidence in the linguistic input. For example, a noun's status as count vs. mass can be inferred from its determiners or broader conceptual knowledge about the kind of entity onto which the noun maps. In general, much of the basic structure of spatial language should be expected to remain intact in the face of spatial impairment. The exceptions occur in cases where the lexical representation is linked to a spatial representation, where that spatial representation can be shown to be impaired, and where the word must be used referentially, i.e., to describe some spatial configuration.

In sum, severely impaired spatial representations would be expected to have impact if both of the following are true: (1) the meaning and use of a spatial expression engages non-linguistic spatial content, and (2) we have some reason to believe that this non-linguistic spatial content is impaired. For example, if a person cannot non-linguistically represent location (say, one object on top of another), then they would not be expected to be able to learn or use the expression "on top of". This is just the equivalent of saying that a blind person does not have the capacity to use color terms referentially – that is, he or she cannot point to or otherwise truthfully indicate that something is red, blue, etc. However, there are numerous aspects of spatial language that do not require spatial *content*. Moreover, there may be some aspects of spatial language that do have spatial content, but the coarseness of coding by language would be expected to yield a very "low bar" for spatial representations. In these cases we may expect preserved competence if such coarse spatial coding is retained in the non-linguistic spatial representations of WS individuals.

2. Previous findings and the Competence/Performance distinction

Evidence for a dissociation between language and space in Williams syndrome was first offered by Bellugi et al. (1988). They reported that adolescents with Williams syndrome could make accurate grammaticality judgments for complex aspects of syntax, even though they performed at the level of 4-year-olds on visual-spatial construction tasks. For example, WS adolescents correctly judged the grammaticality or ungrammaticality of sentences such as "Were delivered the flowers by the messenger?" and were even able to correct these ungrammatical sentences, saying, e.g., "Were the flowers delivered by the messenger?". In contrast, the same groups showed severe impairment in copying figures, even those that are relatively simple for normally developing 6-year-olds (see Figure 2 for examples from our lab). Bellugi et al. argued that language as a system of knowledge was spared in people with Williams syndrome despite the severe deficit in spatial representation. The claim focused on the apparent dissociation between the development of two quite broad and powerful systems of representation – language and space.

More recently, the claim that WS language is spared – that is, unimpaired – has been questioned. Mervis, Morris, Bertrand and Robinson (1999) have argued that, on a number of measures, WS language is better than would be expected for mental age, but is not identical to that expected for chronological age. One clear example comes from standardized tests for receptive vocabulary (Peabody Picture Vocabulary Test; Dunn & Dunn 1981) and grammar (Test for Reception of Grammar or TROG; Bishop 1989), both of which show that language abilities are significantly delayed rel-

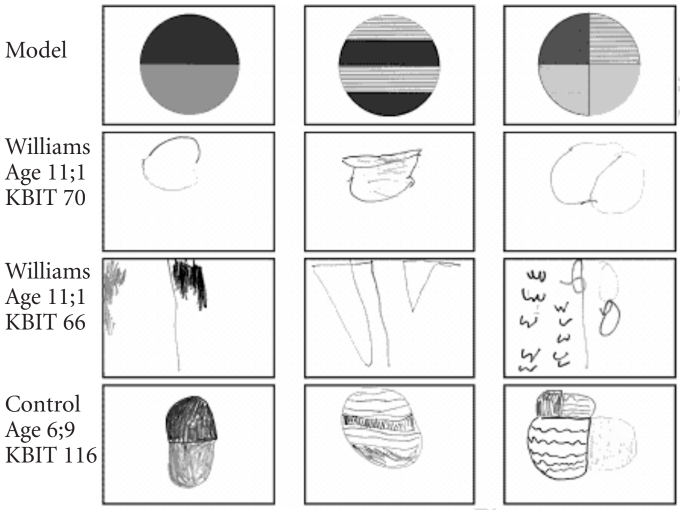

Figure 2. Sample drawings by two WS children, and one normally developing child who was matched for mental age. Matching was done using the Kaufman Brief Intelligence Test (KBIT, Kaufman & Kaufman 1990).

ative to chronological age. Yet, despite this delay, language scores tend to be higher than corresponding scores on so-called non-verbal tests (Mervis et al. 1999). Although this evidence does suggest that WS individuals have only a *relatively* spared capacity for these language abilities, they are consistent with the idea that these aspects of the language system – as measured by standardized tests – are spared, relative to the severe deficits in spatial organization.

More serious challenges to the hypothesis of dissociation have come from researchers who have suggested that aspects of syntax and morphology – and perhaps other areas of language – are impaired, both quantitatively and qualitatively. For example, Karmiloff-Smith, Grant, Berthoud, Davies, Howlin and Udwin (1997) have argued that WS children are impaired in their understanding of linguistic rule systems – arguably one of the defining characteristics of human language. Two widely cited pieces of evidence concern morpho-syntactic rules used to produce adjective-noun agreement within French noun phrases (Karmiloff-Smith et al. 1997), and performance on tests of relative clauses (Karmiloff-Smith et al. 1997; Mervis et al. 1999; Volterra, Capirci, Pezzini, Sabbadini, & Vicari 1996). For example, Karmiloff-Smith et al. (1997) found that WS children had relative difficulty generalizing gender marking across an entire noun phrase: If they heard "*une* plichon" (a novel noun with a masculine sounding ending preceded by a feminine article), they were less likely than normal children of younger ages to correctly infer that they should generalize the feminine marking to adjectives (e.g., "une plichon *blanche*"). Mervis et al. (1999) examined WS children's ability to process relative clauses and found that although grammatical comprehension may be a relative strength for WS children (compared to non-verbal abilities),

"...performance on the most complex constructions was poor. For example, only 18% of the participants (22% of the adults) passed the (TROG) block assessing relative clauses (right branching), and only 5% (9% of the adults) passed the block assessing embedded sentences (left branching)" (p. 85).

