Geometry Playground
Spatial Language
Coding Manual

Toni Dancu,
Josh Gutwill,
& Lisa Sindorf

The Exploratorium

Created: October 26, 2010

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

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 algorhythm 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, lighbulb, 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

SPATIAL LANGUAGE	SPATIAL LANGUAGE TERMS: *Exhaustive* list of core terms that are definitely spatial	*Examples* of terms that are spatial because there's a core term in the definition	*Examples* of terms that are not spatial because core term is not in definition
Shape: Describes the shape of an object (or body)	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	box, doughnut, piece, region, ring	funny, ordinary, partial, portion, regular, scale, weird,
Location: Location or locating of an object relative to background or another object	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	distance, place, enclose, within, after, ahead, remove, contact, group, map, anywhere	coverage
Movement: Any object changing location	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	aim, catch, come, trail, transport, roll, send, wave, hit	action, block, obstruct, crash, get/got, give, go, hold, push, shake, take, use
Size:	big, contract, expand, extend, fat, height, large, little, long, miniature, narrow, short, size, slender, small, skinny, tall, thin, tiny, wide, width	broad, bowed	

Orientation: Direction an object is facing relative to background of another object	along, angle, around, face away, face toward, diagonal, down, horizontal, level, parallel, perpendicular, reverse, slant, slope, stretch, tilt, up, upright, upside-down, vertical,	lean, extend, elongate	
Curvature:	bend, bump, curved, flat, straight		
Congruence: comparing shapes or areas	alike, congruence, differ, difference, different, dissimilar, distinct, identical, just like, like, same, similar		
Construction: Creating, building, or developing a shape or geometrical form	arrange, build, construct, create, develop, divide, draw, erase, form, make, place, put, split	structure, produce	do, play, try, work
Rotation:	around, axis, circular, flip, over, revolve, rotate, spin, spiral, turn, twist		faster, slower
Transformation: changing from 2D to 3D or from morphed to anamorphed	anamorphed, change, compress, different, distorted, made, morphed, reflection, squished, transform	deform, metaphors that require transformation (e.g., wine glass, hourglass, hot air balloon, light bulb, chair, fireworks, flower, hat, skirt), squash	bench, look,

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**."

o "**There** you go, nice work."

2. It is clearly *not* about visiting, exiting, exploring or experiencing a *Geometry Playground* exhibit.
    o "We can hand in our microphones **at** the **front**."
    o "The bathroom is **over there**"
    o "Look at the **big round** blue thing **over there**!" (about an exhibit that is not in the study)
    o "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:
    o the spatial term
    o the talk around it that makes it a VSR
In general, you will not include long (> 2 second) stretches of:
    o Silence
    o Laughter or sounds
    o 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):
    o "Well, do you think, should I, can I try to **draw** my **initials in** the mirror?"
    o "**Make** a **square. Further, further**, okay, you got it."
    o "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 <u>could</u> 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:
   o "Let's **make** the blue as **big** as we can. Hahaha! Oooooh!" [Pause] "Rrrrrgggg! Vrmmm. 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:
   o 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.
   o 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."
   o Non-English language (even if you can translate it yourself) should be considered unintelligible and not be coded.
   o <u>If the context doesn't help and you are still unsure, do not code.</u>

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. <u>When in doubt, assume that the spatial term is used spatially and is on task</u>. Example:
   o 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:
   o 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.

o 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."

- o Directing someone's movements to create a shape: "Almost, perfect **position**. **Back up, back up, stop**. That's a **square**."
- o At Dividing Space: "See how they're [lines] **in between**? It **separates** them. It **builds** a **shape**. You can **put** it **anywhere** you want."
- o "You're **making** it out of light."
  - o **Rotation** — Spinning, rotating or flipping an object over
    - o "Any way you **turn** a **square**, it's still a **square**.
    - o Directing another person to "**spin**" or "**turn around**."
  - o **Transformation** — Changing from 2D to 3D or from morphed to anamorphed
    - o 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**."
    - o "So now set it to **spin** faster. It looks like it's fooling your eyes, right? Like it's all one **solid shape**."
    - o "The **arrow** has this **curve**, and this one's **flat** or **straight here**. But look **in the mirror**."
    - o "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**."
    - o "So the mirror **squishes** pictures. This is always [garbled] when you **move** from a **curved surface** to a **flat** one."
    - o "Which card will **make** that picture?"

