Verification

By Anton and Diana

Big Picture

- How much does the semantics dictate in the verification process?
- Concerning the words “Most” and “More than half,” is there an innate feature of the word that forces an individual to verify truth conditions based on specific methods?
  - OR
- Does semantics leave it up the Logical/Pragmatic Systems in the brain to most effectively evaluate the truth condition on its own without specific guidance or stipulation?

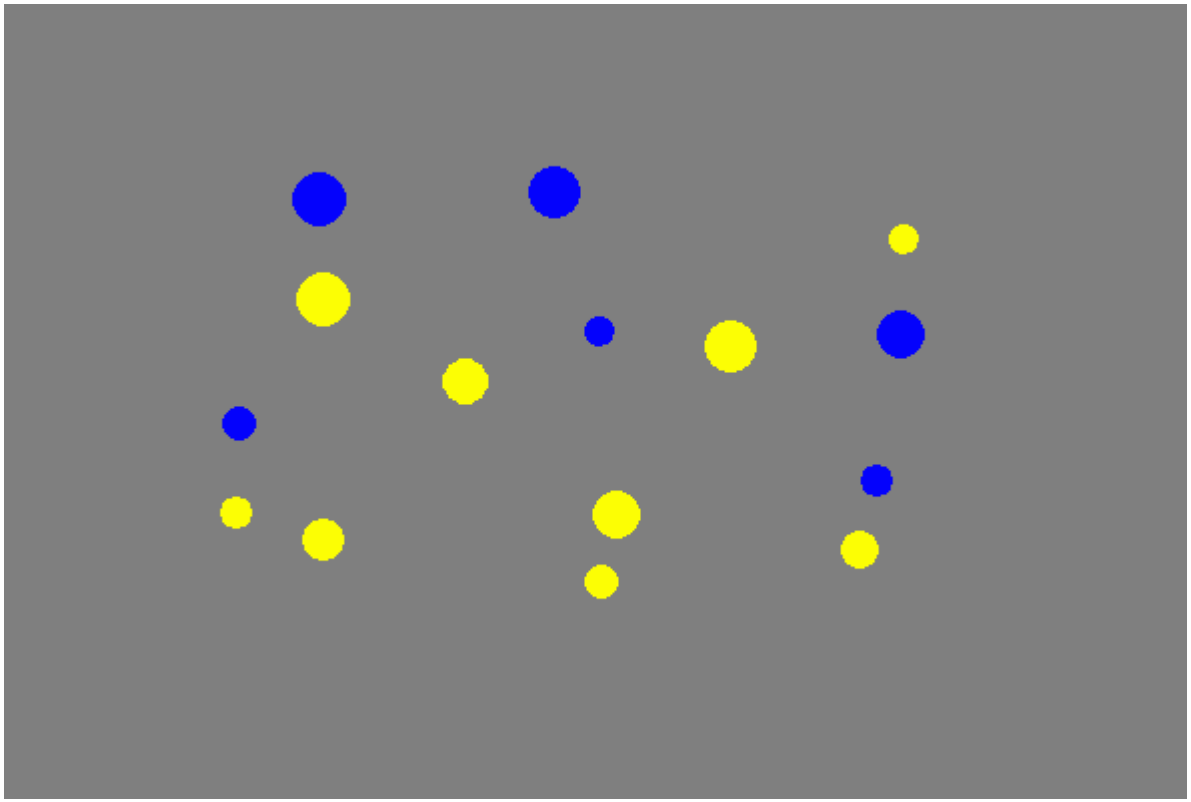
"Most" and "More than Half"

- 1) a. Most of the dots are yellow.
  - b. $|DOT \cap YELLOW| > |DOT - YELLOW|$
- 2) a. More than half of the dots are yellow.
  - b. $|DOT \cap YELLOW| > 1/2 |DOT|$
- Truth conditions are best expressed in this manner (1a/1b, 2a/2b)
- However, this is only the first step. Verification procedures are needed to evaluate these truth conditions.

