

# FOUR PRINCIPLES OF COGNITIVE SCIENCE IN EDUCATION

SELF-GENERATION,  
ERRORS,  
FEEDBACK  
&  
REGION OF PROXIMAL LEARNING

Janet Metcalfe  
and the Group at Columbia University



especially Lisa Son, Bridgid Finn and Nate Kornell

MS 143 & the  
Columbia Metacognition Project



Thanks go to  
IES and to  
NIMH for  
sponsoring  
this research.

THE GOAL OF THIS PROJECT IS TO USE PRINCIPLES OF COGNITIVE SCIENCE TO DEVELOP A PROGRAM THAT CAN BE BROADLY USED TO HELP STUDENTS STUDY.

Why do they need it?

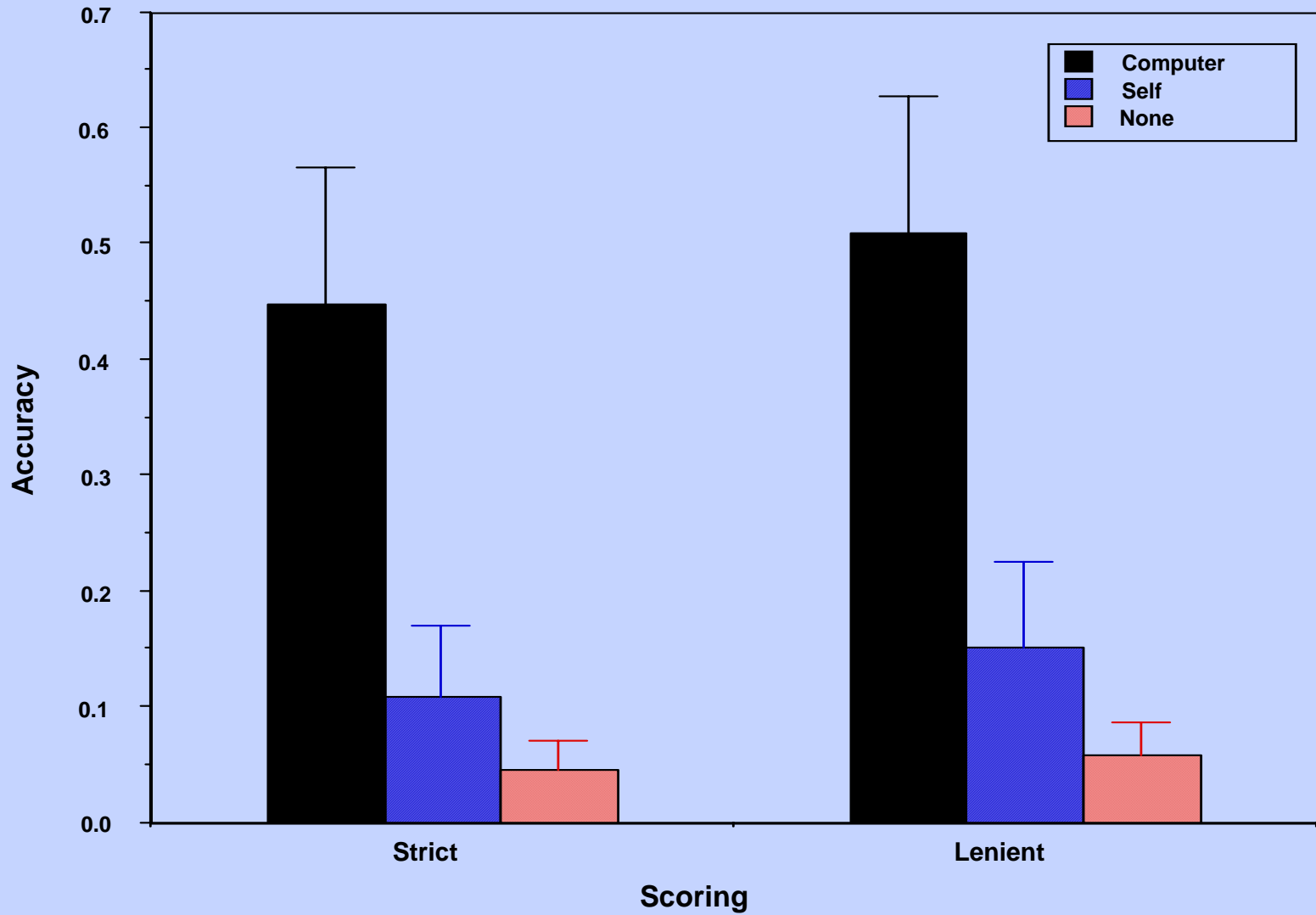
(1) self study is vulnerable to metacognitive illusions

(2) certain effective strategies are difficult to implement on one's own

## BACKGROUND

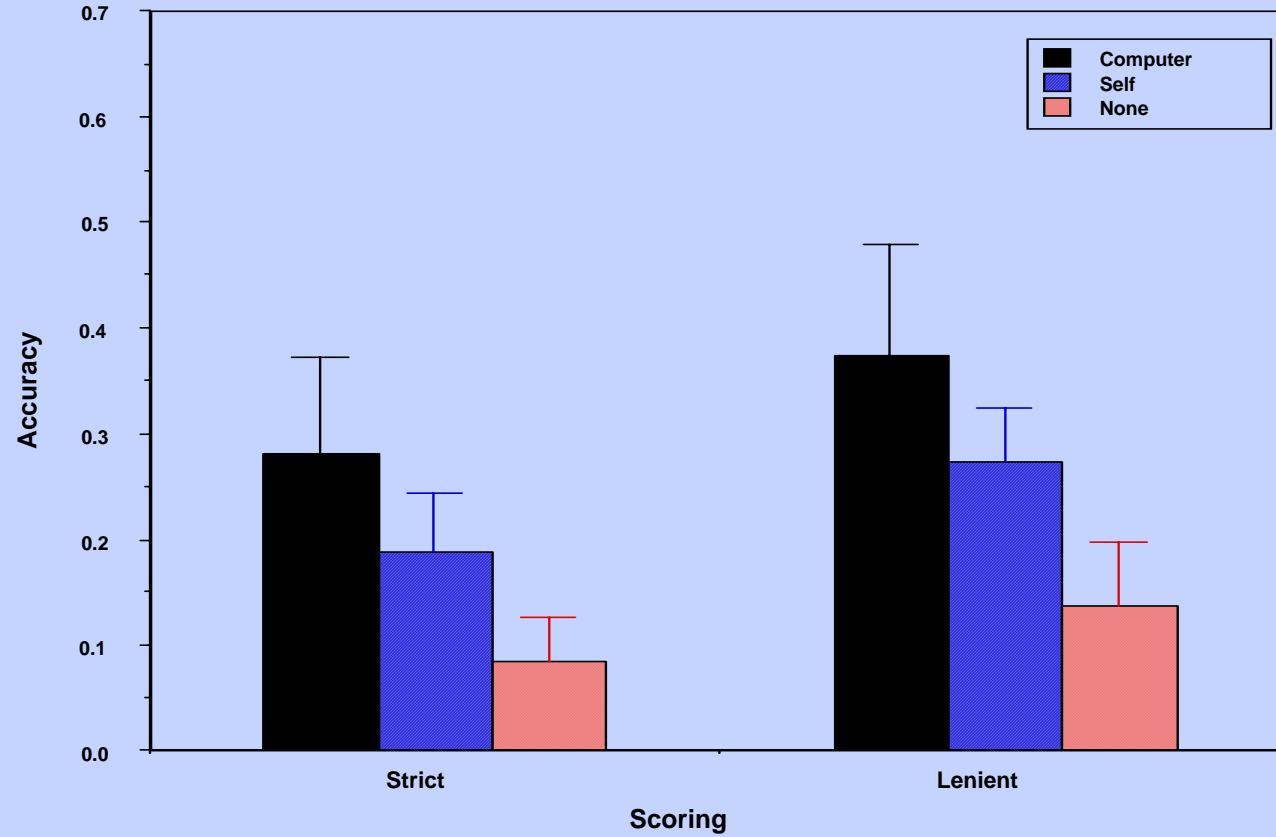
We conducted a 7-week computer-based study program in which the children learned vocabulary words, either those needed for state tests, for their classes, or Spanish-English translations for children learning English.