2. Borderline cases that are VSRs

Spin TV
- o "What do you do **here**?"
- o "Hold it like this. **In front** of you."
- o "You need to **face** the screen."
- o "Go all the way **around**. You have to **move** your **legs**."
- o "Oh, neat, so you can see the **pattern** of the **movement**"
- o Anything you **move**, it's **catching** it and **showing** the **movement**"
- o "Careful, because it'll go **out** and **hit** other people"

Personal Space
- o "I'm standing **inside** the rainbow!" (while on Personal Space)
- o "It really doesn't matter how many people are **on** it."
- o "Two people should be **on** this."
- o 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.)
- o "Come **here**. **Here**!" (as long as "here" is an exhibit)

Dividing Space
- o "Throw it (puck) **up**."
- o "How does it **track** these?"
- o "Does it see **where** they are **from above**?
- o "Let's see if we can **make** it."
- o "The pegs go **in** the holes."
- o "Can you give one **here**?"
- o "Give one **to** me"
- o "**Put** the (unused) pegs **in** the bins"

Mirror Draw
- o (Comparing two stations at MD) "Oh, I see, they're the **same**."
    - o "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.
- o "See if you can **draw** it"
- o "How do you **erase** this?"

Mirror Bench
- o "Does the mirror work from **over here**?"
- o "**Stand up**"
- o "**Put** the sign **back**"

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

3. Borderline Cases that are NOT VSRs

Terms not used in accordance with spatial reasoning definitions
- o "How do you **erase** this?" (at Spin TV)
    - o 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.
- o "It **turned different** colors."
    - o (not used spatially)
- o "That one doesn't stand **out**" (at Spin TV, talking about the colors)
    - o (not used spatially; here, "stand out" is about perception.)
- o "**Turn on** the motor." (not used spatially)
- o "I have no idea what's, **like**, that one."
- o "Give him a **turn**"
- o "What's it **about**?
- o "Good job, you did it! You figured it **out**."
- o "**There** you go, nice work."
- o "**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.

- o "We can hand in our microphones at the **front**."
- o "The bathroom is **over there**."
- o "Come **here** right now, you're in big trouble."
- o "Look at the **big round** blue thing **over there**!" (about an exhibit that is not in the study)
- o "You're not supposed to go **outside** the blue tape **area**"
- o "The lady **at** the **front** said we have to **stay in** the blue **lines**."

o   "**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:
o   "It's a **square**."
o   "The blue **space** is really **big**"
o   "I'm **on** the **line**."
o   "It looks **curved in** the mirror"
o   "I'm **skinny in** the mirror"
o   "You look **shorter in** the mirror"
o   "I have personal **space**"
o   "I want more **space**"
o   "I found the **middle** one"

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

TRICKY CASES (L1s):
o   "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**
o   "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):
- o "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).
- o "The mirror *squishes* pictures" uses the term "squishes" as an action, describing the change in the pictures; therefore, it is coded as an **L2**.
- o "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**
- o 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**").

Spatial Prepositions:		
above	between	over
across	beyond	past
after	by	round
against	down	through
along	from	throughout
along with	in	to
among	in back of	toward
apart	in front of	under
apart from	inside	underneath
around	into	up
as far as	near	upon
as close as	next to	up to
at	off	with
atop	on	within
before	onto	without
behind	on top of	
below	out	
beneath	out of	
beside	outside	

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 <u>underlined</u>**)**. 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 <u>looks like a</u> **regular chair**."
"IF the <u>red things are</u> **close** together it will ***make*** the **space smaller**."
 "***Spin around*** TO ***make*** the **cylinder**."
 "WHEN you <u>look **in**</u> the mirror, the **line** is **curved there**."
 "We have to <u>all be on one</u> **side** FOR <u>a</u> **square**."
"It's **shaped** like an **arrow**, SO it ***makes*** the **hourglass**."
"***Draw*** on the **line**, and THEN <u>it will look</u> **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 <u>we're</u> **in** the **same space**.
"***Draw*** a **straight line**, AND <u>it's gonna look</u> **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:

