Learning Linearly: Preschoolers' Concepts of Math Through Board Games
Interpretation Guide

Background:
Children have a natural interest in math, and math is a part of their everyday play. This can be seen when children play with blocks: "My tower is taller than yours!" or when they role play: "I need to bake five cookies so we all can get one for dessert." Children especially use math ideas during board games: "I need two spaces to win!" They are constantly building on their knowledge of concepts like counting, understanding magnitudes, and estimation. Of particular importance is their development of a linear representation of number, as it is utilized every day in arithmetic, decimals, and discriminating among magnitudes of larger numbers (Whyte & Bull, 2008).

Studies in early childhood math are fairly recent, as many preschool and kindergarten classrooms focus primarily on literacy and social development, and not on science, technology, mathematics and engineering (STEM). Legislation is now being pushed that provides for the essentials of early math skills to be taught at school. It was originally believed that any math experience this early was developmentally inappropriate, but we now know that this is not the case. Children have an extraordinary ability to learn math—*but* this learning is best when there is greater transparency of mapping between the math-related toys they play with, and the desired internal representations. This is formally known as the "representational mapping hypothesis." In short, it is most effective when a game's math-related goals and features are salient.

This study uses the representational mapping hypothesis to look at how children learn counting, magnitude (comparing values of numbers), and numerical estimation on number lines (being able to accurately place an integer on a number line between two values). Interventions of three different math games were used here—a "nonlinear number group, linear color group, and linear number group" (Whyte & Bull, 2008). The board game here at the Bay Area Discovery

Museum is modeled after the "linear number group" intervention, in which children spun a spinner and moved that number of linear spaces while counting aloud the numbers they passed. This intervention was meant to have the clearest mapping between the physical game itself and the goal of the game—to support the child's understanding of linearity and numerical estimation on number lines.

Researchers found:

- ❏ Both the nonlinear game group and the linear number board game group showed improvements from pre-test to post-test in counting and magnitude, which are basic numeracy skills.
- ❏ Only in the **linear number board game group** did the children's **number line representations** improve.
- ❏ The linear number board game had multiple *correlated cues* to numerical magnitude: the number on the spinner corresponding to the distance moved on the board, the greater number of moves corresponding to more time needed, and the greater number of count words used overall in the game—under the representational mapping hypothesis, these cues make it the best format for a board game intended to support children's understanding of numerical magnitude as linearly increasing.

Why is this important?

Children's early math skills are highly related to their later performance in both math and reading through third grade (Booth & Siegler, 2006; Siegler & Booth, 2004). Playing the linear math board game for a few weeks improved children's understanding of linear representation, which in turn facilitates learning of estimation on number lines. This skill has been found to be significantly correlated with improvements in arithmetic abilities and achievement scores. In education, there is increasing recognition of the importance of early STEM experiences, aligned with one of the Bay Area Discovery Museum's missions.

Method:

Recruiting Methods:

Introduce yourself to parents, explaining to them that you are demonstrating a study at the Bay Area Discovery Museum that looks at how young children learn math. Ask if their child would like to play a fun board game with a spinner.

Activity Instructions (the "study method")

Please reference the procedure for the "Linear Number Group" of the original study (Whyte & Bull, 2008)

1. –if child is 2-4, use the 1-10 board, if child is 5 and up, attach the 11-40 section—
2. Place the board game on the table and introduce child to the toy ("This is a fun board game I like to play with my friends. It has numbers on it, and we get to both start here! (point to the 1 space). Which piece do you want to be?" –let them choose).
3. Place both player pieces on the 1 space. "The goal of this game is to get to the Golden Gate Bridge first!"

4. “There are a few rules are you ready? First you need to spin this spinner (spin it so they see), *then* you need to move your piece however many spaces the number you got on the spinner says.” –“But there’s another special rule. When you go over a space on the board, you have to say whatever that number is out loud” (demonstrate).
5. Have them go first, and then you take a turn. Do so until game is complete.
6. “Awesome job!!! Okay, so now I have one more thing I want you to try.” Place number line in front of child (0 on left and 10 on right). Give them digit to hold. “I want you to put this number on the number line where you think it goes…..Great job!” ……
7. Talk with the child’s parent about what the original researchers were studying, and about what the results the researchers found.