### Accuracy - Advanced English Vocabulary (English-Speaking Children)



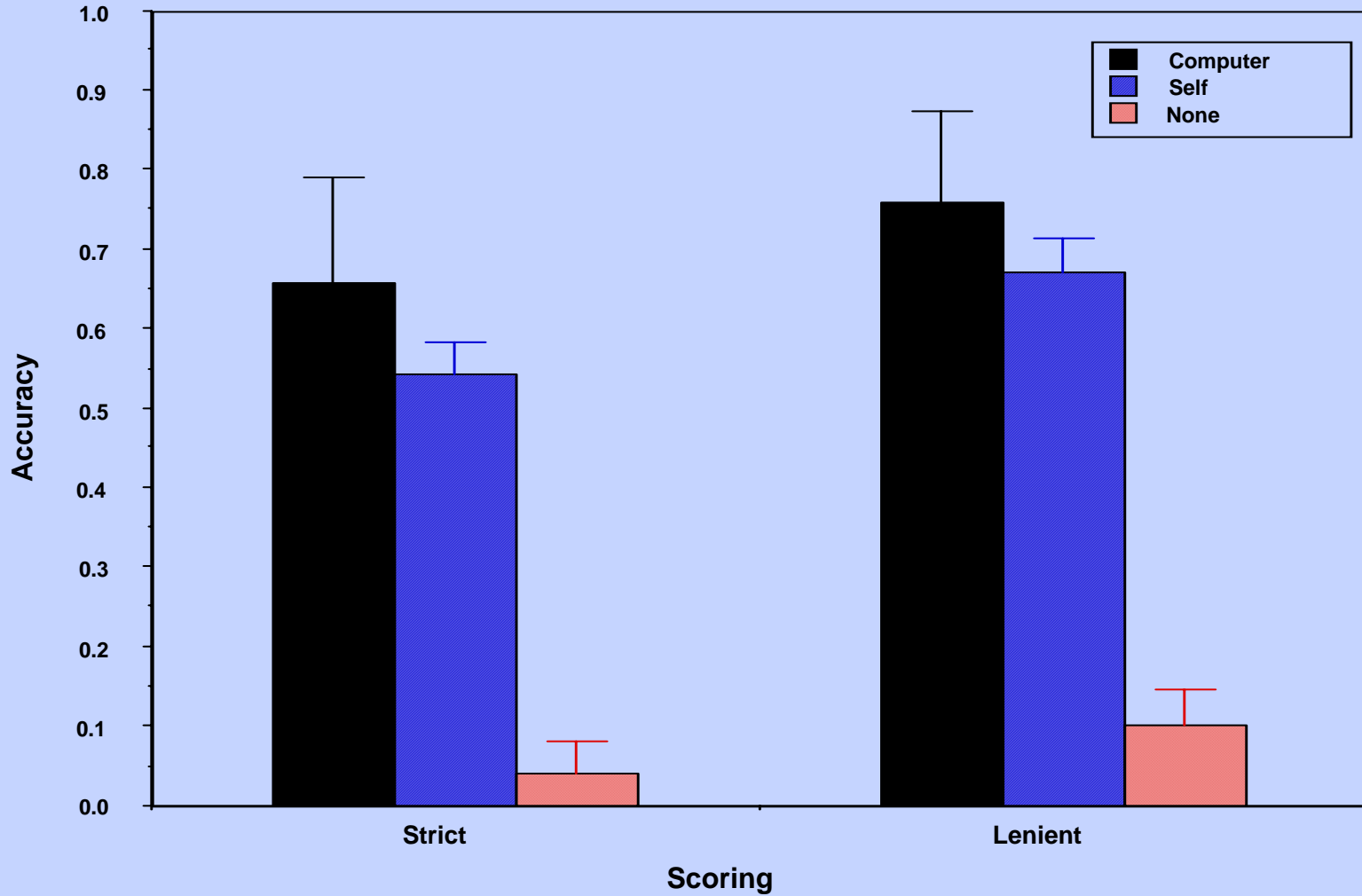
Spanish speaking children learning English vocabulary

Accuracy - Basic English Vocabulary  
(Spanish-Speaking Children)



Even Columbia students showed substantial gains,  
though not as high as the at-risk children.

**Accuracy - Basic Spanish Vocabulary  
(English Speaking CU Students)**



THIS PRESENT RESEARCH ATTEMPTS TO ISOLATE THE COMPONENTS IN THE ORIGINAL TASK.

Does generating help under these real-world conditions?

Does making errors hurt?

How important is feedback?

What is the role of metacognition and choice in determining a Region of Proximal Learning?

