Geometry Playground
Spatial Language
Coding Manual

Toni Dancu,
Josh Gutwill,
& Lisa Sindorf

The Exploratorium


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Primary Contact:
Toni Dancu
The Exploratorium
Piers 15/17
San Francisco, CA 94111-1455
415.528.4479
tdancu@exploratorium.edu
# Table of Contents

**Introduction**

A. Purpose of coding scheme .......................................................... 3  
B. Description of exhibits ............................................................. 3  

**Spatial Language Coding Manual**

**I. How to code Spatial Language Utterances** ........................................ 5  
A. Process of coding spatial language ............................................... 5  
B. How to determine spatial language ............................................... 5  
C. Consider context ............................................................................. 8  
D. Mark the duration of the utterance ............................................... 9  
E. Dealing with unintelligible comments ........................................... 11  
F. Additional examples of spatial language ....................................... 12  
G. Amendments and clarifications .................................................... 15  

**II. How to Code VSR levels** .............................................................. 15  
A. Process of coding VSR levels ....................................................... 15  
B. How to determine VSR levels ....................................................... 15  
C. Consider context ............................................................................. 20  
D. Dealing with unintelligible comments ........................................... 21  
D. Additional examples of VSR levels ............................................... 22  
E. Amendments and clarifications .................................................... 26  

**Citations** ..................................................................................... 28
Introduction

A. Purpose of coding scheme

This coding scheme was developed as part of the Geometry Playground research study at the Exploratorium, a science center in San Francisco, CA. The study compared large-scale immersive exhibits to small-scale tabletop exhibits by creating pairs of exhibits that were alike in content but different in scale. The exhibits’ content—geometry—was ideal for studying the effects of exhibit scale, since geometric concepts and phenomena remain constant regardless of size. Furthermore, studying geometry exhibits allowed us to explore museum visitors’ spatial reasoning. Researchers have identified a relationship between spatial language and spatial reasoning (e.g. Casasola, Bhagwat, & Burke, 2009) and found that exposure to and use of spatial language can help to further develop spatial reasoning skills (Gentner & Christie, 2008; Pruden, Levine, & Huttenlocher, 2011). The scheme detailed in this report was used to investigate the spatial language visitors used as they played and talked at these exhibits. (Dancu, Gutwill, & Sindorf, 2015).

The scheme identifies spatial language utterances, measures their duration, and categorizes them into three levels: Static, Dynamic and Causal (National Research Council, 2006).

The study coded video of 120 adult-child dyads, analyzing adults’ and children’s speech separately. To look at the reliability of this scheme, 25% of the video data were double-coded, resulting in Cohen’s Kappa statistics of .76 for adults and .72 for children (considered good to excellent levels of agreement, Fleiss, Levin, & Paik, 2004).

B. Description of exhibits

The examples in this paper refer to the specific exhibits used in the study; we have included brief descriptions of each exhibit, below. The descriptions group the exhibits by their content pairs: the first exhibit in the pair is the large-scale immersive version and the second exhibit is the small-scale tabletop version. See Dancu, et al. (2015) for a more detailed description.

Mirror Bench (MB) and Mirror Draw (MD) invited visitors to explore the properties of anamorphic mirrors. At Mirror Bench, visitors could sit on a curved bench, and then observe how the nearby curved mirror changed the shape of the bench and their own bodies. Mirror Draw was a tabletop exhibit, where visitors could draw or write on a chalkboard to explore how the mirror transformed the lines and letters.

Personal Space (PS) and Dividing Space (DS) used the Voronoi algorithm to draw lines dividing up a larger area. As people walked on the large floor pad of Personal Space, it created lines halfway between them. Visitors were encouraged to use this property to try to make a square appear on the floor. At Dividing Space, visitors could move colorful pegs around a table and watch lines appear between the pegs.

Spin TV (ST) and Spin Socket (SS) dealt with rotational solids. At Spin TV, visitors spun themselves around while holding a colorful pole. Using a long exposure technology, a
video of their actions transformed the position of the pole and revealed a 3D shape, typically a cone or cylinder. Spin Socket provided visitors with some shapes on small cards. When placed into a socket, the cards could be spun rapidly to reveal a wineglass, lightbulb, or other rotational solid.
Spatial Language Coding Manual

I. How to code Spatial Language Utterances

A. Process of coding spatial language
Mark the start and end times of each utterance that includes spatial language.¹

B. How to determine spatial language
Throughout this document, we refer to utterances that include spatial language as VSRs (short for Verbal Spatial Reasoning). Spatial reasoning is “concerned with understanding, manipulating, reorganizing, or interpreting relationships visually” (Tartre, 1990, p. 216). According to Linn and Peterson (1985), it includes spatial perception (“determining spatial relationships with respect to the orientation of their own bodies”), mental rotation (ability to rotate a figure mentally), and spatial visualization (“complicated, multi-step manipulations of spatially presented information”).

In practice, this means: perceiving objects or spaces and their properties; describing the appearance of and relationships among spatial objects; describing or creating translations in space, such as visualizing objects from multiple perspectives, rotating, flipping or inverting objects mentally; and determining the mechanisms or functions of spatial processes, such as cause and effect.

Watch the video and listen for key words that may indicate spatial language. These words and phrases have to do with shape, location, movement, size, orientation, curvature, congruence, construction, rotation, or transformation (Serra, 2003).

¹ We coded our videos using Studiocode, a video analysis software tool.
List of VSR key words that may indicate spatial language