As an aside…

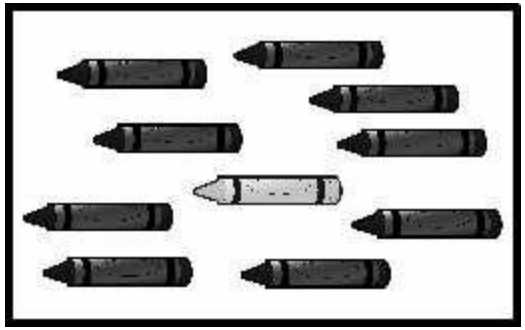
- Why do we not have a word like “Fost” in English or any language with the following semantics:
  - “Fost” of the dots are yellow
  - $|DOT \cap YELLOW| < |DOT - YELLOW|$
  - 10 dots total, and 2/10 are yellow and 8/10 are blue, “Fost” dots are yellow.

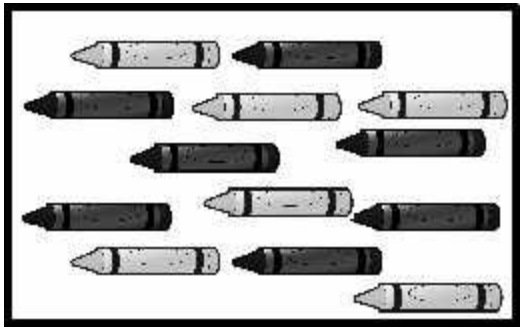
- It’s possible to verify quantifiers like “most” without having a numerical value system.
  - Ex. Children who cannot count past the number 5 can still verify the truth of the word “most.”
  - “Most of the dots are yellow.” we can determine the truth without referencing cardinality



Another Example

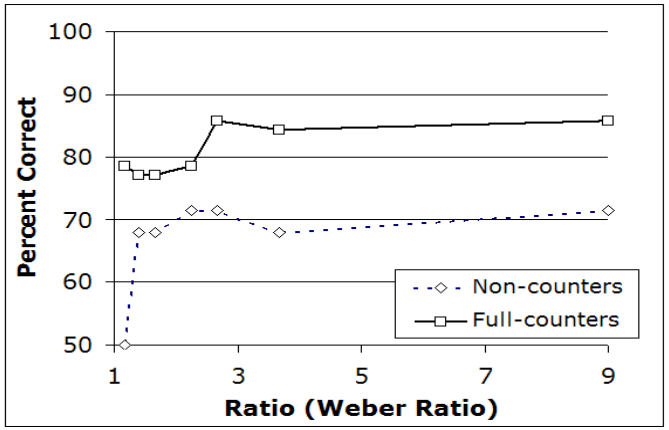
- Halberda et al. (2008) tested three- and four-year-olds' understanding of "Most"
- Two ratios shown
  - Easiest Ratio 1:9 (a)
  - Hardest ratio, 6:7 (b)





Results

- The percentage of correct responses differed between non-counters and full-counters, but the pattern of results was similar for both groups.
- There potentially is a correspondence between verification and counting ability. This could be due to the children's cognition skills rather than their counting ability



Verification using One-to-One Correspondence

- How can we verify the truth of sentences where counting is not possible?
  - Ex. Images are shown to quickly to count
- Cardinality
  - two sets A and B have the same cardinality if and only if the elements of A can be put in one-to-one correspondence with the elements of B:

$$|A| = |B| \Longleftrightarrow \text{OneToOne}(A,B)$$

- With one to one correspondence a speaker can determine if the same cardinality exists between sets. For example the set of yellow dots and the set of non-yellow dots.

One-to-One Plus Correspondence

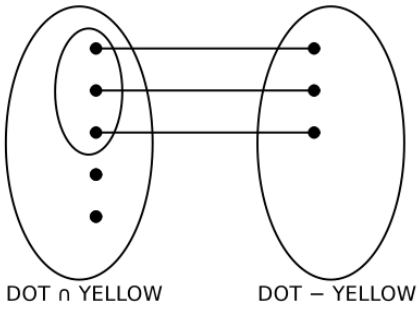
- If there are two sets, A and B, and there is a subset A' that has a one-to-one correspondence with B, then set A must be greater than set B.

One-to-One Plus Contd.