# SELF GENERATION

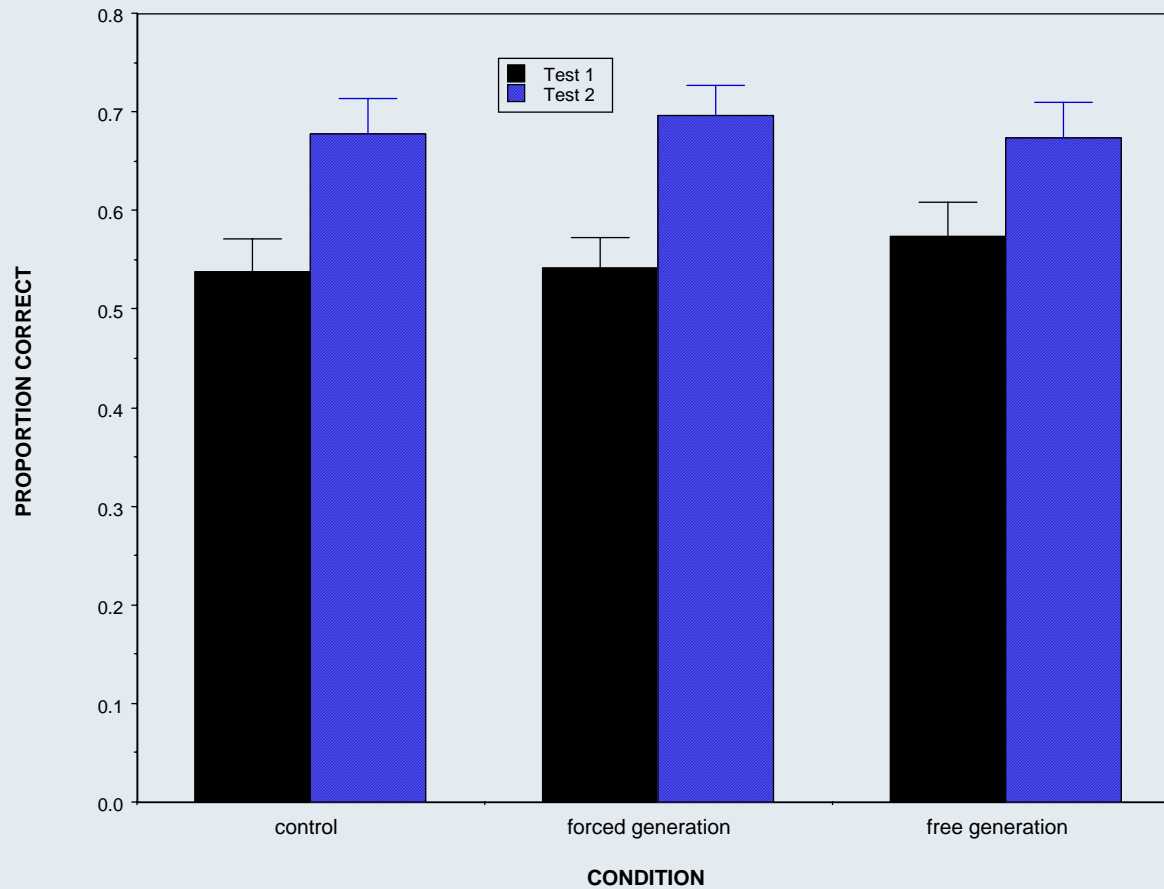
To our surprise, we, several times, failed to find beneficial effects of self generation. As we'll see, the reason was that it is relatively easy to get children to generate the answers (even when they're in the so-called control condition).

16 kids each participated for 4 sessions in the Bronx. Similar studies were run at Columbia.

Conditions were forced generation, free generation or presentation-only control.

Feedback (i.e., the correct answer) was given immediately after the response.

With Columbia students, like the Bronx kids: no generation effect.



# WHY???

1. WE GAVE THE CUE FIRST ALONE WITH A 1 SECOND PAUSE WHICH ALLOWED PEOPLE TO GENERATE EVEN IN THE READ CONDITION.
2. THE GENERATE AND READ ITEMS WERE MIXED WITHIN LIST

If we alter the conditions so people do not generate in the 'read' condition, we get a generation effect.

## Method:

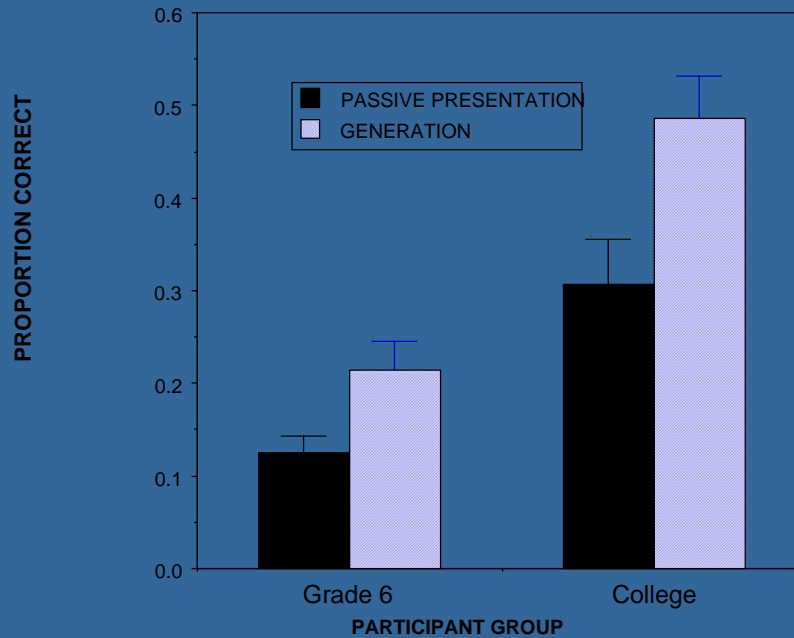
Grade 6 children participated for 2 sessions each, Columbia students for one.

The stimuli were 90 synonyms (e.g., agree- concur) for the Bronx kids or GRE words for the Columbia students.

GENERATE AND READ WERE NOW BETWEEN LIST,

AND THE CUE AND TARGET WERE PRESENTED  
TOGETHER.

# THIS PRODUCED A LARGE GENERATE EFFECT



# PEDAGOGICAL IMPLICATIONS

SELF-GENERATION OF ANSWERS PRODUCES  
LARGE LEARNING BENEFITS.