And (as a result)	First	So (so that)
After That	How	Then
As	If (whenever)	To (in order to)
Because	Next	When
By (as a result of, by means of)	Now (as a result)	Why
Connected	Relationship (relationship with/between)	
For (in order for)	Related (related to)	

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 around**_ 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 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 <u>look **in**</u> the mirror, you <u>don't look **normal**</u>" (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
- "<u>Look **in** the mirror</u> AND see what it looks like." L1
- <u>Try to *draw* a **T**</u>; 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 <u>you ***move*** it</u>. L2
- "<u>That's</u> 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 <u>it looks **normal in** the mirror</u>…" L3 (pauses as child draws)
Utterance 2: "…or <u>try **your name**</u>." 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: "…<u>that's</u> 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 <u>you *move* the…</u> [garbled] it *<u>makes</u>* the **lines**" would be

D. Additional examples of VSR levels

Level 1:	Personal Space	o "It's a **square/circle**/etc." o "My **space** is **bigger** than yours." o "You're **in** my **space**." o "I'm **on** the **line**." o "Our **space** is the **same size**!" o "Look at the **line**." o "I have personal **space**. I want more **space**." o "It (the line) disappears (when you get close). You could have six people **on here** and it would be **like** one."
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)**.**	Mirror Draw	o "Why does it look **curved here**?" o "The **line** is **straight**." o "Your **nam**e is **curved**." (when at MD, one's name is a shape) o "The **arrow** has this **curve**, and this one's **flat** or **straight** here. But look **in the mirror**."
	Spin TV	o "Looks like a **flower** or something." (When looking at a shape created at the exhibit) o "Do you see the **cone around** him?" o "You're **gift-wrapped**." o "That's six **spins**."
	Spin Socket	o "Oh, what matters is **where** the **lines** are **on** the card." (w/o further context) o "These cards are totally **different**." o "What's the **difference between** these?" o "It's a **square**" or "**wineglass**" or "**hourglass**" or "**Hot air balloon**." o "They (arrow cards) look the **same**, why are they so **different**?" o (pointing to the label) "I already found the **middle** one."
	Mirror Bench	o "It looks like a **regular** chair." o "I look **skinny**." Or "I'm **skinny in** the mirror." o "It looks **shorter in** the mirror" or "It looks **curved in** the mirror" or "It looks **squished in** the mirror." o The **shorter** you are here, the **skinnier** you are there (in the mirror)." o "The **further** you are away, the **skinnier** you are"

	Dividing Space	o "Does the blue **area** ever **touch** the red?" o "The blue **space** is really **big**!" o "This is the **same** as the other one, huh?" (talking about two exhibits) o "See how the **lines** are **in between** [the pegs]?"
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	Personal Space	o "So, you're trying to *make* a **square** here." o "Are you supposed to *step on* the **lines**?" o "Why can't I *get in* someone's personal **space**?" o "*Stay on* your **side** of the **line**." o "*Stand* there and *don't move*." 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.
	Mirror Draw	o "See if you can *write* a *T*" o "Now *draw* it **upside-down**." o "Look **there**, **in** the mirror it looks **normal**, but look **here**. It *changes* **shape**."
	Spin TV	o "*Spin* your body *around*." Or "*Turn around*." o "Try *holding* the rod **up and down**." o "Do it very slow so I can see how it *turns*." o "I'm *trapping* you." o **"*Twist*** it, like that, like a **cone**" o "You *put* her *in* a cage." ("Put in" is an action.) o "*Stand* there, I want to *circle around* you" o "*Make* the **cone**. You need to *put* one end of it *by* your head." (no connector word, so L2)
	Spin Socket	o "Which card will *make* that **picture**?" o "You can *make* an **hourglass** with that one." o "This one should *make* that one, and this one should *make* that one." (predicting about the cards on Spin Socket). o "It's gonna *make* an **hourglass**."`
	Dividing Space	o "*Roll* the puck *through* the pegs." o "You can *make* it as **big** as you want."