Activity Tips (e.g., what to observe as the child plays, discussions to have with parents)

Help parents observe:

· How many count words are used during the play of this game?

· Do children try to count just the amount of spaces they spun rather than the numbers they are passing?

· Have you seen board games like this at the toy store or at school? What types of other math games have you seen? What skills do you think they were trying to support?

Keeping kids interested:

· Draw the child’s attention to the spinner (ooh fun!) and the aesthetic of the board game (traveling to the Golden Gate Bridge).

· Move more quickly through the board game (especially on your turn).

· Ask older children to guess what number they will land on after they spin but before they move their player piece.

Results of the Original Study

- ❏ Children who repeatedly played a game like this one, as opposed to a board game with a different shape, or that emphasized color words, showed greater improvements in linear representation (69% pretest to 100% posttest) when they were asked to place a number on a number line.
- ❏ Both groups who played a game relating to number improved more on their counting and magnitude skills compared to the group that played a color game. This shows that these important skills can be supported by math-related activities on the parents’ part, and that regardless of the game format, there is value in practicing number words with children, and engaging them in early math activities.

Questions Parents May Ask:

What age does my child have to be in order to participate?

The original study had 3-4 year olds participate. However, since this is just a demonstration of the study, children of any age are welcome to participate.

Did my child "pass"?
There is no right or wrong way to play the board game and extremely variable results across age groups. This game in the original study was used as an intervention, that was played over multiple weeks with children to look at its impact on their development of early math skills. This demonstration is just to show you what we do in developmental psychology research.

What is the average age that children are able to place numbers correctly on a number line?
Children begin counting very early on, and begin placing numbers correctly on number lines during preschool. As the numbers get larger (1-100 instead of 1-10), the placement becomes harder to get right, even in adults.

Where can I get more information on the study?
Give parents the hand-out flyer.
http://www.parentingscience.com/preschool-board-game-math.html
Visit the National Association for the Education of Young Children (NAEYC) website for families:
http://families.naeyc.org/
and their position statement on mathematics:
https://www.naeyc.org/files/naeyc/file/positions/psmath.pdf

Activities for Parents to Try at the Museum:

- ❏ Try out the nation's first early childhood Fab Lab, engaging STEM skills through hands on learning of bringing your child's ideas to life
- ❏ Explore the museum using the "Math in Motion" Creativity Kit
    - ❏ *Check the calendar on the BADM website for days and times!*
- ❏ In Bay Hall, encourage your child to use number words while fishing! How many fish did they catch? Ask how they can move the blocks in the Port of Oakland section to help develop spatial understanding. Or, play at Fisherman's Wharf by buying some seafood and use number words in relation to money!
- ❏ Let your child guide their own play in Imagination Playground! The giant foam blue blocks are used to build anything your child can think of that will stay standing—which is important for creativity and early math learning! Compare the sizes of different blocks or have your child estimate how many blocks they used in their structure.
- ❏ Check out the STEM Superheroes Series
    - ❏ *Saturday, May 14: Code Our Future: Super Solving with Robots*

Activities for Parents to Try at Home:

- ❏ Play games like Chutes and Ladders, or even make your own linear number board game like the one we used today! http://www.parentingscience.com/preschool-math-games.html
    - ❏ Children do best when exposed to board games in a frequent manner and in a variety of settings--school, home, museum, friend's house, etc.
- ❏ **Use number words in everyday speech very often, pointing out objects by counting them, comparing sizes of objects, estimating values, etc.**