<table>
<thead>
<tr>
<th>SPATIAL LANGUAGE</th>
<th>SPATIAL LANGUAGE TERMS: <em>Exhaustive</em> list of core terms that are definitely spatial</th>
<th>Examples of terms that are spatial because there’s a core term in the definition</th>
<th>Examples of terms that are not spatial because core term is not in definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape:</strong> Describes the shape of an object (or body)</td>
<td>2D, 3D, angle, area, border, boundary, circle, cone, cube, cylinder, dimensional, edge, figure, form, geometric, half, line, pattern, parts, plane, point, rectangle, round, shape, side(s), solid, space, square, surface, triangle, whole</td>
<td>box, doughnut, piece, region, ring</td>
<td>funny, ordinary, partial, portion, regular, scale, weird,</td>
</tr>
<tr>
<td><strong>Location:</strong> Location or locating of an object relative to background or another object</td>
<td>above, after, along, apart, arrangement, area, at, away, back, backward, before, below, between, behind, by, center, close, corner, cover, direction, down, end, external, far, forward, from, front, halfway, here, higher, in, inside, internal, inward, left, location, lower, middle, move, navigation, near, next to, off, on, opposite, out, outside, outward, over, position, rear, right, stay, separate, situated, surround, there, through, together, top, touch, toward, up, way, where</td>
<td>distance, place, enclose, within, after, ahead, remove, contact, group, map, anywhere</td>
<td>coverage</td>
</tr>
<tr>
<td><strong>Movement:</strong> Any object changing location</td>
<td>across, adjust, approach, away, bump, collide, course, cross, follow, lift, make, motion, move, navigate, path, pathway, put, remove, route, run, sit, stay, step, still, stuck, track, travel, traverse, walk, way</td>
<td>aim, catch, come, trail, transport, roll, send, wave, hit</td>
<td>action, block, obstruct, crash, get/got, give, go, hold, push, shake, take, use</td>
</tr>
<tr>
<td><strong>Size:</strong></td>
<td>big, contract, expand, extend, fat, height, large, little, long, miniature, narrow, short, size, slender, small, skinny, tall, thin, tiny, wide, width</td>
<td>broad, bowed</td>
<td></td>
</tr>
<tr>
<td><strong>Orientation:</strong> Direction an object is facing relative to background of another object</td>
<td>along, angle, around, face away, face toward, diagonal, down, horizontal, level, parallel, perpendicular, reverse, slant, slope, stretch, tilt, up, upright, upside-down, vertical,</td>
<td>lean, extend, elongate</td>
<td></td>
</tr>
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<td>---</td>
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<td></td>
</tr>
<tr>
<td><strong>Curvature:</strong></td>
<td>bend, bump, curved, flat, straight</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Congruence:</strong> comparing shapes or areas</td>
<td>alike, congruence, differ, difference, different, dissimilar, distinct, identical, just like, like, same, similar</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Construction:</strong> Creating, building, or developing a shape or geometrical form</td>
<td>arrange, build, construct, create, develop, divide, draw, erase, form, make, place, put, split</td>
<td>structure, produce do, play, try, work</td>
<td></td>
</tr>
<tr>
<td><strong>Rotation:</strong></td>
<td>around, axis, circular, flip, over, revolve, rotate, spin, spiral, turn, twist</td>
<td>faster, slower</td>
<td></td>
</tr>
<tr>
<td><strong>Transformation:</strong> changing from 2D to 3D or from morphed to anamorphed</td>
<td>anamorphed, change, compress, different, distorted, made, morphed, reflection, squished, transform</td>
<td>deform, metaphors that require transformation (e.g., wine glass, hourglass, hot air balloon, light bulb, chair, fireworks, flower, hat, skirt), squash</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>bench, look,</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Other forms of the spatial term are OK. Since circle is a core term; circular, circling, circles, etc are all spatial terms as well.

Note 2: Certain additional terms used in an exhibit’s label were also considered spatial when they were used spatially in the context of that exhibit. For example “write” at Mirror Draw or “plug” at Spin Socket (as in “plug in the card”).
Not sure whether a term is spatial?

First, look to the list above. If you don’t find the term there, you can go to thesaurus.com to check the definitions for the term. If you find a definition that includes a core spatial language term (column 2 in the table), and the speaker is using the uncertain word in accordance with that definition, you can consider the uncertain term spatial.

- Example: The definition of “box” is “container, often square or rectangular.” “Square” is a core term, so we can count “box” as spatial too.

If, however, the definition for that term does not include any core spatial reasoning terms (even if it does include second-tier terms), it should not be coded.

- Example: The definition of “crash” is “accidental hitting.” “Hit” is not a core term (though it is in column 3), so “crash” is not a spatial term.

Some ground rules:

- look only at the definitions, not the synonyms or antonyms
- look only at the definitions of the main entry term
- other forms of the spatial term are OK. Since circle is a core term; circular, circling, circles, etc. are all spatial terms as well. Similarly, if a term’s definition includes “navigation,” that term would be a spatial term, because “navigate” is a core term.
- if the definitions are not in accordance with the manner in which the speaker is using the term, you can go to dictionary.com to see if those definitions contain core spatial terms.

C. Consider context

Once you find a spatial term, listen to the surrounding utterance. In order to trigger the VSR code, the spatial term/phrase must:

1. Be used in accordance with any of the Spatial language definitions for shape, location, size, movement, orientation, curvature, congruence, construction, rotation or transformation provided above. Note that, a term may apply to multiple spatial language categories, not simply the one we’ve placed it in. Speakers may speak spatially about anything—objects (including their own bodies), other people, or space itself. If you are unsure if the term is used in accordance with spatial language definitions, assume that it is.

2. Be on-task. That is, about visiting, exiting, exploring or experiencing a Geometry Playground exhibit. If you are unsure if the term is about the exhibit, assume that it is. If you are unsure about which exhibit they are speaking about, assume it is the exhibit they are currently at.

Examples:
  - “Look how they (lines) move when you move.” (at Personal Space)
  - “See if you can write a T” (at Mirror Draw)
  - “These cards are totally different”
  - “The lines build a shape.”
  - “Spin it around like that.”
  - “What’s that one over there?”
  - “Let’s move on. I think we’re done here.”

(See Clear Examples of VSRs and Borderline Cases that are VSRs, below)

Even if an utterance has a spatial term, the utterance will NOT trigger the VSR code if:

1. It is not used spatially:
   - “I have no idea what’s, like, that one.”
   - “Give him a turn”
   - “What’s it about?”
   - “Good job, you did it! You figured it out.”
“There you go, nice work.”

2. It is clearly not about visiting, exiting, exploring or experiencing a Geometry Playground exhibit.
   - “We can hand in our microphones at the front.”
   - “The bathroom is over there”
   - “Look at the big round blue thing over there!” (about an exhibit that is not in the study)
   - “The lady at the front said we have to stay in the blue lines.”

Note that these utterances, though not sufficient on their own to trigger the VSR code, may be included in the overall code duration if another part of the utterance DOES meet the criteria. (See Relevant Talk below for further examples.)

Note that fragments, such as short responses to questions (“nah” or “OK”) or half-completed statements, are coded the same way as any other utterance—they must contain a spatial term or phrase to be coded. Similarly, repetitions and clarifications are coded the same way as any other utterance—if they contain a spatial term or phrase, they are coded.