actual change or potential for change. Theoretically, these comments are about **Spatial Transformations** (NRC: Learning to Think Spatially, 2006)**.**		o "Look, it *makes* different **spaces**, sort of **like** the other one" o "The **size** hasn't *changed*." o "*Move* those red pegs *around* and see what it does." o "*Make* it like an **obstacle course**" o "How **big** can you *make* the blue **area**?" or "Try to *make* the blue **area bigger**." o "It looks like the red ones are *making* these things either **big** or **small**." (Cause/effect but no connector)
	Mirror Bench	o "It looks like we're *sitting* **straight** *in* the chair." "in" lets us look to the verb, "sitting" is active) o "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). Theoretically, these	Personal Space	o "<u>Get **on** one **side**</u> of it– Dad *get over* **there**. We need to all be **at one side** TO *make* a **square**." o "The **lines** always *stay* **halfway between** you and your neighbor. And that's WHY <u>I can't *get in* your **space**</u>." o "Look HOW <u>they (lines)</u> *move* WHEN <u>you</u> *move*." o "*Step* right **here** at the same time, and NOW <u>we're</u> **in** the **same space**. o "*Get off*. NOW <u>I can *go wherever* I want</u>."
	Spin TV	o "*Spin around* TO *make* the **cylinder**." o IF you <u>hold the rod **tilted toward**</u> your head, it will *make* a **hat.**" ("tilted toward" is a statement about position rather than an action)
	Mirror Draw	o "<u>WHEN you look **in** the mirror</u>, the **line** is **curved there**." o "When they're <u>trying to *draw* a map of the world</u>, this [mapping a 3D world onto a 2D map] is some of the challenges they have. BECAUSE the <u>world is a **sphere**</u>, or actually more like an **oval**." o "It's a **rectangle**. BECAUSE this (chalkboard) <u>is **flat**</u> and this (mirror) <u>is **round**</u>." o "*Draw* a **straight line** AND it's gonna look **curved**." o It looks like **pie** right **here**, but IF you <u>look in the mirror</u>, it's **straight**, it's **opposite**"
	Dividing Space	o "IF the <u>red things are **close** together</u> it'll *make* the **space smaller**." o "IF you <u>take this one (peg)</u> you can *make* it **bigger**! Maybe it's **bigger** with just one (puck) as opposed to two?" o "Is there a RELATIONSHIP BETWEEN HOW **close** you *put* the red things, and the **size** of the blue?" o "*Put* the red things **close together** TO *make* the **space** smaller."

comments are about **FUNCTIONAL INFERENCE** (NRC: Learning to Think Spatially, 2006).	Spin Socket	o "***Put*** the pegs **here** TO ***change*** it" o "You *take* them ***off***, THEN it <u>gets</u> **bigger**" o "You <u>can</u> ***make*** the blue **area** as **big** as you want BY *taking* them all ***off***." o "WHEN you ***spin*** it, it 'll ***make*** the **hourglass**" o "It's **shaped** like an **arrow**, SO it ***makes*** the **hourglass**." o "Do they (spinning cards) ***make*** something **different** WHEN <u>they're slow</u>?" o "<u>This one's a</u> **cube** and this one's an **hourglass**, BECAUSE <u>this one is more</u> **to the right**." o "This one goes **inward**<u>, and that one goes</u> **outward**. SO it ***makes*** a **diamond**." o "AS you ***move*** the blue piece, HOW do the **shapes around** it ***change***?
	Mirror Bench	o "It looks **stretched here**, but THEN IF <u>you look</u> **in** the mirror it's **normal**" o "WHEN you <u>look</u> **in** the mirror, HOW does it **change** your **body**? o "IF you ***stand further away***, <u>you get</u> **taller**" o "The <u>mirror</u> ***squishes*** <u>you</u>, SO <u>you look</u> **skinny**."