- OneToOnePlus(A,B) $\Leftrightarrow\Rightarrow$ $\exists A'$[OneToOne(A',B) and $A' \subset A$]
- |DOT$\cap$YELLOW| > |DOT$-$YELLOW|

  $\Leftrightarrow\Rightarrow$ $\exists$*A'[OneToOne(A', (DOT$-$YELLOW)) and A' $\subset$(DOT$\cap$YELLOW)]*

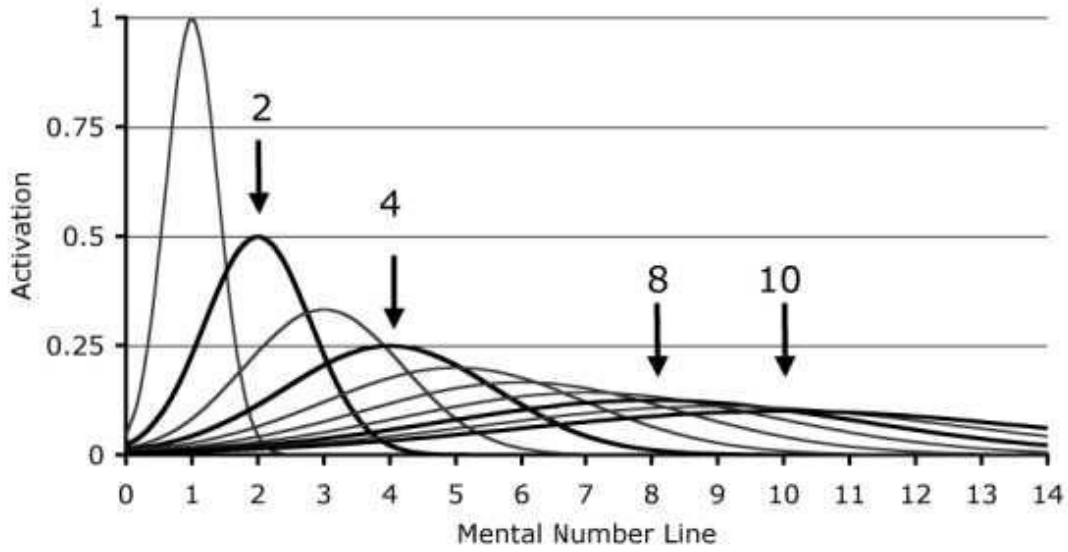
  $\Leftrightarrow\Rightarrow$OneToOnePlus(DOT$\cap$YELLOW,DOT$-$YELLOW)



Verification using the Approximate Number System

- Approximate Number System (ANS)
- Verification **without** cardinality or One-to-One correspondence
- From birth, humans share with many nonverbal animals an **Approximate Number System (ANS) that very quickly (within** 150ms of visual stimulus onset (Nieder and Miller 2004)) generates representations of pluralities in ways that effectively order those pluralities according to cardinality— albeit stochastically, and within certain limits described by Weber's Law
- Weber's Law – you can determine which of the two sets is greater based on the ratio of the cardinalities rather than knowing the specific number

- The closer you are to a 1/1 ratio the more difficult it is to determine which has a greater cardinality
- If you can determine the approximate ratio between the cardinality of two sets, it's not necessary to know the exact cardinality of each set to determine which is greater



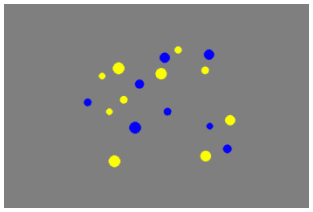
Summary

- Verification theories
  - One-to-One
    - One-to-One Plus
  - Approximate Number System (ANS)

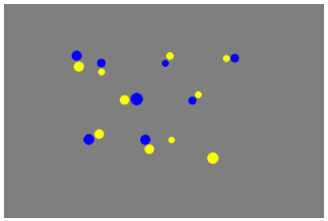
Experiment I

- Experiment Design
  - 200 ms display of dots (yellow and blue)
  - Participants were asked to determine whether the sentence “Most of the dots are yellow” was true or false for each trial
  - Number of dots of each color was between 5 and 17
  - Greater sets were randomized between yellow and blue
  - Each participant received ten trials for three conditions
    - Scattered Random
    - Scattered Pairs
    - Column Pairs
  - Participants were 12 adults with normal vision
  - Participants answered true or false by pushing buttons on a keyboard