**D. Mark the duration of the utterance**

*Overview:*
In general, you will include in the VSR instance:
- the spatial term
- the talk around it that makes it a VSR

In general, you will not include long (> 2 second) stretches of:
- Silence
- Laughter or sounds
- Off topic talk

Note that the target individuals are coded separately. Thus, if you are coding an adult, only the adult’s speech, silence, or sounds are considered. If a child interrupts (to ask a question, laugh, etc) during an adult’s VSR, the child’s utterances do not affect the boundaries of the adult’s code.

The rest of this section will provide more specific descriptions of what to include or exclude from your codes.

*First, what do you include? Spatial terms and Relevant Talk*
Ideally, the words to include in an utterance will be obvious. For example, a person will say, “Let’s make a square.” and that entire utterance will be coded. Sometimes, people will include other talk before, during or after the spatial terms that are all about the exhibit or phenomenon. We call these words “Relevant Talk” and all of these words should be included. Examples (with spatial terms in bold):
- “Well, do you think, should I, can I try to **draw** my **initials** in the mirror?”
- “**Make a square. Further, further**, okay, you got it.”
- “I want to **spin**, hold it, wait a second, uumm, how do I, okay, I’ll **spin** it faster.”

In all of these cases, the entire utterance would be included as part of the VSR.

*What is Excluded? Use the 2-Second Rule*
Once you have located the “core” of the VSR—the spatial term and surrounding talk—create a temporary code that includes this Core Statement. Then, listen to the 2.0 seconds before and after the Core Statement.

If the visitor *does not* engage in any Relevant Talk (defined below) outside of the core, start and end the code at the edges of the Core Statement.
If the visitor does engage in Relevant Talk during the 2.0 seconds before or after the Core Statement, extend the code to include the Relevant Talk. Then, from the new edge of the code, listen again to the 2.0 seconds before or after. Continue checking the 2 second boundaries until the visitor does not engage in any further Relevant Talk.

For the purpose of coding:

“Relevant Talk” includes:

- Any on-task talk about visiting, exiting, exploring, or experiencing GP exhibit(s), including the non-spatial talk that wasn’t enough to trigger a VSR on its own.
  - “Look at that, that’s so interesting.”
  - “I don’t get it”
  - “Let your sister have a turn. We’ll all get a chance.”
  - “It’s MY turn!”
  - “I feel dizzy now”
  - “Which exhibit do you want to do next?”
  - “I can’t see”
  - “Let’s go, we’re done here.”
  - “Let’s go return our microphones.”
- Interjections that contain clear meaning:
  - Okay
  - Umm/Oh/Ah
  - Uh huh
  - Yeah
  - Mmm
  - Ugh
  - Whoa
  - Hmm
  - Hmm?
  - Huh?

“Relevant Talk” does NOT include

- Silence
- Unintelligible, non-English language, or garbled talk
- Non-word sounds such as
  - laughter
  - grunts
  - humming
  - whistling
  - shrieking
  - animal noises
- Clearly off topic remarks (totally unrelated to the exhibits), such as:
  - I need to go to the bathroom
  - I can’t believe Ginny called you last night
  - I want to take my mic off
  - Testing 1-2-3 Testing (the mic’s)

Off topic remarks of this kind will be very rare. If you’re unsure if a remark is off topic, consider it to be Relevant Talk.
Thus, each VSR will start and end with Relevant Talk, and be surrounded on both sides by a >2.0 second “window” of Non-Relevant talk (silence, laughter, sounds, clearly off-topic remarks). A VSR could contain short (<2.0) segments of Non-Relevant talk within it.

To find the window:
A. Get the start and stop times of the Core Statement as accurately as possible.
B. Listen to the 2.0 seconds before and after the Core Statement. If you hear nothing, the code can end at the edge of the Core Statement. If you hear Relevant Talk, expand the code to the edge of the Relevant Talk.
C. Repeat as needed until you find a full 2.0 seconds of Non-Relevant talk.

When you hear another statement at around 2.0 seconds, and it’s borderline:
D. Get the start and stop times of the Core Statement as accurately as possible.
E. Then move the scrubber back or ahead 2.0 seconds.
   a. If you are at the beginning of an utterance: If you can hear any Relevant Talk (even half a word) from that point forward, include that talk.
   b. If you are at the end of an utterance: If you can hear the entire next statement from this point forward, end the code where it already is. But, if you hear anything from the middle of the first word on, include that talk in the code.

Examples:
- “Let’s make the blue as big as we can. Hahaha! Ooooooh!” [Pause] “Rrrrrgggg! Vrrrrmm. Mine got bigger.” (Spatial terms in bold). You would check the duration from the end of “can” to the beginning of “Mine.” If it is 2.0 or more seconds, the exclamations and pause would be excluded and there would be two VSRs. If the duration is less than 2.0 seconds, there would be one long VSR that would include everything in this example.

E. Dealing with unintelligible comments

Deciding whether something is unintelligible
When trying to decide if something is unintelligible, follow these rules of thumb:
- If you listen to an instance 5 times and still can’t make out what they are saying, treat what you can’t understand as unintelligible, and do not code it.
- If, as you are listening, you think you hear a spatial term, you can look at the context to help interpret their words. For example, if someone is pointing at the label at ST, and you hear “…[garbled]-tational …olid”, you can be reasonably sure that they are reading the label and saying “Rotational Solid.”
- Non-English language (even if you can translate it yourself) should be considered unintelligible and not be coded.
- If the context doesn’t help and you are still unsure, do not code.

If part of an instance is unintelligible, but the intelligible part contains at least one spatial term, look to the context to determine if it is a VSR. When in doubt, assume that the spatial term is used spatially and is on task. Example:
- At Spin Socket: “When they spin, [garbled].” This would count as VSR because “spin” is a spatial reasoning term and they seem to be talking about the exhibit’s phenomenon.

Counterexamples:
- At Spin Socket: “They look kind of [garbled]. The two of them [garbled].” This would not count as VSR, even though it sounds like a comparison, because there’s no spatial reasoning term.
At Personal Space: (Pointing to the stripes on someone’s shirt): “Look, your [garbled] lines [garbled].” The word “lines” is spatial, so you would look to the context. In this case, the context (point at stripes on a shirt) indicates the person is not talking about the lines on the floor.

**Start/Stop times and unintelligible comments**

If part of an utterance is unintelligible, treat it as you would other Non- Relevant talk. In other words, a garbled word or two in between Relevant Talk would be included in a VSR code, but a long (>2.0) span of garbled talk (alone or combined with silence or other Non-Relevant talk) would be excluded.