The evidence on relative clauses makes an important point, because the tests that were used in these studies are assumed to be diagnostic of underlying linguistic knowledge. But in fact, they extensively recruit mechanisms of memory and attention, which may be impaired independently of linguistic knowledge. We make the distinction here between "*competence* (the speaker-hearer's knowledge of his language) and *performance* (the actual use of language in concrete situations" (Chomsky 1957: 4). In evaluating a person's knowledge of spatial language, it will be important to carefully consider how much of a person's performance reflects "memory limitations, distractions, shifts of attention and interest, and errors... in applying... knowledge of the language in real performance" (ibid.: 3). This problem exists, of course, for all psychological studies of language, but it is exacerbated in the case of unusual populations, where disorders of memory and attention might lead to significantly different patterns of performance without reflecting differences in knowledge.

The results from the TROG provide a good example of this problem. This widely used standardized test is assumed to measure various aspects of grammatical knowledge. Items in the TROG do require knowledge of targeted grammatical structures, but they also require proficiency in a number of other, more general cognitive capacities. To illustrate, consider an item from the TROG that is used to test comprehension of relative clauses (see Figure 3). The child is shown four pictures, and is asked to point to the one where "The circle the star is in is red". In order to point to the correct picture, the child must be able to process the relative clause structure, which is an embedded structure of roughly the form

[[The circle [the star is in (t)] is red]]

Center-embedded structures such as this are known to be difficult to process, both among children and adults (e.g., Sheldon 1974; Correa 1995; Fodor, Bever, & Garrett 1974). Moreover, this specific form of the sentence does not contain any overt relative clause markers (i.e., *that, which, who*), which will further increase the difficulty of the task (e.g., Rayner, Carlson, & Frazier 1983; Ferreira, Henderson, Anes, Weeks, & McFarlane 1996). And aside from these linguistically relevant processing demands, the task also requires considerable visual-spatial processing and memory: One must visually scan and attend to all four items and then map the center embedded structure onto the correct visual item, essentially re-coding the linguistic structure as, perhaps, two coordinated structures (such as shown below) that would map more simply onto the visual items.

[[The star is in the circle] and [The circle is red]]

Errors could be made at any number of steps. The child might be able to parse the sentence but not convert it into the coordinated structure. She might not be able to sys-

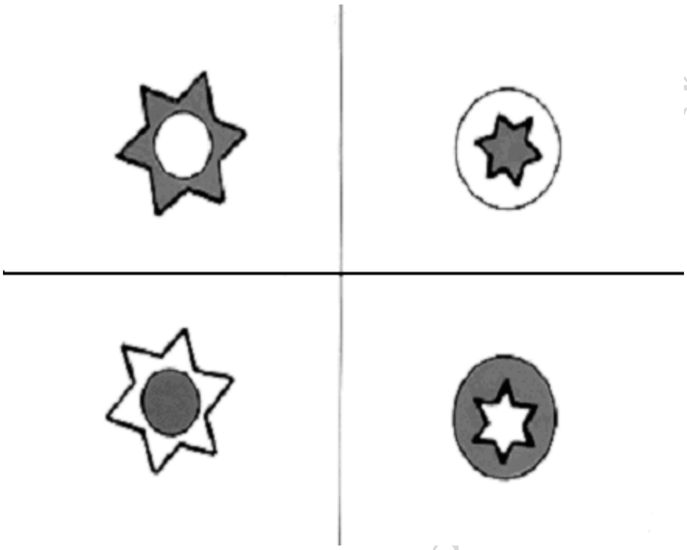

Figure 3. Test item taken from the Test of Receptive Grammar (TROG, Bishop 1989), designed to test comprehension of relative clauses. The child is shown all four pictures and asked to point to the one where "The circle the star is in is red" (Note that in the original test item, the darker color is red, and the lighter color is white). The test item requires cognitive capacities beyond the processing of a relative clause (see text for discussion). (Picture reproduced by permission of publisher).

tematically scan all four options while carrying out this conversion. She might not be able to remember the original sentence after thoroughly scanning the items. And there are many other possibilities. A child who has either attentional or memorial deficits (as WS individuals do; Jarrold, Baddeley, & Hewes 1999; Wang & Bellugi 1994; Vicari, Brizzolara, Carlesimo, Pezzini, & Volterra 1996) might fail the task, leading the researcher to incorrectly conclude that the child cannot represent the linguistic structure used for relative clauses. Of course, it is also possible that the child *is* in fact impaired in this aspect of linguistic knowledge and that the TROG test is fairly representing this impairment. Our point is just that, given the task requirements of these items in the TROG, one cannot tell whether linguistic competence – the ability of the grammatical system to generate the structure at all – is impaired or whether impaired processing mechanisms mask or suppress performance.