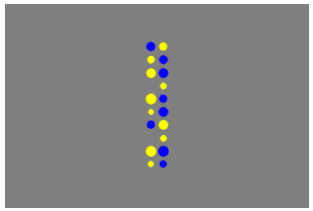
- Scattered Random



- Scattered Pairs



- Column Pairs



Predictions

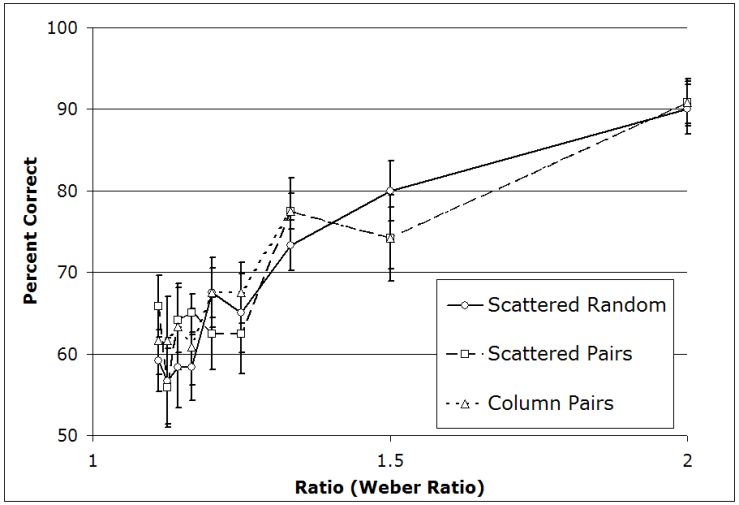
- The 200ms display time does not permit verification procedures based on explicit counting, ruling out direct cardinality-based
- Participants might use One-to-One correspondence
  - This will be more effected by dot layout. More accurate on scattered pairs or column pairs. But the ratio should have nothing to do with it
- Participants might use (ANS)
  - Responses would be more affected by ratio and not the dot layout.
- Participants might switch processes based on each individual trial. The trials that have easier layouts/ratios would allow for more accurate judgments
- These predictions rely on the assumption that it is possible to determine One-to-One correspondence in such a short period of time; a previous experiment showed that the amount of time was sufficient (Halberda et al 2007).

Results

- Significant effect of ratio. Participants did better with easier ratios and have no significant effect of condition or trial type
- Participants relied on the number of dots rather than other factors
- Ratio effects judgment the most
- Supports the hypothesis based on ANS
- Scattered pairs and column pairs where One-to-One procedures seem to be more logical, ANS procedures were still used

More Results

- Chart shows that individuals stuck to ANS to determine cardinality even though for Scattered Pairs and Column Pairs One-to-One correspondence would have been more effective.
- Going back to the Big Picture Question, this supports the idea that there is something about the semantics of the words that is forcing individuals to stick to one procedure despite how effective it is, rather than allowing the logical/pragmatic systems in the brain to choose which is the best method depending on which stimuli being presented.



Even More Results

- The results of Experiment 1 support that regardless of the type of stimuli, the brain defaults to ANS even if a more logical/effective operation could be used
  - Ex. Column Pairs and One-to-One correspondence.
- Goes back to the Big Picture Question, this supports the idea that there is something about the semantics of the words that is forcing individuals to stick to one procedure despite how effective it is rather than allowing the logical/pragmatic systems in the brain to choose which is the best method depending on which stimuli being presented.

More on ANS

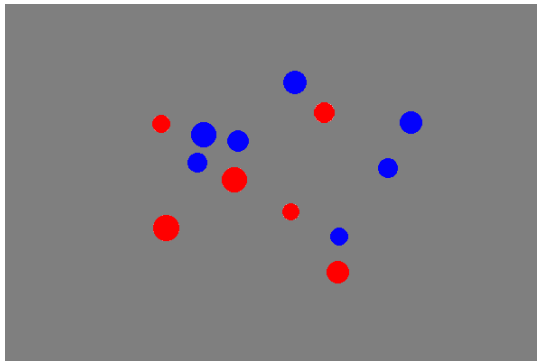
- **Subtraction Procedure**
  - To determine the entire set and then determine the subset that equals to yellow dots. By subtracting those you figure out the remainder of non-yellow dots
    - Superset of All Dots – Set of Yellow Dots = Set of Non-Yellow Dots
  - Possible no matter how many non-yellow colors are present because you only have to figure out two different sets
- **Selection Procedure**
  - To determine each of the non-yellow color sets and then add them together
  - Possible only when there is one non-yellow color because if there are more sets to attend to it becomes confusing for the participant
    - Non-Yellow Color Set 1 + Non-Yellow Color Set 2 + Non-Yellow Color Set 3 = Total Non-Yellow Colors