**F. Additional examples of spatial language**

**Clear Examples of VSRs**

- **Shape** — Utterance describes the shape of an object (or body)
  - “It’s a square/circle/etc.”
  - “It has five sides.”
  - (When looking at a shape created at an exhibit) “Looks like a flower or something.”
  - “Look at the line.”
  - “See if you can write a T” (Letters and names count as shapes)
- **Location** — Discusses location of one object relative to background or to another object
  - Dad asks, “Does the blue area ever touch the red?” Daughter answers, “Not really.”
    - Only the question here is coded VSR.
  - At Dividing Space: “See how the lines are in between [the pegs]?”
  - “I’m in my space.” or “You’re in my space.”
  - “The one in the middle.”
- **Movement** — Any object changing location
  - “The puck made it through the pegs!”
  - “Look how they (lines) move when you move.”
  - Dad asks: “As you move the blue pieces toward the red ones, what happens?” and daughter answers: “It gets smaller”
    - The question is about location and the answer is about size.
- **Size** — One object is larger/smaller/taller/shorter/wider/thinner/bigger/smaller than another
  - “It looks like the red ones are making these things either big or small.”
  - “How big can you make the blue area?”
  - “It got smaller.”
  - “Look how skinny and tall I am.”
- **Orientation** — Direction an object is facing relative to background or other object
  - “Try holding the rod up and down.”
  - “It looks like we’re sitting straight in the chair.”
  - “Now draw it upside-down.”
- **Curvature** — Mentions curvature or straightness of something.
  - “The line is straight.”
  - “Your name is curved.”
- **Congruence** — Mentions similarities or differences between shapes or areas
  - “These cards are totally different.”
  - “What’s the difference between these?”
- **Construction** — Creating, building, or developing a shape or geometrical form
  - “Get on one side of it [Personal Space] – Dad get over there. We need to all be at one side to make a square.”
  - “Well, it’s a triangle, almost.”
Directing someone’s movements to create a shape: “Almost, perfect position. Back up, back up, stop. That’s a square.”

At Dividing Space: “See how they’re [lines] in between? It separates them. It builds a shape. You can put it anywhere you want.”

“Your’re making it out of light.”

Rotation — Spinning, rotating or flipping an object over

“Any way you turn a square, it’s still a square.”

Directing another person to “spin” or “turn around.”

Transformation — Changing from 2D to 3D or from morphed to anamorphed

At Spin Socket, naming the shape that’s created by the spinning shape and persistence of vision would count. For example: “It’s a square” or “wineglass” or “hourglass” or “hot air balloon.”

“So now set it to spin faster. It looks like it’s fooling your eyes, right? Like it’s all one solid shape.”

“The arrow has this curve, and this one’s flat or straight here. But look in the mirror.”

“When they’re trying to draw a map of the world, this [mapping a 3D world onto a 2D map] is some of the challenges they have. Because the world is a sphere, or actually more like an oval.”

“So the mirror squishes pictures. This is always [garbled] when you move from a curved surface to a flat one.”

“Which card will make that picture?”

2. Borderline cases that are VSRs

Spin TV

“What do you do here?”

“Hold it like this. In front of you.”

“You need to face the screen.”

“Go all the way around. You have to move your legs.”

“Oh, neat, so you can see the pattern of the movement”

Anything you move, it’s catching it and showing the movement”

“Careful, because it’ll go out and hit other people”

Personal Space

“I’m standing inside the rainbow!” (while on Personal Space)

“It really doesn’t matter how many people are on it.”

“Two people should be on this.”

At Personal Space: “We’re the same person!” (the term “same” should compare shape or area. Since we’re not sure what the speaker means, we assume it is about the areas on PS.)

“Come here. Here!” (as long as “here” is an exhibit)

Dividing Space

“Throw it (puck) up.”

“How does it track these?”

“Does it see where they are from above?

“Let’s see if we can make it.”

“The pegs go in the holes.”

“Can you give one here?”

“Give one to me”

“Put the (unused) pegs in the bins”
Mirror Draw
- (Comparing two stations at MD) “Oh, I see, they’re the same.”
  - “Same” is a spatial term. This is said as the visitors are realizing that the two mirrors or stations are the same; because we don’t know if they are talking about the shape of the chalkboards or mirrors, we assume they are and code as a VSR.
  - “See if you can draw it”
  - “How do you erase this?”

Mirror Bench
- “Does the mirror work from over here?”
- “Stand up”
- “Put the sign back”

General (at any exhibit)
- “Is anyone in line?”
- “Move over so I can see.”
- “Get off”
- “Come here”
- “Move”
- “What do you do here?”

3. Borderline Cases that are NOT VSRs
Terms not used in accordance with spatial reasoning definitions
- “How do you erase this?” (at Spin TV)
  - Although “erase” is a spatial term (about deconstruction), erasing at Spin TV is involves waiting for the image to disappear rather than active deconstruction of the image like at MD. No spatial reasoning is required to wait for the image to fade.
  - “It turned different colors.”
    - (not used spatially)
  - “That one doesn’t stand out” (at Spin TV, talking about the colors)
    - (not used spatially; here, “stand out” is about perception.)
  - “Turn on the motor.” (not used spatially)
  - “I have no idea what’s, like, that one.”
  - “Give him a turn”
  - “What’s it about?”
  - “Good job, you did it! You figured it out.”
  - “There you go, nice work.”
  - “Come on, seriously?” when used idiomatically

Not about the exhibit (off task)
Once in a while, visitors will use spatial terms at the exhibit, but that are unrelated to the exhibit. Alone, these terms are not sufficient to create a VSR. However, if you are unsure whether a statement is about an exhibit, assume that it is and code it as a VSR.
- “We can hand in our microphones at the front.”
- “The bathroom is over there.”
- “Come here right now, you’re in big trouble.”
- “Look at the big round blue thing over there!” (about an exhibit that is not in the study)
- “You’re not supposed to go outside the blue tape area”
- “The lady at the front said we have to stay in the blue lines.”
“Where’s Haley?” while at an exhibit, but while Haley is not with them; this is about locating the person, not about visiting, exiting, exploring or experiencing the exhibit.