As it turns out, children with WS do possess the linguistic knowledge required to represent sentences with relative clauses, as shown by their ability to produce these. Zukowski (2001) designed tasks that created felicitous conditions for eliciting subject and object relative clauses – tasks very different from those in the TROG. She reasoned that a child who could *produce* a relative clause must be equipped with the grammatical knowledge to represent these structures. If a person is capable of producing a well-formed sentence with each or both of these clauses, then it is the case that they possess the representational machinery to generate these structures. Zukowski's results showed that WS children who failed the TROG were nevertheless able to produce grammatically well-formed relative clauses in her task. In our view, this is evidence that the machinery for syntactic competence is present in people with Williams syndrome. As Zukowski (2004) points out, this evidence also rules out the possibility that people with WS perform poorly on tests such as the TROG because their grammars simply do not generate these structures.

To illustrate, consider the following situation aimed to elicit a subject gap relative clause. Zukowski showed children a scene displaying two boys – one sitting on a horse and the other standing on a horse. While the child looked at the scene, a change took place: One boy turned green and the other boy turned purple. When one WS individual was asked about the change, he said "The boy who was sitting on the horse turned green, and the boy who was standing on a horse turned purple." Zukowski also found that WS children were able to produce relative clause structures in situations that elicited object gap relative clauses. She showed children a scene displaying a girl chasing a cat and a dog chasing a cat. While the child viewed the scene the experimenter said: "Here are two cats, and a girl is chasing one cat, and a dog is chasing another cat. Let's see what happens..." Then, while the child continued to look at the scene, a change took place. For example, a small bird (Bill) looked at the cat that the girl was chasing. The experimenter then asked the child about the change. One WS child responded: "Bill is looking at the cat that the girl's chasing". These examples illustrate that WS individuals do indeed have the competence to produce relative clause structures.

Zukowski's findings on relative clauses illustrate the importance of evaluating task requirements before drawing a conclusion of sparing or impairment in the grammatical system. The same principle holds for studies of spatial language. Although there have not been many studies of spatial language in WS, several have reported deficits in spatial language. Some of these have been anecdotal, reporting that WS people make unusual errors in the use of certain spatial terms (Rubba & Klima 1991). Other studies have been more systematic and experimental. But we believe that these studies may suffer from problems of interpretation similar to those discussed above.

In one study, Karmiloff-Smith et al. (1997) examined spatial language using items from the TROG that tapped comprehension of spatial and other relational terms such as *longer/bigger/taller*, *in/on*, and *above/below*. A sample of one such item is shown in Figure 4. Karmiloff-Smith et al. tested 18 WS individuals with chronological ages ranging from 8;4–34;10, who had a mean TROG test age of 6 years, 3 months – lower than their mean chronological age (18 years, 2 months). Analysis of different item types showed that WS subjects had some difficulty on the items testing spatial language: 27.0% errors on items *longer/bigger/taller*, 14.5% errors on items *in/on*, and 27.9% errors on items *above/below*. Although these error rates are still considerably lower than those on 'complex' grammatical items (e.g., embedded structures; 67.9% errors), the authors followed up with a closer look at the spatial items of the TROG.

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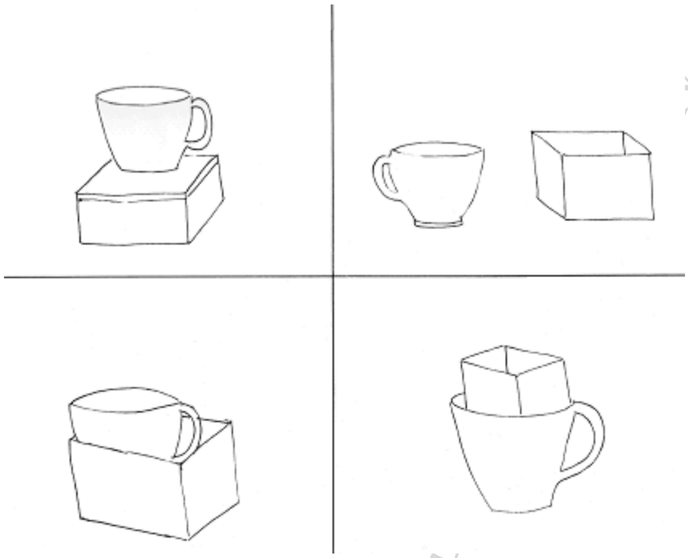

Figure 4. TROG item (Bishop 1989) used to test comprehension of spatial terms. The child is shown all four pictures and asked to point to the where "The cup is in the box". As in Figure 3, the test item requires considerable cognitive processing beyond the comprehension of the target spatial term. (Picture reproduced by permission of publisher).

To do so, they developed a new test which was patterned after the TROG but included 48 spatial and 48 non-spatial items (Phillips, Jarrold, Baddeley, Grant, & Karmiloff-Smith 2004). They tested 32 WS individuals (chronological ages 8;3–38;1) and two control groups – one group of typically developing children and one group of children who had moderate learning difficulties. Although the groups were individually matched to the WS individuals on receptive vocabulary, Phillips et al. again found that WS individuals performed more poorly than their matched controls on items testing spatial and relational terms (e.g., *longer/bigger/taller*, *in/on*, and *above/below*). They did not differ on items that tested non-spatial terms (e.g., *neither/nor)*, and the authors concluded that spatial language may be an area of special impairment.