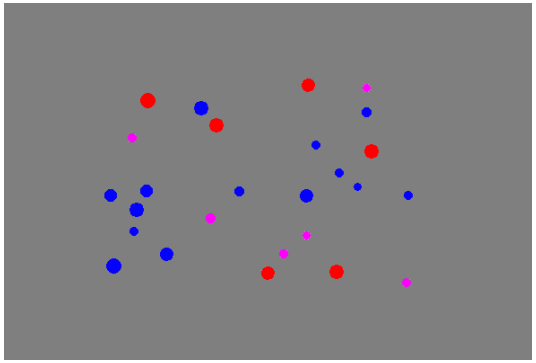
Predictions of Subtraction vs. Selection

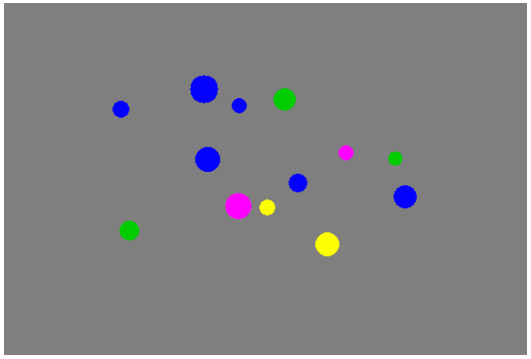
Number of colours present	2	3	4	5
Subtraction Procedure	good	good	good	good
Selection Procedure	better	impossible	impossible	impossible

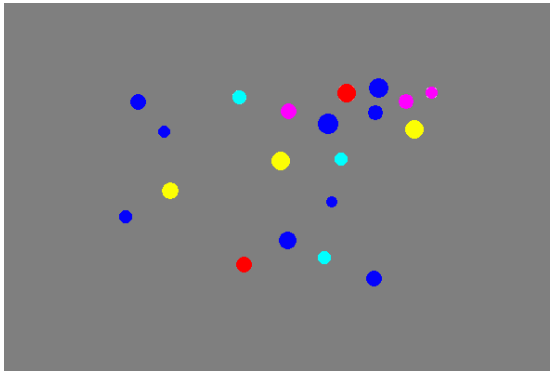
Experiment II

- Experiment Design
  - Participants saw a 150ms display containing dots of at least two colors and at most five colors
  - Yellow dots present on every trial
  - Participants asked to judge the truth value of "Most of the dots are yellow"
  - Number of yellow dots and the number of non-yellow dots was between 5 and 17
  - Larger yellow sets versus larger non-yellow sets were randomized
  - Participants answered true or false by pushing buttons on a keyboard
  - 15 trials in each ratio bin for each of the 4 conditions
  - Half of the trials were area controlled
    - Pixel space of the yellow dots wasn't greater than the non-yellow dots
  - Half were size controlled
    - The average size of the yellow dot was equal to the size of the non-yellow dots.









Predictions

- **3 Hypotheses**
  - 1. Use subtraction procedure on all trials. Response should be unaffected by the number of colors. It doesn't matter how many colors there are
  - 2. Selection procedure on all. If there are more than two colors, the accuracy should fall drastically
  - 3. Switch depending on individual trial. The accuracy on two colors should be the best but the accuracy of more than two colors while not as good, should never fall to chance levels (50% accuracy)

Results

- Results favor the first hypothesis in which they used subtraction on all trials.
- If they had used selection procedure for the two color trials it should have been more accurate.
- Participants did not switch based on each individual trial which would have theoretically been more accurate
- Like in the last experiment participants approximated the cardinality indirectly rather than using a more direct method

More Results

- After identifying in Experiment 1 that an individual will default to ANS, Experiment 2 refines the previous experiment by showing in more detail how humans use ANS
- Subtraction method is utilized versus the Selection method.
- Back to the Big Picture:
  - Even though the Selection method would be more accurate on trials with two colors present, and the Subtraction method would be more accurate in all other cases, individuals stuck with the Subtraction Method.
  - Again, this shows that there must be something in the semantics of the words that is causing this to occur, rather than allowing an individual's Logical/Pragmatic Systems to take over and seek out the most accurate procedure.

Conclusion

- Even when the circumstances would have dictated one method over another as the most effective the results showed that one method seems to be prescribed in the semantics.
- This shows that there are underlying process o semantics that dictate other processes in the brain.
- If semantics left all the verification work to the Logical/Pragmatic Systems of the brain, the participants would have probably chosen the method based on effectiveness rather than continually defaulting to one method, ANS-Subtraction.