G. Amendments and clarifications

When creating VSR boundaries, there will be moments when it’s hard to tell if a particular piece of talk is inside or outside of the 2 second boundary. Use your judgement to code these according to the scheme. When interrating and resolving disagreements, if you can’t decide whether something was in or out after double checking the timing, default to the shorter VSR or the VSR that is split into two pieces. (In other words, choose the one that includes less silence/relevant talk)

When talking about the TV screen on ST, we decided that, like talk about “erasing” the image, talk about the screen fading (fade out, fade away, fade in, etc) or image disappearing (“clear off,” etc) is not spatial, even though it may have a spatial preposition.

II. How to Code VSR levels

A. Process of coding VSR levels

For each VSR, find the spatial term(s) and use it to label the level of that VSR: what the spatial term is about. It may be about static features of objects (Level 1), dynamic processes (Level 2) or cause and effect (Level 3) (National Research Council, 2006). Often visitors will mention a few spatial terms; always label the highest level reached within a specific utterance. Spatial terms may be included in questions as well as statements. Note that Level 2 or 3 may contain components that are from the previous levels, but should only be coded as the higher level.

B. How to determine VSR levels

Level 1: VSRs that use only Static spatial terms, such as objects (lines, shapes, other nouns) or descriptions (shape, size, color, location, other adjectives) and some prepositions. Level 1 will often sound like an observation, focusing on describing an object. Level 1 also includes comments about the result of a transformation that don’t mention the action of transforming.

Examples:
- “It’s a square.”
- “The blue space is really big”
- “I’m on the line.”
- “It looks curved in the mirror”
- “I’m skinny in the mirror”
- “You look shorter in the mirror”
- “I have personal space”
- “I want more space”
- “I found the middle one”

Level 1 does not include statements with active or process-oriented spatial terms. See Level 2.

TRICKY CASES (L1s):
- “We can get the same space. We’re sharing space.” Although “sharing” or “get” might sound dynamic, like a level 2, they aren’t spatial terms, so we ignore it. L1
- “The size is the same” or “The size is different.” The term “size” is a static noun; “same/different” are static adjectives. Though the phrase might imply something happened (if you move a piece, now the size is different) the process is not explicitly mentioned so it is an L1 (note that “differ” and “differs” are verbs and about process, and would be L2).
“It’s squished.” “Squished” is an adjective that describes the object. It sounds more like an observation, and is L1.

“Look at the line, it bumps” (at MD) Similar to squished, “bumps” describes a static trait of the line—it has a bump in it. This sounds like an observation. L1

“The blue touches the red.” (at DS). Similar to the above, “touches” describes the location of the blue and red. L1

“That’s six spins.” The term “spins” is a noun here, so, even though spinning is typically an action, in this sentence, the number of spins is static; this is L1.

“Here.” (giving a card at SS). Though some movement (of the piece) is implied, the word “here” refers to a static location. L1

Prepositional phrases are tricky. If the spatial term is a preposition (such that it answers the question, “Where?”), we look to what the phrase is paired with to get a sense of whether the spatial term is static or dynamic (see list of spatial prepositions below). Spatial prepositions are static Level 1’s if they are alone (e.g., “Up there,” or “over here”) or paired with the following verbs:

- To be
  - “It’s under your feet” = L1
  - “I’m on the line” = L1

- To look
  - “Look at the mirror” = L1
  - “Look at my space”) = L1

Level 2: VSRs that include Dynamic spatial terms (in italics), generally about changing features of objects (transformation such as changing shape, motion such as moving location, or other verbs), dynamic processes (the creation of objects or images; completed actions such as “spun around,” and “made a shape;” lack of action such as “stay in one place,” or “he’s just standing in one place;” or other verbs) and some prepositions. Typically, Level 2 spatial terms will focus on the action, using verbs and adverbs to describe it. The idea is that the speaker’s spatial terms are about actual change or potential for change.

Examples:

- “You’re trying to make a square here.”
- “Roll the puck through the pegs”
- “Spin your body around.”
- “Come here”
- “Move over.”
- “Stay on your side of the line”
- “Stand there and don’t move.”

Level 2 is not about appearance (something looks a certain way), which is a static feature and would be Level 1.

Level 2 does not include statements about implied action. Saying “The line looks different now” might imply that a change/action has occurred, but the act of changing and/or the cause are not mentioned explicitly. This comment would be Level 1.

Level 2 does not include statements that also identify a cause or effect and employ a connecting term for the dynamic process. See Level 3.
TRICKY CASES (L2s):

- “The size hasn’t *changed*” or “The size *changed*” explicitly mentioned a process (change) so they are a L2 (note similarity to the tricky cases in L1).
- “The mirror *squishes* pictures” uses the term “squishes” as an action, describing the change in the pictures; therefore, it is coded as an L2.
- “Now I can *go wherever* I want.” Wherever is an adverb, not a preposition, but it is paired with “go.” Since this term at these exhibits is typically active (meaning go to whatever place), we coded “wherever” as an active term. L2
- Prepositional phrases are tricky because they require additional information to determine whether the spatial term is static or dynamic. If the spatial term is a preposition (such that it answers the question, “Where?”), we look to what the phrase is paired with to get a sense of whether the spatial term is static or dynamic (see list of spatial prepositions below). If a prepositional phrase is paired with an action verb (even if it is not a spatial term), it should be coded as an L2 (e.g., “*Get in the middle,*” “*Walk on the line,*” “*Move in a circle,*” “I *stepped on the line*”).

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<thead>
<tr>
<th>Spatial Prepositions:</th>
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<td>above</td>
<td>between</td>
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<td>across</td>
<td>beyond</td>
<td>past</td>
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<td>after</td>
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<td>along</td>
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<td>among</td>
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<td>apart</td>
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<td>apart from</td>
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<td>below</td>
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<td>beneath</td>
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<td>beside</td>
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**Level 3:** VSRs that include talk about **Cause and Effect:** that is, that make a connection between some end state and the conditions or change in the context that brought about the end state (Bloom and Capatides, 1987). (End state and conditions/context are underlined). Causes can be vague (it, that, etc), but the effect should indicate that the speaker has some end state in mind. The connection made MUST include a causal key word (which are CAPITALIZED). See list below.