- ❏ Play with numbers! You could try paint-by-number for an art activity! Support their numerosity (counting abilities), 1-1 correspondence (knowledge that a number corresponds to one thing when counting), and cardinality (understanding that the last number counted in a set of objects represents how many total objects there are). A fun way to incorporate cardinality could be to have your child count their stuffed animals—or something they collect—and ask how many are in their room!
- ❏ Calendars and rulers are awesome things to take advantage of—they have linear numbers!!!
- ❏ Measure your child's height to show them how much they've grown
- ❏ Sing songs like "One, Two, Buckle My Shoe" and "5 Little Monkeys Jumping on the Bed"
- ❏ For wonderful ideas: http://www.parentingscience.com/preschool-math-lessons.html

References

Booth, J. L., & Siegler, R. S. (2006). Developmental and individual differences in pure numerical estimation. *Developmental Psychology*, 41, 189 –201.

Siegler, R. S., & Booth, J. (2004). Development of numerical estimation in young children. *Child Development*, 75, 428 – 444.

Whyte, J. C., & Bull, R. (2008). Number games, magnitude representation, and basic number skills in preschoolers. *Developmental Psychology*, 44(2), 588-596.

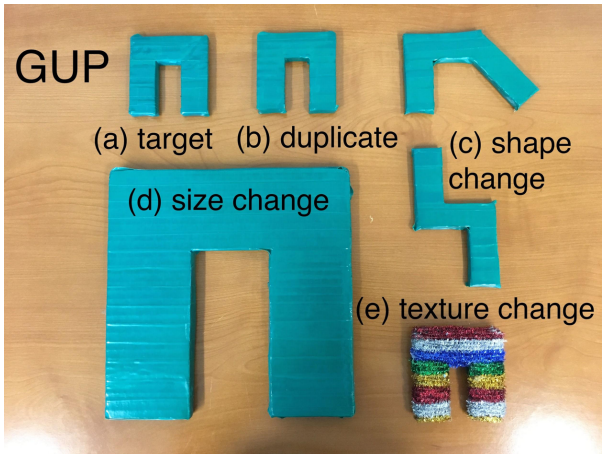
"Word Learning" Interpretation Guide

Word Learning is Smart: Exploring the Extension of Novel Words

Background:

Studies in word learning have shown that young children learn by tracking connections between words and what the object looks like. When learning new words, children weigh various factors such such as shape, color, and texture differently, depending on their background knowledge of the object. When children extend a new word to something that is *animate* (e.g. an animal), they rely on shape and texture. So, they think only an object that shares the same form *and* texture (i.e., fur) as a "dog" should also be labeled with the word "dog." In contrast, when children label new objects with a word that refers to something *inanimate* (like a rock), they pay attention only to whether the new objects share the same **shape**.

The "word learning" activity is based off Experiments 1 and 2 in Booth and Waxman, 2002, and selectively demonstrates two critical conditions: the original animate condition and googly artifact condition.



In their experiment, researchers created four sets of novel objects. In **Experiment 1**, researchers used a set of Gup and Riff without googly eyes and told a brief story about each target object that indicated the object was either animate or inanimate. In **Experiment 2**, researchers repeated the same procedure as Experiment 1, with the addition of googly eyes pasted on each set of the objects to visually appear animate. In the study, each child participated in only only one condition out of the four. Each set of Gup and Riff consisted of 6 objects: the target (a), one duplicate match (b), two shape changes (c), one size change (d), and one texture change (e).

Experiment 1:

In the **original animate vignette,** the researcher presented the target object and told a brief story that indicated the object was animate (e.g., *Gup was really hungry, so Gup ate six candy bars.*) Then the researcher presented the duplicate object match, and asked the child whether the object was "a Gup." The researcher then asked the child to make this judgment about each of the other objects in the set, individually.

In the **original artifact vignette**, the researcher presented the target object and told a brief story that indicated that the object was inanimate (e.g., *Danny used Riff to fix something in his yard, but Riff broke so Danny went to the store to buy a new Riff.*) Then the researcher presented the duplicate object match, and asked the child whether

the object was “a Riff.” The researcher then asked the child to make this judgment about each of the other objects in the set, individually.

Experiment 2:
In the **googly eye animate vignette**, the researcher followed the same procedure as the original, but all objects had googly eyes pasted on, so they also visually appeared animate.