The Phillips et al. task was very similar to the TROG. Subjects were required to listen to a sentence (e.g., "The duck is above the boat") while being shown four pictures – one that correctly represents the sentence and three pictures that depict the same objects as the target picture but in different arrangements. The subjects' task was to point to the picture that they believed correctly represented the sentence. A similar method was used by Lichtenberger and Bellugi (1998), who asked WS subjects to "choose one of four pictures that best represent(s) the preposition or spatial phrase (e.g., through, between, above, in front of)" (Bellugi, Lichtenberger, Jones, Lai, & St. George 2000: 22). Lichtenberger and Bellugi also found poorer performance among WS people than controls.

What should we conclude from these results? The lexical items tested – words such as *above/below* or *in/on* – might have deficient representations at any of the levels of description that we considered earlier. Or, WS subjects might have intact representations of the semantic, syntactic, and spatial properties of the terms, but fail the task because it taxes more general computational mechanisms, such as attention or memory.

Consider one of the spatial items included in the TROG, shown in Figure 4. The child is shown the panel with four choices and told to find the picture where "the cup is in the box". All four choices show a cup and a box, but only one of the pictures depict these two objects in the correct relationship. Two other pictures show different relationships between the objects, i.e., 'cup *on* the box' and 'cup *next to* box'. And the final choice shows a relationship of "in", but with figure-ground reversal, such that the "box is in the cup".

To get this test item correct, one must be able to form an accurate linguistic representation of the sentence "The cup is in the box". The crucial elements are (a) correct assignment of the two objects to the roles of "figure" and "reference object", which are carried syntactically by the subject and object of the preposition; and (b) correct spatial representation of the relationship "X IN Y" (contrasted with *on* and *next to*). Having done this, the subject must then scan all four pictures and form spatial representations of the relationships depicted there. Finally, he or she must map the heard sentence onto the pictures and decide which one matches. If any of these component processes is impaired – or if the mechanisms that align these processes smoothly during comprehension are impaired – the person will fail. The evidence for impairment suggests only that some process, mechanism, or representation is disrupted; or that the combination of these taxes the system more in people with WS than in normal individuals. It does not show that there is impairment in the linguistic representations of these terms, however.

3. Sparing and deficit in two domains of spatial language

We now turn to studies from our own lab examining the nature of spatial language in Williams syndrome. Keeping in mind the central question – the sites of possible impairment in spatial language – our strategy has been to examine both lexical and syntactic expression of space using experimental tasks that are quite different from standardized tests. We will report the results of studies in two spatial domains – the language of dynamic spatial events and the language of spatial terms such as *above/below*, which engage spatial reference systems. To preview, our findings suggest that much of the *structure* of spatial language – including syntactic, semantic, and spatial representations – is preserved in WS children and adults. Weakness appears where there is corresponding weakness in the non-linguistic spatial representations that interact with or are tightly coupled to spatial language.

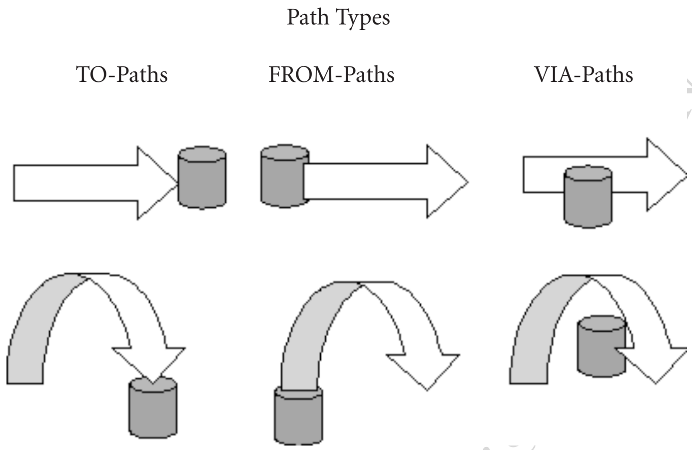

Figure 5. Basic English spatial prepositions typically encode three types of Paths: TO, FROM, and VIA, with each term engaging different constraints for reference object (Jackendoff 1983).

3.1 Case 1: The language of dynamic spatial events

The linguistic representation of Motion events has obvious links to non-linguistic spatial representations: To describe an event of walking, running, or skipping, one must be able to represent the corresponding actions, which are inherently spatial, and encode them with appropriate verbs, which have argument structure. Moreover, Motion events often involve paths which must also be represented non-linguistically and converted into an appropriate linguistic expression.

Consider the following Motion event: A bird flies out of a bucket, past a cup, and into a bowl. According to Talmy (1985), events such as this are expressed using several key components. In English, these include (a) the *Figure* object, or object that undergoes the motion ('the bird'); (b) the *Manner of the Motion* that it performs ('fly'); (c) the *Path* the Figure object traverses ('out', 'past', and 'into'); and (d) the *Reference* object, which defines the region within which the Figure is located ('a bucket', 'a cup', and 'a bowl'). The Path and the Reference object together make up the entire Path expression ('out of a bucket', 'past the cup' and 'into a bowl'). According to Jackendoff (1983), Path expressions fall into three basic types: TO-Paths have a Reference object that is a Goal or endpoint of the Figure (e.g., '*into* a bowl'), FROM-Paths have a Reference object that is a Source or starting point of the Figure (e.g., '*out of* a bucket'), and VIA-Paths have a Figure that moves past the Reference object (e.g., '*past* the cup'), (see Figure 5 for an illustration of TO-, FROM-, and VIA-Paths).