Examples:
“IF you look **in** the mirror, it looks like a **regular chair**.”
“IF the red things are **close** together it will **make** the **space smaller**.”
“**Spin around** **TO** make the cylinder.”
“WHEN you look **in** the mirror, the **line** is **curved** **there**.”
“We have to all be on one **side** **FOR** a **square**.”
“It’s **shaped** like an **arrow**, SO it **makes** the **hourglass**.”
“**Draw on** the **line**, and THEN it will look **curved in** the mirror”
“**AS** you **move** the blue piece, HOW do the **shapes around** it **change**?
“You can **make** the blue **area** as **big** as you want **BY** taking them all **off**.”
“**Step** right **here** at the same time, AND NOW we’re **in** the **same space**.
“**Draw a straight line**, AND it’s gonna look **curved here**.”

**Determining whether the speaker has an end state (effect) in mind:**
Although causes can be vague (it, that, etc), the effect should indicate that the speaker has some end state in mind. To determine whether the speaker has some end state in mind, look for one or more of the following to be present in the effect:

-- **specific nouns and verbs**, not pronouns or simple verbs (do, is, looks) (“It **makes** something IF you do that” NOT “It does something IF you do that.”.; “It’s an **hourglass** if you do that”, NOT “It looks weird IF you do that.”)

Note that this means “when you look in the mirror” is sufficient for a cause, but “how it looks in the mirror” is NOT sufficient for an effect.

-- **modifiers**, such as skinny (“Look how **skinny** it looks WHEN you look in the mirror” NOT “Look how it looks WHEN you look **in** the mirror”)

-- a sense that the **speaker knows or can predict what will happen**, and is not exploring (“IF you **walk on** it, it **makes a square**” NOT “**Walk on** it, see IF it does something”)

**List of Causal Key Words:**

<table>
<thead>
<tr>
<th>And (as a result)</th>
<th>First</th>
<th>So (so that)</th>
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<tbody>
<tr>
<td>After That</td>
<td>How</td>
<td>Then</td>
</tr>
<tr>
<td>As</td>
<td>If (whenever)</td>
<td>To (in order to)</td>
</tr>
<tr>
<td>Because</td>
<td>Next</td>
<td>When</td>
</tr>
<tr>
<td>By (as a result of, by means of)</td>
<td>Now (as a result)</td>
<td>Relationship (relationship)</td>
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<td>Connected</td>
<td>Related (related to)</td>
<td>Why</td>
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<tr>
<td>For (in order for)</td>
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</tr>
</tbody>
</table>
Note that Causal Key words may sometimes be used in ways that are not causal. Many of them (so, and, now, to, for, by…) come up very often in speech for other reasons. To help you figure out if they are used causally, first look for the change in context or conditions and end state. Then, figure out if the connector is used in a way that means the same thing as the phrase in parentheses. If you could substitute the parenthetical phrase for the causal key word, it’s very likely that it is used causally.

The following are NOT causal key words: But, Or, Unless, Or else, Will, Going to

Level 3 is NOT stating two causes.
Level 3 is NOT stating two effects.
Level 3 is NOT stating a cause and effect with an implied connection (no connector).
Level 3 is NOT an unrelated cause, effect and/or connecting term.

TRICKY CASES (should be coded L3s)

General:
- “We’re supposed to move him TO make a square” (even though this starts with “we’re supposed to,” it still has the change in context (move around) end state (make a square) and connecting term (to)).
- “TO do a cylinder, hold it like—“ (moves hoop to show how to hold it). Adult doesn’t finish her sentence, but from what she says there is a change in context, a causal connector, and an end state. From the context of her gesture we can be sure of her meaning.

Vague causes/effects:
- “Is it different WHEN you change it?” is vague but contains a change in context (you change it) and an end state with modifier (it’s different), and a connector (when); it is an L3.
- IF you look in the mirror, it changes. (Vague, but has a change in context (look in mirror) and an end state with specific verb (it changes) and a connector (if).

Connecting term is far from the cause or effect:
- “Draw an N on the line. Oh, that looks great, keep going, nice job. NOW it’s curved.” (“on the line” is the condition, “it’s curved” is the end state. It can be hard to follow the chain of reasoning in these cases. Use the context to help you. We expect these will be rare.)

Multiple cause/effect in one utterance:
- “See the little part that went off the line? You went along the line AND that part looks straight, AND THEN it bumps.” (Going along the line is the condition leading to the end state of looking straight, and going off the line is the condition that leads to “bumps.” You don’t need to separate the parts out, just label the whole thing L3).

TRICKY CASES (NOT L3s)
Connecting term is not used causally:
“Ashley, it’s your turn NOW. Try to **draw** a T.” The connecting term “now” doesn’t mean “as a result” and is not related to a cause and effect. L2

“SO the mirror **squishes** pictures.” “So” doesn’t mean “so that” here. (Even though the mirror is a cause of the squished pictures.) L2

“SO look **in** the mirror, you don’t look normal” (same as above) L1

“THEN it says, try an X. Make it look normal.” (“Then” doesn’t connect “try an X” and “look normal”.) L2

End state is too vague—no specific nouns, verbs, modifiers or predicted effect:

- Let’s see what happens IF we **put** these **here**.” L2
- “**Put** the pegs here TO find out what it does.” L2
- “Look **in** the mirror AND see what it looks like.” L1
- Try to **draw** a T; look HOW that looks **in** the mirror L2 (in the mirror is a cause here—part of the conditions that lead to the (vague) end state “how it looks”)
- Watch what happens IF you **move** it. L2
- “That’s BECAUSE of the **shape** of the mirror” (“Shape of the mirror” is the cause; “that” is too vague for an end state.) L1

**Phrases that have cause and effect but no connector:**

- The mirror **squishes** the **line**. L2
- My **fat arm** looks skinny **in** the mirror. L1
- You wanna do the **flat circle** like that (pointing at label)? Hold it **out** like this, **stand in** the **middle**, and **turn** all the way **around**. L2

**C. Consider context**

For Levels 1 and 2, you should code only what is said in one code instance.

Utterance 1: “Ok, **put** one **arm up** and hold the other…” (pauses >2 seconds to read silently) L2

Utterance 2: “…**out** to the **side**. Copy this picture.” L1

For Level 3, you can use the speaker’s previous utterance as context.

Sometimes cause and effect utterances are linked, but are not uttered quickly enough to be coded as a single utterance. When coding for level 3, make a judgment call. If you think the previous utterance of the speaker is related to the one you are currently coding, you can use it as context.

Utterance 1: “Try to **draw** a big letter X **SO** it looks normal **in** the mirror…” L3 (pauses as child draws)

Utterance 2: “…or try **your name**.” L3 (another effect).