IN A CLASSROOM SITUATION, WHERE ONE CAN'T HAVE EVERY STUDENT GENERATE ALL THE TIME, ONE CAN GET GENERATION BENEFITS BY

(1) LEAVING A PAUSE BEFORE GIVING THE ANSWER

AND

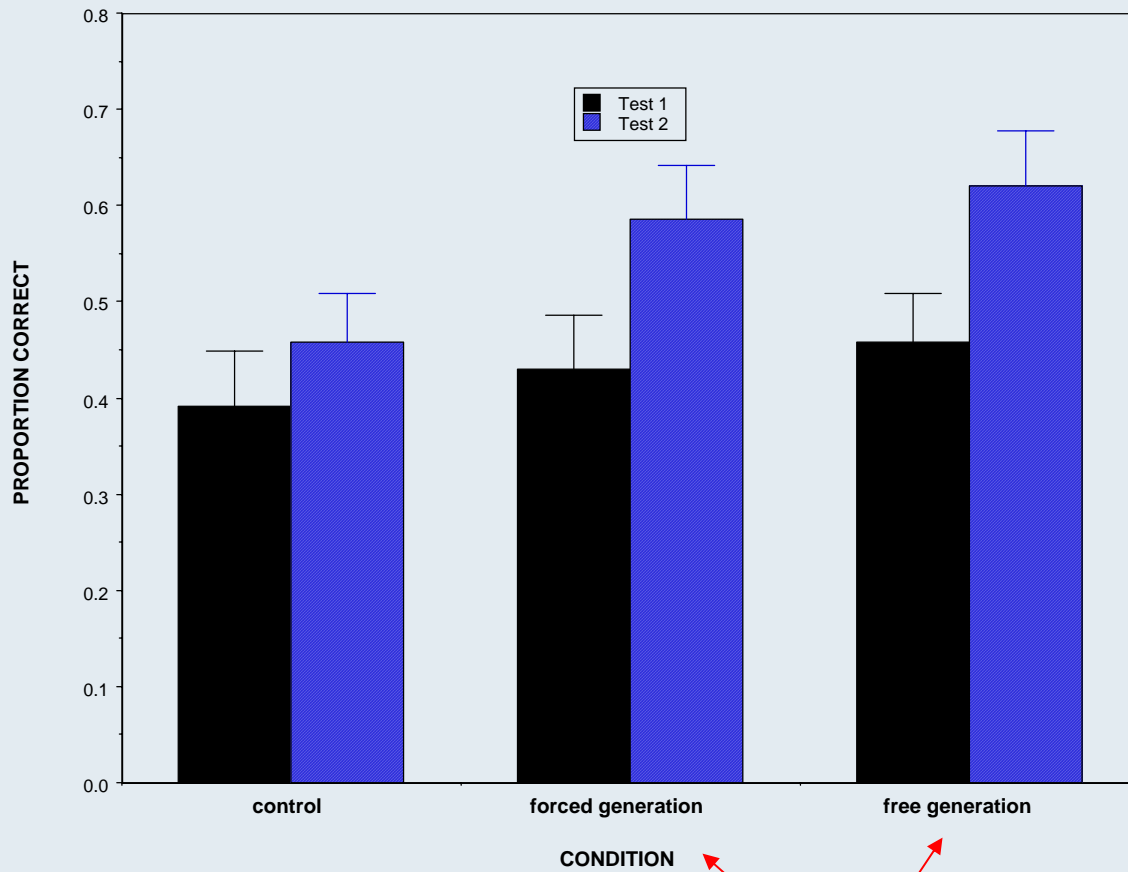
(2) MIXING IN QUESTIONS TO INDIVIDUAL STUDENTS, WHO MUST THEN GENERATE THE ANSWERS THEMSELVES, FROM TIME TO TIME.



# ERRORS

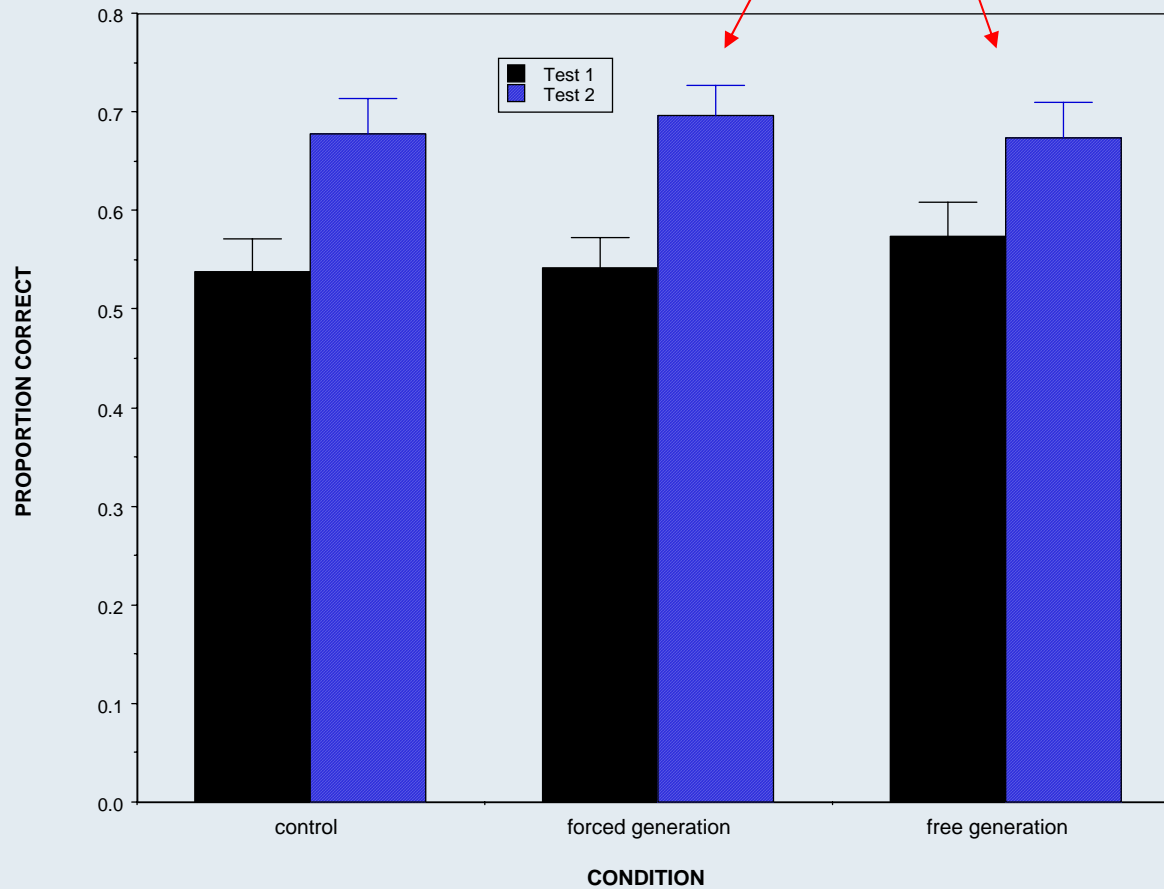
We observed no effect of whether we **forced** people to generate an answer (which resulted in a huge number of errors) or whether we allowed them to generate only if they felt confident in their answers (which resulted in few errors).