Recall that the lexical representation of each item includes various pieces of information: Its ontological category, phonological form, syntactic category, and link to a spatial representation. Following our example, Figure and Reference objects are syntactically encoded by noun phrases (e.g., *the bird, a bucket, a cup*, and *a bowl*). Each is also linked to a spatial representation that specifies the object's geometric structure. In contrast, the lexical representation encoding Path specifies that its syntactic category is a preposition (e.g., *out, past*, and *in*). Each of these is also linked to a spatial representation that specifies the direction of the Path relative to the Reference object (e.g., that "out" is a FROM-path), and the geometry of the Reference object (e.g., that it must be construable as a 'container' for the term "out" but a surface for the term "off"). Thus, the lexical components that encode Motion events contain both linguistic and spatial information and these must be preserved in order to produce a syntactically and semantically well-formed description of the event.

Do WS individuals have the capacity to perceive Motion events accurately and to convert their representations into language? In a first study, we showed a large set of videotaped Motion events to WS children and adults, and to normally developing children, and asked them to tell us "What happened?" (Landau & Zukowski 2003; Lakusta, Licona, & Landau 2004). The normal children included a set of 5–6 year olds, who were matched by mental age to the WS children, and a set of 3–4 year olds, who had lower mental ages than the WS children (as measured by the raw scores of the Kaufman Brief Intelligence Test; Kaufman & Kaufman 1990). The groups had the following mean ages: WS children (N = 12, 9;7), WS adults (N = 13, 21;9), mental age matches (N = 12, 5;0), 3–4 year-olds (N = 12, 3;9). The 80 videotaped events were developed and used by Supalla and Newport to evaluate motion verbs in American Sign Language (Newport 1990; Supalla 1982; Supalla, Newport, Singleton, Supalla, Medly, & Coulter in press). The events portrayed Figure objects performing Motion in a variety of Manners (e.g., jumping, sliding, or flying) over a variety of Paths (TO, FROM, or VIA). For example, one event showed a girl jumping into a circular hoop that lay flat on the ground; another showed a cow falling off the end of a truck, etc. Each event showed just one Figure and one Reference object, hence naturally encoded just one kind of Path (TO, FROM, or VIA). Our question was how well people with WS could express the different components of the Motion events and whether this would differ from the expressions of normally developing children.

We found that the structure of spatial language was preserved in WS children and WS adults – in terms of both linguistic (syntactic and semantic) and spatial representation. WS children and adults correctly encoded objects with Nouns (NPs), actions with Verbs (VPs), and spatial relations with Prepositional Phrases (PPs). Their sentences were also syntactically well-formed, including the appropriate number of syntactic arguments for the various verbs that were assembled correctly into grammatical sentences. Perhaps even more impressive was the preservation of spatial information by WS children and adults. Both WS groups named the Figure and Reference objects using the same nouns as the other groups, indicating that they represented the objects in much the same way. They also used the same Manner of Motion verbs as the other groups, showing that they correctly represented the difference between walking, running, hopping, twirling, flying, etc. And they expressed the Path accurately – using prepositions that were from the appropriate Path type category (TO, FROM, or VIA) and fit the geometric constraints of the Reference object (e.g., 'in' vs. 'on') within these categories.

The only place where we found a difference was in *how often* WS children included VIA- and FROM-Path expressions, relative to the uses of mental age-matched children (5–6 year olds). Specifically, whereas all groups included TO-Paths expressions whenever required (e.g., "into the pool"), the WS children often omitted VIA-, and especially, FROM-Path expressions. For example, in describing an event showing a girl walking past a block, WS children were more likely than MA controls to omit the Path and the block, saying, "The girl was walking" (rather than "The girl was walking past a block"). Similarly, when describing an event that showed a block falling off a swing, WS children were more likely than MA controls to omit the Path and the swing, saying, "The block fell". Note that such descriptions are perfectly grammatical – expressing the Path in these constructions is completely optional (and corresponds to the fact that Motion verbs typically take only a single obligatory argument, the theme/actor). Rather, such descriptions just omitted Path information. Since this effect was most pronounced for FROM-Paths, where the Reference object is the Source, we called this effect "Source Vulnerability".

What does this Source Vulnerability reflect? One possibility is the "Path Term Impairment" hypothesis – that omissions reflect impairment in the representation of Path terms. Such impairment could be at the level of correctly categorizing the Path types for the purposes of language (i.e., differentiating between TO, FROM, and VIA path types), or violating some aspect of the syntax of the verbs or prepositions that are selected. This hypothesis can be ruled out, since WS children and adults selected appropriate Path terms, and used them in appropriate syntactic contexts. It therefore appears that the vulnerability in expressing FROM-Paths is not due to impaired knowledge of this aspect of spatial language. In fact, the spatial language of dynamic events, as we have tested it, appears to be entirely preserved in people with WS.