The previous utterance may also clarify vague end states:

Utterance 1: “Look, the **line** looks **straight here** but **curved here**…” L1

Utterance 2: “…**that’s** BECAUSE of the **shape** of the mirror” L3 (now we know what “that” refers to)

Note that the level of the previous utterance does not change based on later utterances.

Do not look back more than one utterance.
Do not use the other mic’d person’s utterances as context for coding the level of the focal utterance.

**D. Dealing with unintelligible comments**

Based on the VSR scheme, you may sometimes have coded an utterance that has an intelligible spatial term as well as some garbled talk. In these cases, code based on the words you can understand.

- “...[garbled]...lines” would be L1
- “...[garbled]...makes lines...” would be L2
- “WHEN you move the... [garbled] it makes the lines” would be
### D. Additional examples of VSR levels

**Level 1:**
VSRs that use only Static spatial terms, such as objects (lines, shapes, other nouns) or descriptions (shape, size, color, location, other adjectives) and some prepositions. Level 1 will often sound like an observation, focusing on describing an object. Level 1 also includes comments about the result of a transformation that don’t mention the action of transforming. Theoretically, these comments are about Spatial Structure (NRC: Learning to Think Spatially, 2006).

<table>
<thead>
<tr>
<th>Personal Space</th>
<th>Mirror Draw</th>
<th>Spin TV</th>
<th>Spin Socket</th>
<th>Mirror Bench</th>
</tr>
</thead>
<tbody>
<tr>
<td>“It’s a square/circle/etc.”</td>
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<td>“It’s a square/circle/etc.”</td>
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<tr>
<td>“My space is bigger than yours.”</td>
<td>“My space is bigger than yours.”</td>
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<td>“My space is bigger than yours.”</td>
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<td>“You’re in my space.”</td>
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<td>“You’re in my space.”</td>
<td>“You’re in my space.”</td>
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<td>“I’m on the line.”</td>
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<td>“I’m on the line.”</td>
<td>“I’m on the line.”</td>
<td>“I’m on the line.”</td>
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<td>“Our space is the same size!”</td>
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<td>“Our space is the same size!”</td>
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<tr>
<td>“Look at the line.”</td>
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<td>“Look at the line.”</td>
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<tr>
<td>“I have personal space. I want more space.”</td>
<td>“I have personal space. I want more space.”</td>
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<td>“It (the line) disappears (when you get close). You could have six people on here and it would be like one.”</td>
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<td>“The line is straight.”</td>
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<td>“Your name is curved.” (when at MD, one’s name is a shape)</td>
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<tr>
<td>“The arrow has this curve, and this one’s flat or straight here. But look in the mirror.”</td>
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<tr>
<td>“Looks like a flower or something.” (When looking at a shape created at the exhibit)</td>
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<tr>
<td>“Do you see the cone around him?”</td>
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<tr>
<td>“Oh, what matters is where the lines are on the card.” (w/o further context)</td>
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<tr>
<td>“These cards are totally different.”</td>
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<td>“These cards are totally different.”</td>
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<tr>
<td>“What’s the difference between these?”</td>
<td>“What’s the difference between these?”</td>
<td>“What’s the difference between these?”</td>
<td>“What’s the difference between these?”</td>
<td>“What’s the difference between these?”</td>
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<tr>
<td>“It’s a square” or “wineglass” or “hourglass” or “Hot air balloon.”</td>
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<tr>
<td>“They (arrow cards) look the same, why are they so different?”</td>
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<td>(pointing to the label) “I already found the middle one.”</td>
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<td>“It looks like a regular chair.”</td>
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<tr>
<td>“It looks shorter in the mirror” or “It looks curved in the mirror” or “It looks squished in the mirror.”</td>
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<tr>
<td>The shorter you are here, the skinnier you are there (in the mirror).”</td>
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<tr>
<td>“The further you are away, the skinnier you are”</td>
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<td>“The further you are away, the skinnier you are”</td>
<td>“The further you are away, the skinnier you are”</td>
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<td>Dividing Space</td>
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<td>o “Does the blue area ever touch the red?”</td>
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<td>o “The blue space is really big!”</td>
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<tr>
<td>o “This is the same as the other one, huh?” (talking about two exhibits)</td>
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<tr>
<td>o “See how the lines are in between [the pegs]?”</td>
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<table>
<thead>
<tr>
<th>Personal Space</th>
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<tbody>
<tr>
<td>o “So, you’re trying to make a square here,”</td>
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<tr>
<td>o “Are you supposed to step on the lines?”</td>
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<tr>
<td>o “Why can’t I get in someone’s personal space?”</td>
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<tr>
<td>o “Stay on your side of the line.”</td>
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<tr>
<td>o “Stand there and don’t move.”</td>
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<tr>
<td>o “Almost, perfect position. Back up, back up, stop. That’s a square.” (“up” is a spatial preposition, and “back” is an action verb in this case.)</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Mirror Draw</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>o “See if you can write a T”</td>
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</tr>
<tr>
<td>o “Now draw it upside-down.”</td>
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</tr>
<tr>
<td>o “Look there, in the mirror it looks normal, but look here. It changes shape.”</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Spin TV</th>
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</thead>
<tbody>
<tr>
<td>o “Spin your body around.” Or “Turn around.”</td>
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<tr>
<td>o “Try holding the rod up and down.”</td>
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<tr>
<td>o “Do it very slow so I can see how it turns.”</td>
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<tr>
<td>o “I’m trapping you.”</td>
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<tr>
<td>o “Twist it, like that, like a cone”</td>
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<tr>
<td>o “You put her in a cage.” (“Put in” is an action.)</td>
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<tr>
<td>o “Stand there, I want to circle around you”</td>
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<tr>
<td>o “Make the cone. You need to put one end of it by your head.” (no connector word, so L2)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Spin Socket</th>
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<tbody>
<tr>
<td>o “Which card will make that picture?”</td>
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<tr>
<td>o “You can make an hourglass with that one.”</td>
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<tr>
<td>o “This one should make that one, and this one should make that one.” (predicting about the cards on Spin Socket)</td>
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<tr>
<td>o “It’s gonna make an hourglass.””</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Dividing Space</th>
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<tbody>
<tr>
<td>o “Roll the puck through the pegs.”</td>
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<tr>
<td>o “You can make it as big as you want.”</td>
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</tbody>
</table>
actual change or potential for change.

Theoretically, these comments are about Spatial Transformations (NRC: Learning to Think Spatially, 2006).