In the **googly eye artifact vignette**, the researcher followed the same procedure as the original, but all objects had googly eyes pasted on, so they also visually appeared animate.

Researchers Found:

- In the **original animate vignette**, nothing about the object visually suggests the object is animate or inanimate. The brief story indicates the object is *animate*, so children extended the new word to only the duplicate and size change object.
- In the **original artifact vignette**, nothing about the object visually suggests the object is animate or inanimate. The brief story indicates the object is *inanimate*, so children extended the new word to the duplicate, size change *and* texture change object.
- In the **googly eye animate vignette**, eyes are glued onto the objects, which suggests that the objects are animate. The brief story indicates the object is *animate*, so children extended the new word to only the duplicate and size change object.
- In the **googly eye artifact vignette**, eyes are glued onto the objects, which suggests that the objects are animate. The brief story indicates the object is *inanimate*, and extended the new word to the duplicate, size change *and* texture change object. Although the eyes suggests animacy, this shows that children paid attention to the story and used the information to extend the new word.

These results confirm that preschoolers don’t infer what a new word means based solely on what a labelled object *looks* like. In the study, children used the information they heard from the story about the new object to label the distractor objects. Preschoolers can use rich background information to complement or even override an object’s visual appearance when they’re figuring out what a new word means.

Why is this important?
As educators, we want to gain insight to how children learn new words. Parents and educators might think that children learn new words by associating a new word based on similarity in shape between a known object and a new object. For example, when deciding whether other objects should also be labeled with a word like “dog,” children pay attention to both whether the new objects have the same form as dogs, but also whether they have the same texture (i.e., fur). Thus, they can use a wide variety of conceptual (instead of merely visual) cues to understand the extent of a new word’s meaning.

Method:

Recruiting methods:

Introduce yourself to parents, explaining to them that you are demonstrating a study that looks at how children learn new words. Ask their child if they would like to play a game with fun toys.

Important notes:

If children are young (2-3 year old), do only the original animate condition, and don't ask confirmation questions in the vignette. If children don't identify the duplicate object as the target object, do only the first condition.

It may be helpful to hold on to the target objects when presenting the objects to prevent them from getting distracted.

Activity Instructions (the "study method"):

Please reference 2.1.3. Procedure of the original study (Booth & Waxman, 2002, B14-16)

Original Animate Vignette

1. Place target Gup on table and say:
    a. *"Wow, look at this gup! You know what? I have something very special to tell you about this Gup. Do you want to hear it? Listen carefully now because I am going to ask you some questions about what I say. This Gup is usually very hungry. One day when it was walking through the forest, this Gup found 6 candy bars. Can you believe that? So where was this Gup walking when it found the candy bars? That's right! And it was so happy when it found them that it jumped up and down and gobbled up all the candy bars. Ok, so what did the Gup do when it found the candy?*
    b. If child provides incorrect answer or says they don't know, provide correct answer. If child gets question right, praise child for correct answer! For younger children, no need to ask follow up question.
2. With target Gup visible, say *"Now I am going to show you some other things. Each one might be a Gup or it might not be a Gup. I need you to tell me if you think each one is a Gup or is not a Gup, ok? Do you think you can do that?"*
3. Present the duplicate Gup and ask *"Is this another Gup?"* Then, remove the duplicate Gup from view.
4. Present other Gups (size change, shape change, texture change) in a random order one at a time. With each of the new objects ask, *"Is this another Gup?",* then remove from view. (predicted answers: duplicate: yes, size change: yes, shape change: no, **texture change: no**)

Googly Eye Artifact Vignette

5. Place target Riff with googly eyes on table and say:
    a. *"Wow, look at this Riff! You know what? I have something very special to tell you about this Riff. Do you want to hear it? Listen carefully now because I am going to ask you some questions about what I say. Danny usually keeps this Riff in his basement. But one day Danny took it outside because he needed to use it to fix something. Now why did Danny take this Riff out of the basement? That's right, and when his Riff got worn out*

doing the job, Danny went to the store and bought a new one. Ok, so where did Danny go to buy a new Riff?

   b. If child provides incorrect answer or says they don't know, provide correct answer. If child gets question right, praise child for correct answer!