Another possibility – which we consider more plausible – is the "General Processing Demands" hypothesis: That the frequent omission of FROM-Paths stems from the role of general processing demands that are involved in describing Motion events. Accurately describing an event requires attending to the event in order to form an accurate non-linguistic representation, then parsing the event into linguistically relevant units, and finally formulating a linguistic structure. A tendency to omit FROM-Paths may reflect fragility in attending to or retaining information about the origin or Source of the event – which might be generally less salient or important to the observer. When observers view Motion events, the most salient aspect (at least on an intuitive level) is the Figure object that is in motion. In cases of TO-Paths, the Figure moves from some origin, along a Path, and then ends up at the Reference object, which is the Goal. In these cases, the Figure object is spatially coincident with the Reference object at the end of the event – just the time when observers must produce a description. Thus the Figure and Reference object are likely to be joint foci of attention when the description is being produced. In contrast, in the case of FROM-Paths, the Figure moves from the Reference object (which is now also the origin), along a Path, and it ends up at some point. In these cases, it could be easy to forget the origin (Reference object) and the Path leading FROM it, resulting in failure to include a Path expression. This problem could be exacerbated for people with WS, who have impaired visual-spatial memory (Jarrold et al. 1999; Wang & Bellugi 1994; Vicari et al. 1996).

If it is true that Goals are naturally more salient than Sources in Motion events, then we should observe the Source vulnerability in normally developing children if we increase the processing demands of the task by showing subjects events that include both Source and Goal Reference objects that fall at the ends of both a FROM-Path and a TO-Path. Lakusta and Landau (2005) tested this possibility by showing subjects (N = 10 WS children, mean age 13;7, N = 10 mental age matches, mean age 5;9) events that included both Path types, for example, an event in which a bird flew from a bowl into a bucket. We found that *both* WS children and MA controls frequently included TO-Paths, but not FROM-Paths. That is, if shown the flying bird event, children in both groups were more likely to say, "The bird flew *into* the bucket", than either "The bird flew *from* the bowl" or "The bird flew *from* the bowl *into* the bucket". We also found that the Source Vulnerability extended beyond Manner of Motion events to events that are not as clearly spatial, including Change of Possession, Attachment/Detachment, and Change of State events. For example, when children were shown an animated Change of State event in which a tiger's ears changed from red to black, they were much more likely to say "His ears turned to black" rather than "His ears turned from red to black".

Because we observed Source Vulnerability over a broad range of subject groups and a broad range of event types (i.e., Manner of Motion as well as Non-Manner of Motion), we hypothesize that fragility in representing Sources may be a fundamental characteristic of normal event representation. The bias to represent Goals more strongly than Sources is then reflected in the spatial language that is used to describe events. The similarity of the language produced by WS children, WS adults, and normal children and adults suggests commonality across all groups. Thus, the pattern shown by WS individuals reflects a normal part of the cognitive architecture – a structured aspect of event representation. We conjecture that this event structure should also be reflected in our non-linguistic representations of events – a possibility we are currently testing.

3.2 Case 2: The language of static spatial relationships

In a series of studies, we asked whether children and adults with Williams syndrome are impaired in their representation of spatial terms that encode static spatial relationships (Landau & Hoffman 2005). We focused on terms such as *above, below, left,* and *right*, which are of particular interest because their accurate use requires representations of spatial reference systems. These reference systems are formally equivalent to a set of orthogonal axes, with its origin centered on some designated "reference object" (see Regier & Carlson 2001, for discussion of conditions where the origin may be off-center). One's choice of reference object is quite varied and will depend on a host of factors: An object can be located relative to another object, a person, a region of space, etc. Once the reference object is chosen and the reference system is centered on it, a person can map a linguistic term onto the relevant region. For example, the term *above* maps onto that region of the reference system that is positive along the Y axis extending from the origin. Acceptable uses of the term usually span a region that extends outwards from the axis into a pie-shaped wedge (see, e.g., Hayward & Tarr 1995; Munnich, Landau, & Dosher 2001).

The importance of non-linguistic representations of reference systems (often called "coordinate systems" in the literature) is uncontested: Almost all theoretical discussions of our capacity to locate objects – from the role of eye movements to reaching and grasping to navigation – assume the capacity to mentally impose reference systems on objects and layouts. The neural plausibility of these reference systems has been shown in studies that demonstrate damage to one or more reference systems in adults who have sustained brain lesions. The variety of phenomena has led investigators to propose that human spatial representations are characterized by a number of different kinds of reference systems, including object-centered, ego-centered, and environment-centered (Behrmann 2000; Colby & Goldberg 1999; Landau 2002; McCloskey 2001). Yet language systematically engages only some of these reference systems; in English, there is a set of terms for reference systems centered on a single object (*top, bottom*, etc.), a layout of two or more objects (*above, below*, etc.) and the earth (*north, south, east, west*). Languages do not appear to engage retinocentric reference systems with a special subset of terms (Carlson-Radvansky & Irwin 1993; Landau 2002).

The tight link between non-linguistic representations of space and linguistic terms suggests that our use of spatial terms such as *above* and *below* draws on corresponding non-linguistic representations. In terms of our earlier discussion, the lexical representation for these terms would include a spatial representation that "points to" a non-linguistic reference system that describes the location of X relative to Y. Depending on the set of terms, the reference system will be centered on another object, a layout, the earth, etc. The close link between non-linguistic representations and language predicts that the same or highly similar spatial structures should be engaged by both linguistic and non-linguistic tasks.