**REVIEW OF THE EXPERIMENTS:**

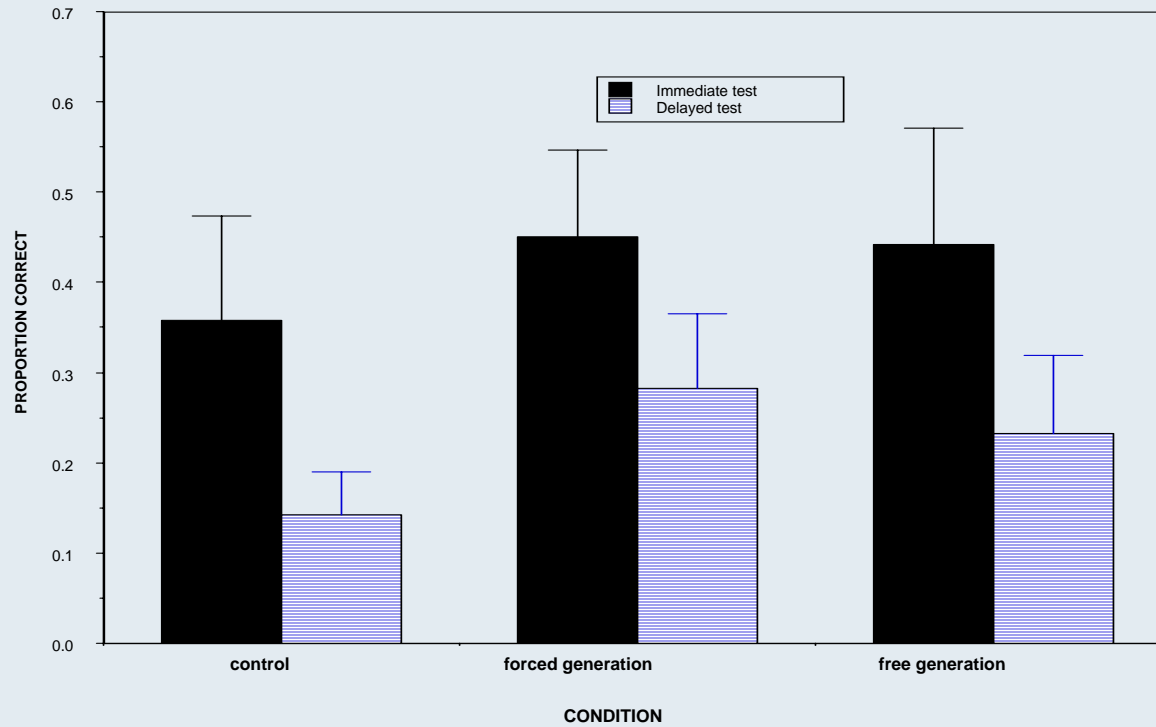


**NO EFFECT OF ERRORS  
BRONX 6TH GRADE**

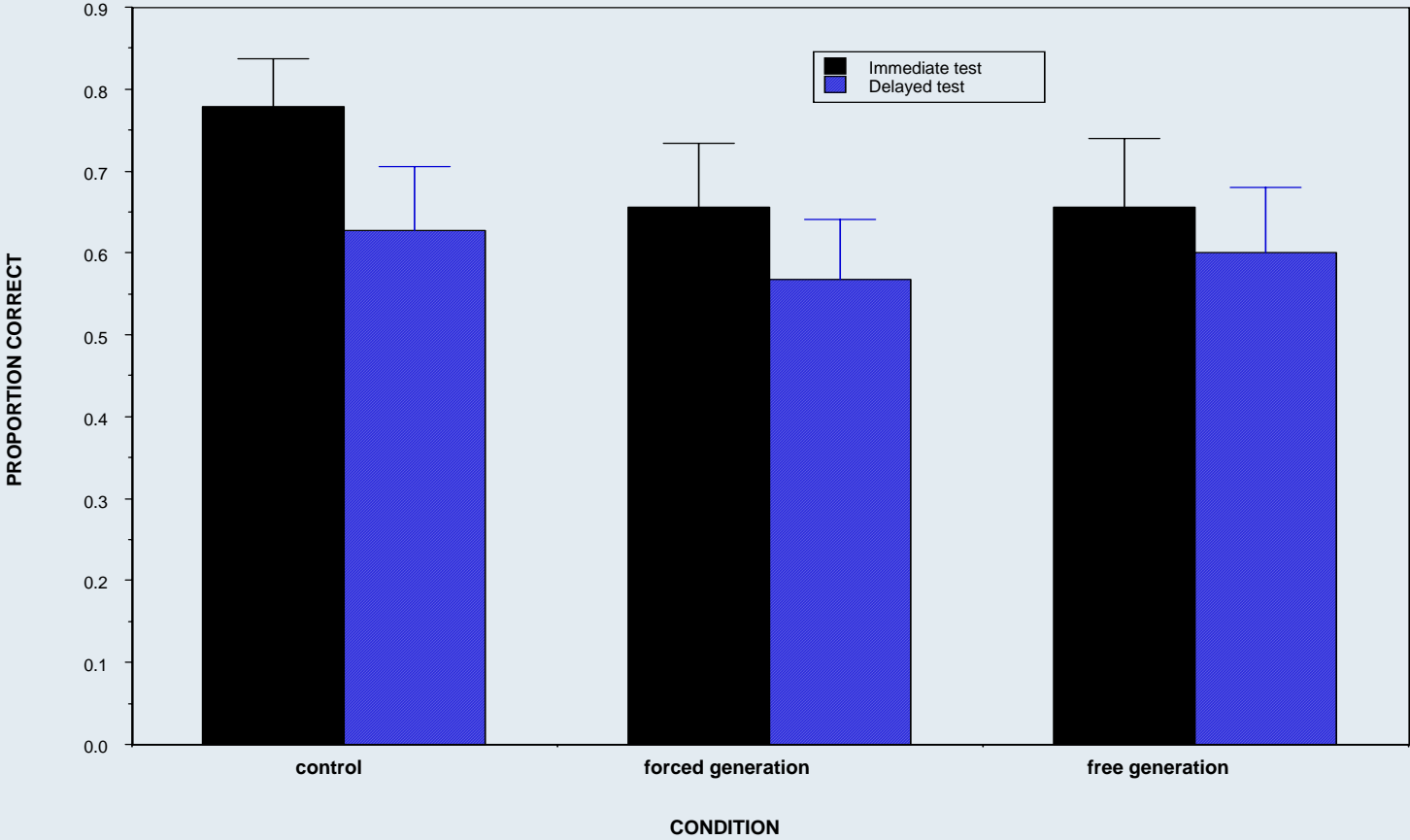
# AGAIN, NO EFFECT OF MAKING ERRORS, COLUMBIA STUDENTS