E. Amendments and clarifications

Tricky cases Level 1 and 2: idioms
"You're ***running out*** of **space**" L2
"How does it ***come up in*** the mirror?" L2 borderline
"My name didn't ***come out*** right." L1

Sometimes the spatial term and its paired verb are idioms, and 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

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

such as "it" are OK, this seems just too vague. Gestures alone cannot be causes, though they can add context ("hold it like this" is OK). This is VERBAL spatial reasoning.

Cause/effect using NON-VSR context for half of a Level 3:
"Why isn't it working right now?" (no spatial term, not coded. Then, new VSR)
"Oh, it's because you're *covering* it *up*." L2

No spatial terms, only part of relevant talk:
"She's crying BECAUSE she didn't get to do it."

Long convoluted reasoning:
Mom: "Why does he have so much space?"
Kid: "He's in the middle… "
Mom: (overlapping with kid's VSR)
"Let's trap him in. Now he's stuck!"
Kid: "Not if I move…"

This is a long chain of reasoning, where Mom and Kid use personal space. There are a few possible cause/effect relationships. The guy has a lot of space because he's in the middle; He's stuck, but not if I move; or He's in the middle but not if I move. The first two involve both Mom and Kid's VSRs, so, since the kid didn't say the whole thing, she doesn't get L3. The third one "He's in the middle/not if I move" is all VSRs from the kid, but this interpretation seems less plausible. L2

Cause and effect using observations or rules to justify thinking or predict what will happen:
"This one *made* the **hourglass** SO that one will *make* the **diamond**.
"*Moving* to a **different** cel makes the calls get transferred. SO this could be a tower."

Here, "so" means something like "therefore."

Cause/effect as definition:
"WHEN it *spins*, it's called a **rotational solid**."

Cause/effect using prior context for Level 3:
We want to give credit to one speaker for putting cause and effect together, even if they do so slowly. If an adult says a cause, then an effect (in two VSRs) it's OK to use the child's VSR talk to help you tell if the two adult VSRs are indeed related, and that they are still on the same topic.
Adult: "How **big** can you *make* the blue **area**?...." L2
Child: "I know how! *Take* them all *out*…" L2
Adult: "…Oh, IF you *take* them all *out*, you can." L3

Vague causes:
"To *make* a **line** *going* **straight** *across*, try *following*…"
"To *make* a **line** *going* **straight** *across*, try this."

Citations

Bloom, L., & Capatides, J. B. (1987). Sources of Meaning in the Acquisition of Complex Syntax: The Sample Case of Causality. *Journal of Experimental Child Psychology*, 43, 112-128.

Callanan, M. A., Shrager, J., & Moore, J. L. (1995). Parent-child collaborative explanations: Methods of identification and analysis. *The Journal of the Learning Sciences*, *4*(1), 105-129.

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.

Dancu, T., Gutwill, G., & Sindorf, L. (2015). Comparing the Visitor Experience At Immersive and Tabletop Exhibits. *Curator, 58*(4).

Fleiss, J. L., Levin, B., & Paik, M. C. (2004). The Measurement of Interrater Agreement *Statistical Methods for Rates and Proportions* (Third ed., pp. 598-626). Hoboken, NJ: John Wiley & Sons, Inc.

Gentner, D. & Christie, S. (2008). Relational language supports relational cognition in humans and apes: A response to Penn, Holyoak & Povinelli. *Behavioral and Brain Sciences, 31*, 137-183.

Linn, M. C., & Petersen, A. C. (1985). Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis. *Child Development, 56*(6), 1479-1498.

National Research Council. (2006). *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*. Washington, D.C.: National Academies Press.

Pruden, Levine, S., & Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter? *Developmental Science, 14*(6), 1417-1430.

Serra, M. (2003). Discovering geometry: An investigative approach. Emeryville, CA: Key Curriculum Press.

Tartre, L. (1990). Spatial Orientation Skill and Mathematical Problem Solving. *Journal for Research in Mathematics Education, 21*(3), 216-229.

Thesaurus.com (n.d.). *Roget's 21st Century Thesaurus, Third Edition*. Retrieved May 15, 2010, from Thesaurus.com website: http://www.thesaurus.com