This theory of linkage has obvious relevance to the question of whether and how spatial language might be impaired in people with Williams syndrome. The hallmark of the spatial impairment in WS is severely distorted copying of figures and severely impaired visual construction tasks, which often require constructing copies of a spatial configuration in an adjacent (blank) space. Interestingly, copying in both cases requires that the individual set up a (mentally-imposed) reference system on the blank space in which the copy will be made; and then transfer spatial information from the model to the copy space. The only way this can be done is to establish corresponding reference systems and carry spatial information from the model space into the copy space. Absence of the capacity to set up reference systems could lead to severe spatial impairment of the kind we see in Williams syndrome. It might also lead to impaired learning of those terms that rely on these spatial representations.

In order to test this possibility, we followed up on a series of studies by Hayward and Tarr (1995), who sought to test the idea that normal mature use of spatial language is homologous to non-linguistic spatial cognition. In their studies, normal adults carried out two tasks (see Figure 6). In the Language task, people saw arrays in which one geometric object (Figure) was located relative to another (Reference object) and they were asked to fill in the blank in sentences such as "The (figure) is _____ the (reference object)". By sampling locations around the Reference object, Hayward and Tarr were able to determine whether people's use of spatial terms reflects any spatial structure. The findings showed that it did: People used basic spatial terms such as *above*, *below, left,* and *right* in very high proportions along the cardinal axes centered with their origin on the Reference object, and these uses declined with distance from the axes, "fanning out" to create a broad but constrained region of acceptable use for the terms.

In the Non-Linguistic task, people were shown Figure-Reference object arrays that sampled similar locations to those used in the Language task (Figure 6). However, this time, people were briefly shown the array followed by the same array or one in which the Figure had moved a small amount from its original location. They judged whether the second array was the same or different from the first. Performance showed that people were most accurate on locations falling directly along the extension of the Reference object's cardinal axes. Hayward and Tarr concluded that the evidence from the two tasks suggested similarity in the spatial representations underlying the two task types – both engaged axial structures. Similar effects have been shown in cross-linguistic extensions of these experiments (Munnich et al. 2001) and in other labs (but see Crawford, Regier & Huttenlocher 2000 for a different interpretation).

In our experiments on Williams syndrome, we adapted Hayward and Tarr's tasks to generate evidence for or against use of reference systems in both Non-linguistic and Linguistic tasks. In our Non-linguistic task, we showed WS and normal children (Ns = 10 in each group, mean ages = 10;4 and 5;5, respectively) a single "Model" panel with a square reference object and a circle. The location of the circle varied over trials, with some locations falling on the extension of the square's axes (three each above, below, left, and right of it) and some off its axes. Children were asked to observe this array, then match it to one of two test arrays shown below the Model; one array was identical to the Model, and the other was identical except that the circle had been moved to a new location 1/4" away from the original site. The results showed that both WS and normal children performed better when the Model showed a circle in on-axis locations than in off-axis locations, consistent with the pattern found by Hayward and Tarr among adults. This suggests that even WS children organized their matching responses using an axial structure, performing better when they could take advantage of axes that they mentally imposed on the Reference object.

To see whether this axial structure emerged in language tasks, we tested both production and comprehension of basic spatial terms. In the Language Production task, children with WS and mental-age-matched normally developing children were shown a Figure (circle) and a Reference object (square) on an otherwise blank sheet of paper. They were asked to name the spatial relationship between the two, by completing the

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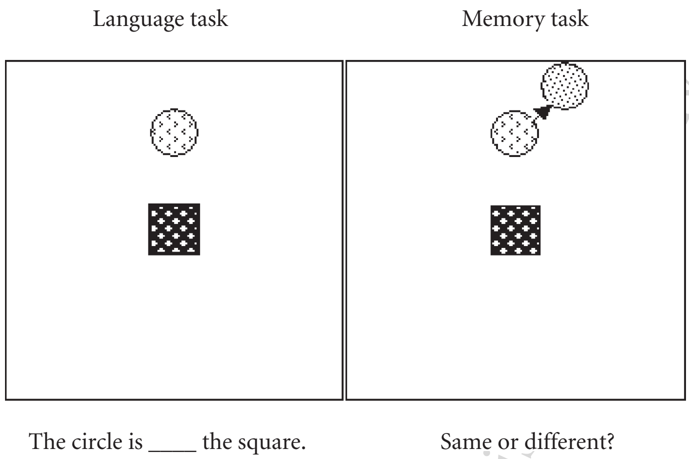

Figure 6. Sample of stimuli used in tests of static spatial relations (after Hayward & Tarr 1995; Munnich, Dosher, & Landau 2001). The Language task (Panel A) required people to fill in an appropriate term to express the spatial relationship. The Non-Linguistic task (Panel B) required people to remember the location of the target object, and judge whether it had moved after a brief delay.

sentence: "The circle is (*where?*) to the square". The space around the Reference object was sampled as in the Non-linguistic task, with Figure objects sometimes falling along the (virtual) axes of the Reference object and sometimes off these axes. In the Language Comprehension task, the same children were shown a Reference object (square) on an otherwise blank sheet of paper, and were asked to "Put a dot _____ to the square." We tested fourteen "vertical axis" terms (*above/below, right above/right below, way above/way below, on top of/underneath, on the top of/on the bottom of, over/under, higher than/lower than*), four "horizontal neutral" terms (*next to, right next to, beside, on the side of*) and four "horizontal directional" terms (*on the right/on the left of, to the right/to the left of)*.