# Bronx SIXTH GRADE AGAIN NO EFFECT OF ERRORS



# Columbia students: NO EFFECT OF ERRORS



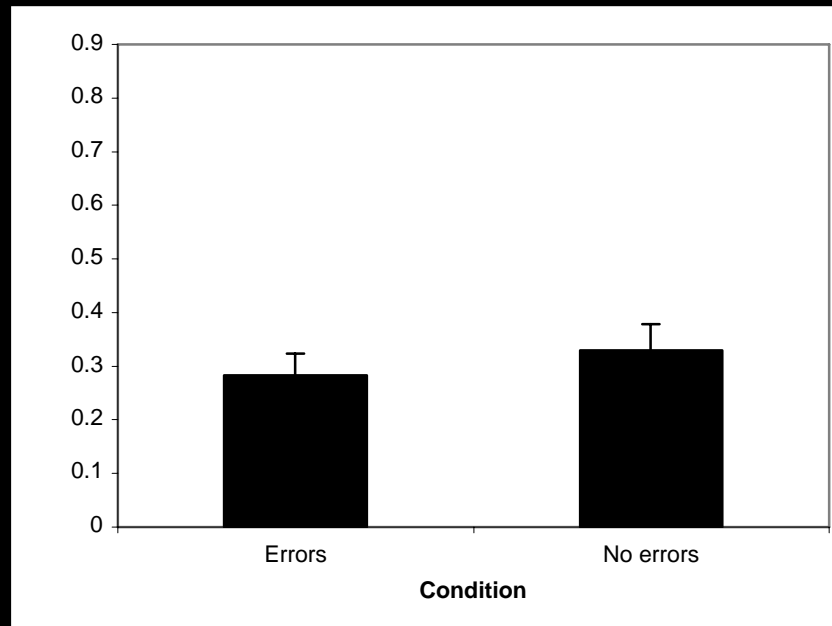
However, it seems like committing an error **should** be problematic.

So we ran two more experiments directed at errors specifically.

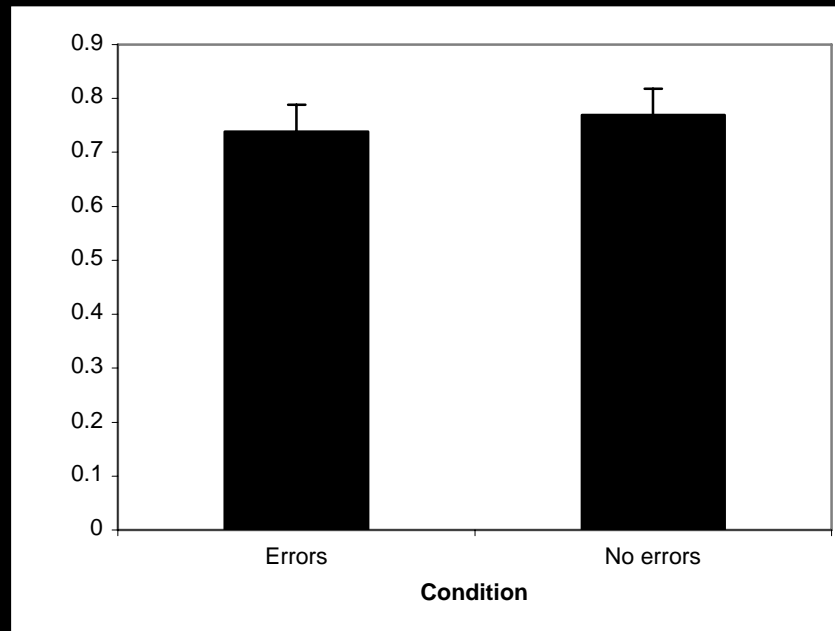
## Bronx

Children were either forced to generate--producing many errors or told to generate, but not to guess, producing few, in a between list design.

They were given immediate feedback. **Errors made no difference.**



# Columbia



The same experiment was run with more difficult materials. **Again, there was no effect.**

# PEDAGOGICAL IMPLICATIONS

We have no evidence to support the contention that making errors is harmful, **as long as corrective feedback is given**, even though we have now sought such evidence 6 times.

There is no advantage to not answering and not making an overt mistake, as long as feedback is given.

Indeed, getting students to answer , even when they make a mistake, increases their involvement--they can't be passive--and does no harm as long as the correct answer is given.