Mirror Bench

- “Look, it makes different spaces, sort of like the other one”
- “The size hasn’t changed.”
- “Move those red pegs around and see what it does.”
- “Make it like an obstacle course”
- “How big can you make the blue area?” or “Try to make the blue area bigger.”
- “It looks like the red ones are making these things either big or small.” (Cause/effect but no connector)
- “It looks like we’re sitting straight in the chair.” “in” lets us look to the verb, “sitting” is active)
- “It’s squishing us”

Level 3:
VSRs that include talk about Cause and Effect; that is, that make a connection between some end state and the conditions or change in the context that brought about the end state (Bloom and Capatides, 1987). (End state and conditions/context are underlined). Causes can be vague (it, that, etc), but the effect should indicate that the speaker has some end state in mind. The connection made MUST include a causal key word (which are CAPITALIZED).

Personal Space

- “Get on one side of it– Dad get over there. We need to all be at one side TO make a square.”
- “The lines always stay halfway between you and your neighbor. And that’s WHY I can’t get in your space.”
- “Look HOW they (lines) move WHEN you move.”
- “Step right here at the same time, and NOW we’re in the same space.”
- “Get off. NOW I can go wherever I want.”

Spin TV

- “Spin around TO make the cylinder.”
- “If you hold the rod tilted toward your head, it will make a hat.” (“tilted toward” is a statement about position rather than an action)

Mirror Draw

- “When you look in the mirror, the line is curved there.”
- “When they’re trying to draw a map of the world, this [mapping a 3D world onto a 2D map] is some of the challenges they have. BECAUSE the world is a sphere, or actually more like an oval.”
- “It’s a rectangle. BECAUSE this (chalkboard) is flat and this (mirror) is round.”
- “Draw a straight line AND it’s gonna look curved.”
- “It looks like pie right here, but if you look in the mirror, it’s straight, it’s opposite”

Dividing Space

- “If the red things are close together it’ll make the space smaller.”
- “If you take this one (peg) you can make it bigger! Maybe it’s bigger with just one (puck) as opposed to two?”
- “Is there a RELATIONSHIP BETWEEN HOW close you put the red things, and the size of the blue?”
- “Put the red things close together TO make the space smaller.”
<table>
<thead>
<tr>
<th>Spin Socket</th>
<th>Mirror Bench</th>
</tr>
</thead>
<tbody>
<tr>
<td>- “Put the pegs here TO change it”</td>
<td></td>
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<tr>
<td>- “You take them off, THEN it gets bigger”</td>
<td></td>
</tr>
<tr>
<td>- “You can make the blue area as big as you want BY taking them all off.”</td>
<td></td>
</tr>
<tr>
<td>- “WHEN you spin it, it’ll make the hourglass”</td>
<td></td>
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<tr>
<td>- “It’s shaped like an arrow, SO it makes the hourglass.”</td>
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<tr>
<td>- “Do they (spinning cards) make something different WHEN they’re slow?”</td>
<td></td>
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<tr>
<td>- “This one’s a cube and this one’s an hourglass, BECAUSE this one is more to the right.”</td>
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<tr>
<td>- “This one goes inward, and that one goes outward. SO it makes a diamond.”</td>
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</tr>
<tr>
<td>- “AS you move the blue piece, HOW do the shapes around it change?”</td>
<td></td>
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<tr>
<td>- “It looks stretched here, but THEN IF you look in the mirror it’s normal”</td>
<td></td>
</tr>
<tr>
<td>- “WHEN you look in the mirror, HOW does it change your body?”</td>
<td></td>
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<tr>
<td>- “IF you stand further away, you get taller”</td>
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<tr>
<td>- “The mirror squishes you, SO you look skinny.”</td>
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</tbody>
</table>
E. Amendments and clarifications

Tricky cases Level 1 and 2: idioms

“It’s hard to tell if they are descriptive (L1) or dynamic (L2). Though we wouldn’t use this strategy normally, in these cases we tried paraphrasing the utterance to get a better sense of the meaning. Thus, for “running out of space” no physical “running out” happens, but since we’d paraphrase it as something like “Your space is shrinking,” we called it L2. For “How does it come up in the mirror,” the paraphrase is something like “how does the flat picture transform when it’s reflected from the chalkboard up to the mirror?” It’s also possible that it just means, “How does it appear in the mirror?” Since the VSR scheme tells us ‘when in doubt, assume the spatial term is used spatially,’ we assumed here that “come up” has the more spatial meaning of “move from chalkboard to mirror” or “transform” instead of “appear.” Thus, we coded it L2. For “didn’t come out right,” the paraphrase is “doesn’t look how I want it to.” This phrase seems more solidly about appearance than the other one (even though there is a potential element of transformation here too), so we coded it L1.

Tricky cases Level 3:

For a level 3, at least one part (cause or effect) must have a spatial term:

“Look, she’s crying BECAUSE she didn’t get to go. Let your sister sit on the chair now.” There’s a cause/effect statement here about why she’s crying, but it has no spatial terms. L2

<table>
<thead>
<tr>
<th>OUT (Not level 3)</th>
<th>IN (Level 3)</th>
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<tbody>
<tr>
<td><strong>Cause and effect are the same thing:</strong></td>
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<tr>
<td>“Get on the chair; see if you can fit on the chair.”</td>
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<tr>
<td>This seems like she’s just repeating her instructions twice, in a different way. Similarity:</td>
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<tr>
<td>“We can get the same space. See, NOW we’re sharing space.”</td>
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<tr>
<td>Again this seems like a repetition of the same idea.</td>
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<tr>
<td><strong>Gestural Causes:</strong></td>
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<tr>
<td>[Adult puts down a peg on DS] “…SO that will make half of it.”</td>
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<tr>
<td>He probably means “I’m putting the peg here so that will make half of it,” but, even though we thought vague causes</td>
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</table>

**Cause/effect involving specific “See if” or “What if”**  |
| “Try to draw and see if it turns out right side up or upside down.”   |
| “What if you go up and down, does it change?”  |

**Emotional/behavioral cause effect:**  |
| “We stay forever, BECAUSE we look so skinny.”  |
| “I spun around four times AND NOW I’m nauseous.”  |

**Incorrect or somewhat unclear cause/effect:**  |
| “Let’s crowd him in, NOW you’re stuck.”  |
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Citations


Casasola, M., Bhagwat, J., & Burke, A. S. (2009). Learning to form a spatial category of tight-fit relations: how experience with a label can give a boost. Developmental Psychology, 45, 711-723.