The results of the two Language tasks were quite similar, showing that both WS and normally developing children respected the cardinal axes when using the spatial terms. In Production, this was evident in their use of "vertical" terms such as *above/below*, *over/under* and "horizontal" terms such as *next to* and *beside*. The former terms were used densely along the vertical axis of the reference object, and the latter were used densely along its horizontal axis. Normal children also showed control over direction of the terms, with different terms distinguished within the vertical axis (e.g., *above* vs. *below*). Children with WS, however, showed some fragility in this aspect of their production – their most systematic error involved producing vertical positives (e.g., *above, over*) for locations that were vertical negatives (e.g., *below, under*). These errors were asymmetrical; that is, positives were used for negative locations, but not vice versa, suggesting that lexical retrieval problems may have caused them to retrieve the positive term more frequently overall. The occasional reversal of positives and negatives occurs among normally developing 3 year-olds (see Clark 1972), suggesting that the WS pattern might reflect developmental arrest. Horizontal directional terms, such as *right/left* were not produced by either group of children – not surprisingly, since the terms are generally difficult, and the children could easily substitute terms like *next to* or *near* for these locations.

In the Comprehension task, the children's use of cardinal axes was again evident – this time from their placement of dots in response to the different terms. When queried on vertical terms, children placed dots along the vertical axis; when queried on horizontal terms, they placed dots along the horizontal axis. However, there were also strong indications that representation of direction was fragile in both normal children and children with WS. For one thing, the horizontal directional terms (*right/left*) elicited many *directional* errors, with "right" dots being placed along the left side of the horizontal axis, and "left" dots being placed along its right side. These errors for right and left occurred often among both groups of children; they also occurred prominently among WS adults, who were tested at a later date. This suggests fragility in the representation of direction for the horizontal axis for normal children (who eventually resolve this) and for children with WS, who apparently do not resolve the problem. The fragility among children with WS was not exclusively confined to the horizontal axis; rather, there were several errors for vertical terms in which the axis was correct, but the direction was wrong. Although these errors were rare among WS children, they reinforce the results of the Production task, which suggested some fragility in directional representations for vertical terms.

These linguistic results show that children and adults with WS – like normally developing children and normal adults – recruit spatial reference systems when they must produce or comprehend terms that refer to spatial locations organized around these reference systems. Note that it would have been possible for WS people – who show severe impairment in copying and visual construction tasks – to be incapable of engaging these structured reference systems. The findings are consistent with the strong hypothesis that spatial reference systems are part of the spatial representations of people with Williams syndrome. These spatial representations have been recruited during the learning process, resulting in lexical representations for terms such as *above*, *below*, *right,* and *left* (among others) that engage the reference systems that are the foundation for diverse spatial capacities.

At the same time, we found that directional representations within these axial systems were fragile: The directional distinctions for certain terms sometimes disappeared, leaving a representation that included the relevant axis (i.e., vertical or horizontal) without direction along that axis. Interestingly, we believe that this directional fragility is probably a characteristic of both linguistic and non-linguistic systems. The directional difficulty in *language* appears to persist among adults with Williams syndrome, and it is characteristic of learning even among normal children, who often reverse *right* and *left*. The directional fragility in *non-linguistic* spatial representation has been shown in several contexts, both in our lab (see Landau & Hoffman 2005) and in studies of normal adults (e.g., Logan & Sadler 1996; Carlson-Radvansky & Jiang

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1998). Thus the directional fragility in language may reflect a vulnerability that has its origins in the larger system of non-linguistic spatial representation.

In sum, our experiments illustrate that spatial structure – specifically, axial reference systems – can be readily observed in both non-linguistic and linguistic tasks. The similarity in structure across language and non-language domains gives credence to the notion that static spatial terms engage non-linguistic spatial representations – and that these are available for linguistic uses even in people who are otherwise severely spatially impaired.

4. Conclusions

Our purpose in this chapter has been to shed light on the issue of how we talk about what we see. To do so, we have explored the nature of the mapping between language and spatial representations, proposed specific hypotheses about the possible sites of autonomy and interaction between these two systems of knowledge, and tested these hypotheses by examining spatial language in people with Williams syndrome. The results suggest strong preservation of structure, despite severe impairment in non-linguistic spatial representations. They also highlight the fact that spatial language is an amalgam of characteristics, sharing some but not all properties of other spatial systems, and possessing properties of its own. Because of this complex profile, omnibus hypotheses of breakdown or sparing are too simplistic and indeed have been proven to be false. Rather, much of spatial language emerges unscathed in Williams syndrome because it does not mirror other spatial systems, but engages them. Much of what is engaged is coarsely coded and preserved; some of what is engaged is more precisely coded and may be fragile, leading to corresponding fragility in language. Finally, the failure to find massive breakdown in spatial language (commensurate with non-linguistic breakdown) confirms a high degree of specialization in language and suggests that spatial language can emerge rather independently of much of the information that is represented in non-linguistic spatial systems.

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