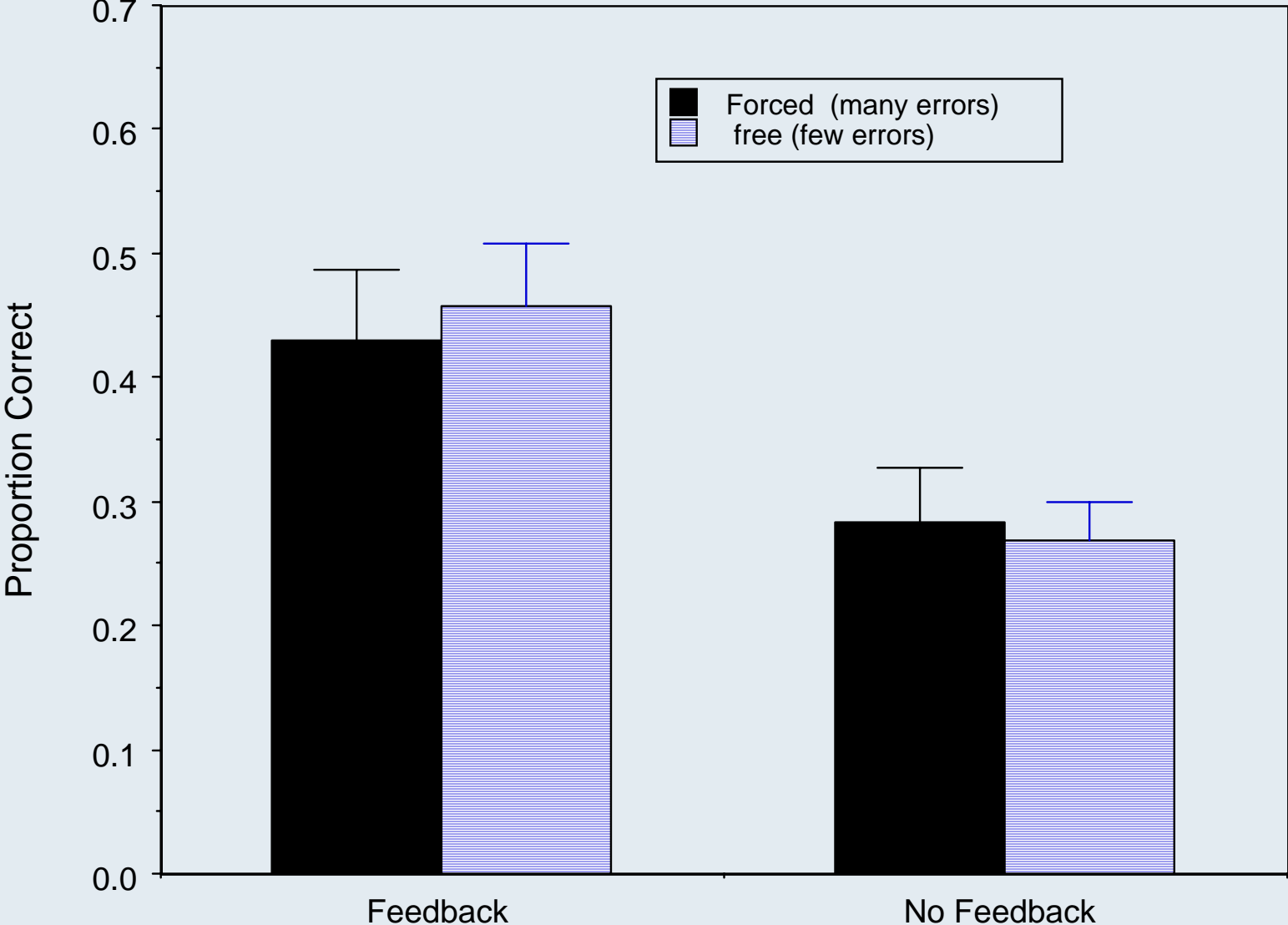
FEEDBACK

So far, I have shown results only when feedback was given.

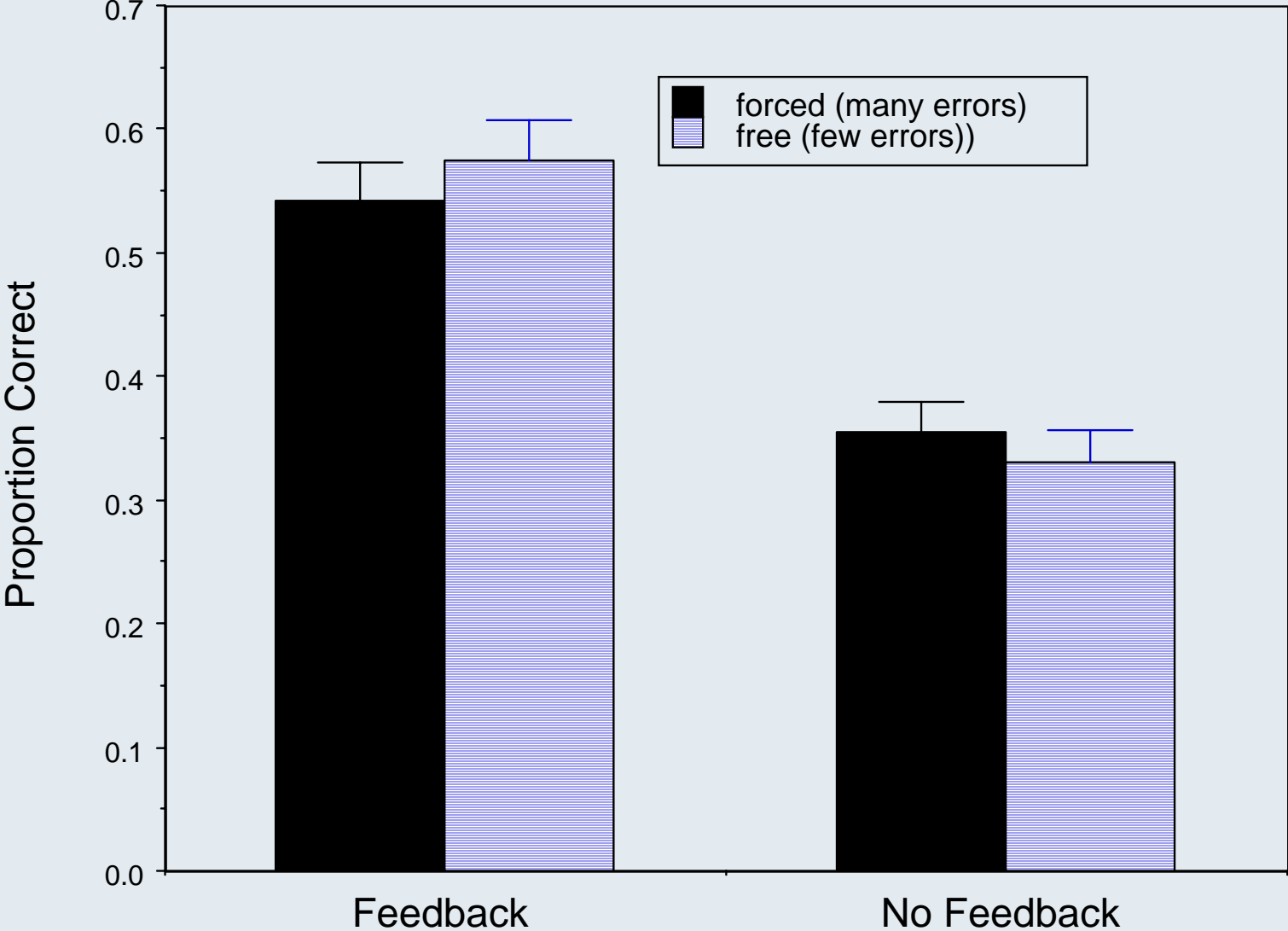
But, in the studies discussed earlier, we also had **no feedback** conditions (with both forced and free generation).

IN EVERY CASE, FEEDBACK HELPED.