6. With target Riff visible, say *"Now I am going to show you some other things. Each one might be a Riff or it might not be a Riff. I need you to tell me if you think each one is a Riff or is not a Riff, ok? Do you think you can do that?"*
7. Present the duplicate Riff and ask *"Is this another Riff?"* Then, remove the duplicate Riff from view.
8. Present other Riffs (size change, shape change, texture change) in a random order one at a time. With each of the new objects ask, *"Is this another Riff?"*, then remove from view. (predicted answers: duplicate: yes, size change: yes, shape change: no, **texture change: yes**)
9. Praise child for playing the game and talk with the child's parent about what the original researchers were studying, and discuss with parents the results the researchers found.

Activity Tips (e.g. what to observe as child plays, discussions to have with parents)

Help parents observe:

- What properties does the child use to identify the target object, the shape, size, or texture?
- Does the child understand that the eyes suggest animacy?
- Does the child understand what each story indicates about the target object?

Keeping kids interested:

- Remind children that they will be able to get a sticker/prize at the end of the activity!
- Be enthusiastic when telling them the story and showing them the new toys!

Results of Original Study

- For both the original Gup and googly Gup, children in the animate condition extended novel labels on the basis of both shape and texture,which means children agreed that the "size change Gup" was a Gup, while the others were not. This makes sense when you think about learning about what the words for animate things like animals refer to - both the shape of the animal *and* its "texture" (e.g., fur, scales…) are critical to its identity!
- Children in the artifact condition extended the new words to all the objects that shared the same shape as the original, regardless of whether the texture had changed. This also makes sense when you think about how much less important texture is than shape for inanimate objects (a pink plastic hammer is still a "hammer"!).

Questions Parents May Ask

Q: *What is the appropriate age?*

A: The original study looked at children between the ages of 3-4; however, since this is just a demonstration of the study, children of any age are welcome to participate!

Q: *What were the results from the study?*
A: The results show that children paid attention to what the experimenters *said*, as opposed to just the appearance of the items (e.g., that they had eyes) in determining the meaning of the new words.

Q: *Where can I get more information on this study?*
Give parents the insert for this study, which has ideas for exploring related concepts in the museum and at home.
Direct parents to http://www.psychology.northwestern.edu/research/ and http://lcdlab.berkeley.edu/ to learn more about current research in language and child development.

Activities for Parents to Try at the Museum:

- Ask children to teach you about the underwater creatures in Bay Hall - what do they call specific animals they don't know the words for yet (e.g., do they call all underwater animals "fish" or do they combine other words: snake+fish = eel)?
- Play sorting games with the blue blocks in front of Discovery Hall, or the materials in the Art Studios or Fab Lab - what is your child paying attention to in grouping objects (e.g., shape, color, texture, function)?
- Use translations on museum plaques to start a conversation with your child about other languages (do they know what language they speak? Would they be able to understand someone speaking another language? Why or why not? What makes languages different? What languages would they like to learn?).

Activities for Parents to Try At Home:

- Teach children names to objects they may not know, show them a similar object and ask what is the name of the new object?
- Explain, explain, explain! Children are always constructing new hypotheses for what words mean, and they can use conceptual or linguistic information like the stories in this study to help them identify which is correct.
- Pay attention to the mistakes they make - children are very sophisticated learners, and often their mistakes in language reveal how they're interpreting the world, and the aspects of words' meanings that they're still working on mastering.
- When you come across unfamiliar words reading books together at home, encourage your child to think of what that word might mean based on the rest of the sentence and story around it (a.k.a. using "context clues"), before telling them what it means.

References:

Booth, A.E., & Waxman, S.R. (2002). Word learning is "smart": Evidence that conceptual information affects preschoolers' extension of novel words. Cognition 84, B11-B22.