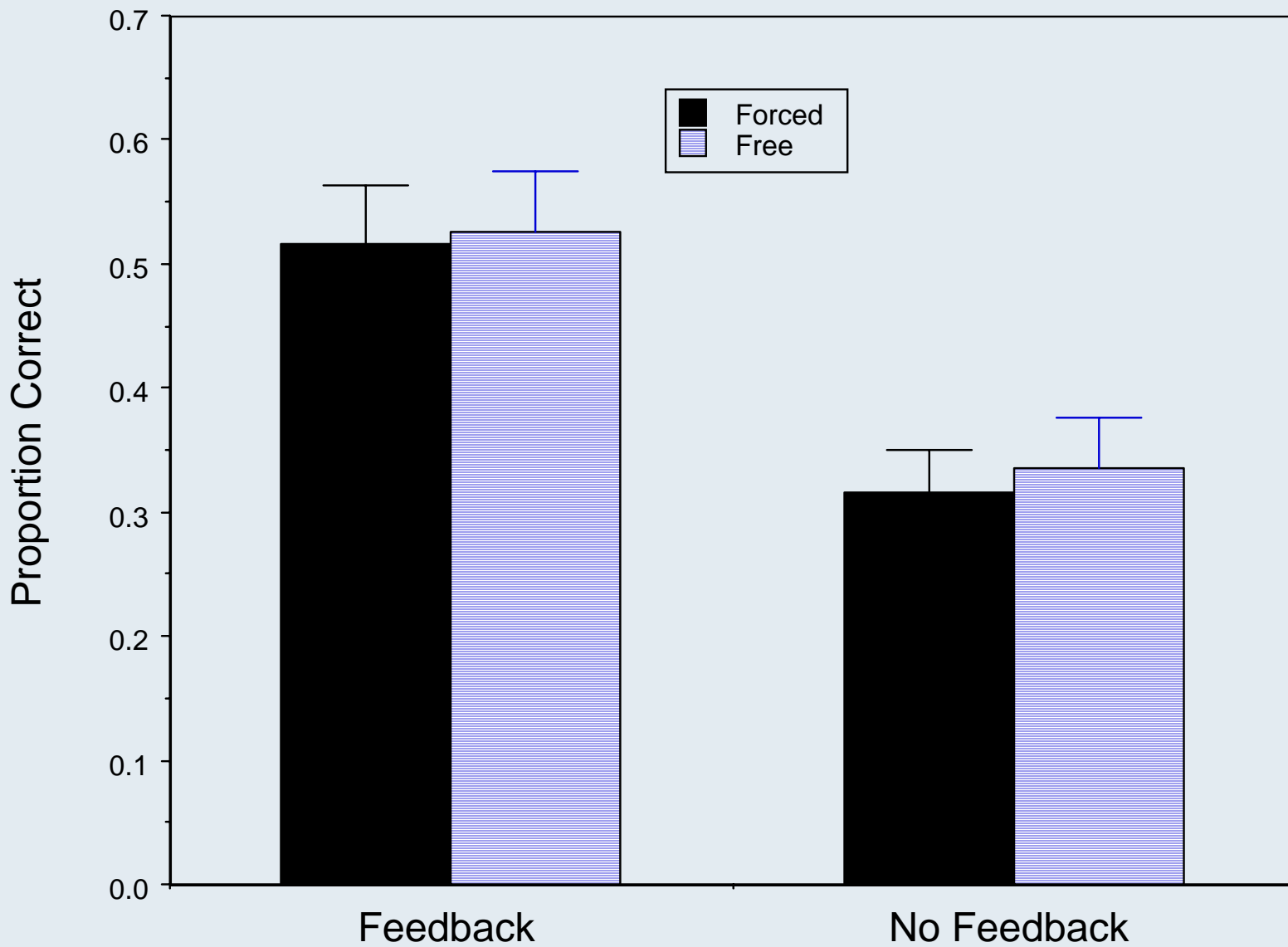
Data from Bronx students



Data from Columbia Students



Data from Columbia, Experiment 2



In all three experiments, the effects of initial feedback also held up in the second test, despite the fact that there was an additional learning trial, in which everything was presented, between the first and second test.

In the final feedback experiment we investigated the issue of how important it is to give immediate, as compared to delayed, feedback.

There were five conditions:

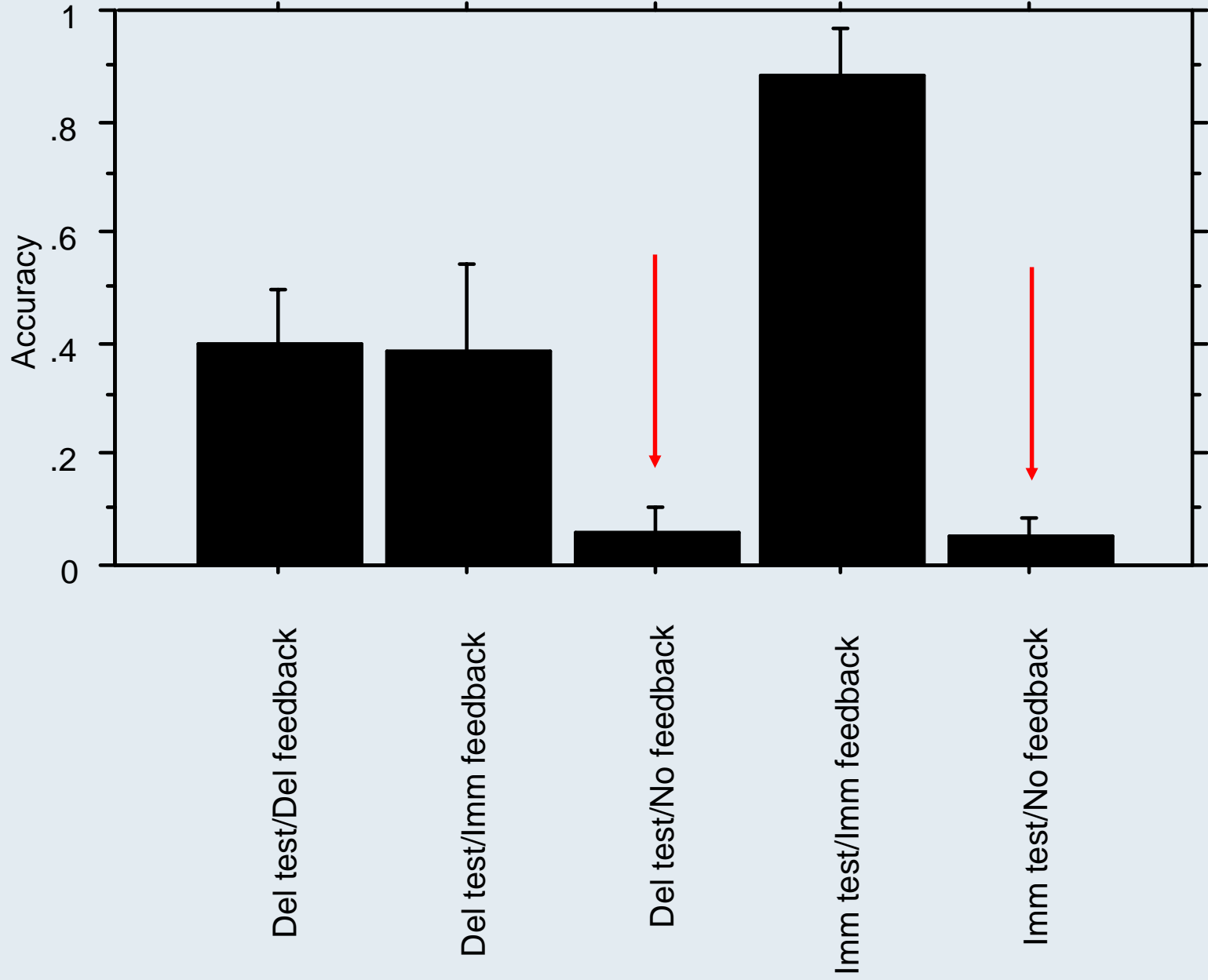
Immediate feedback      immediate test

No feedback              immediate test

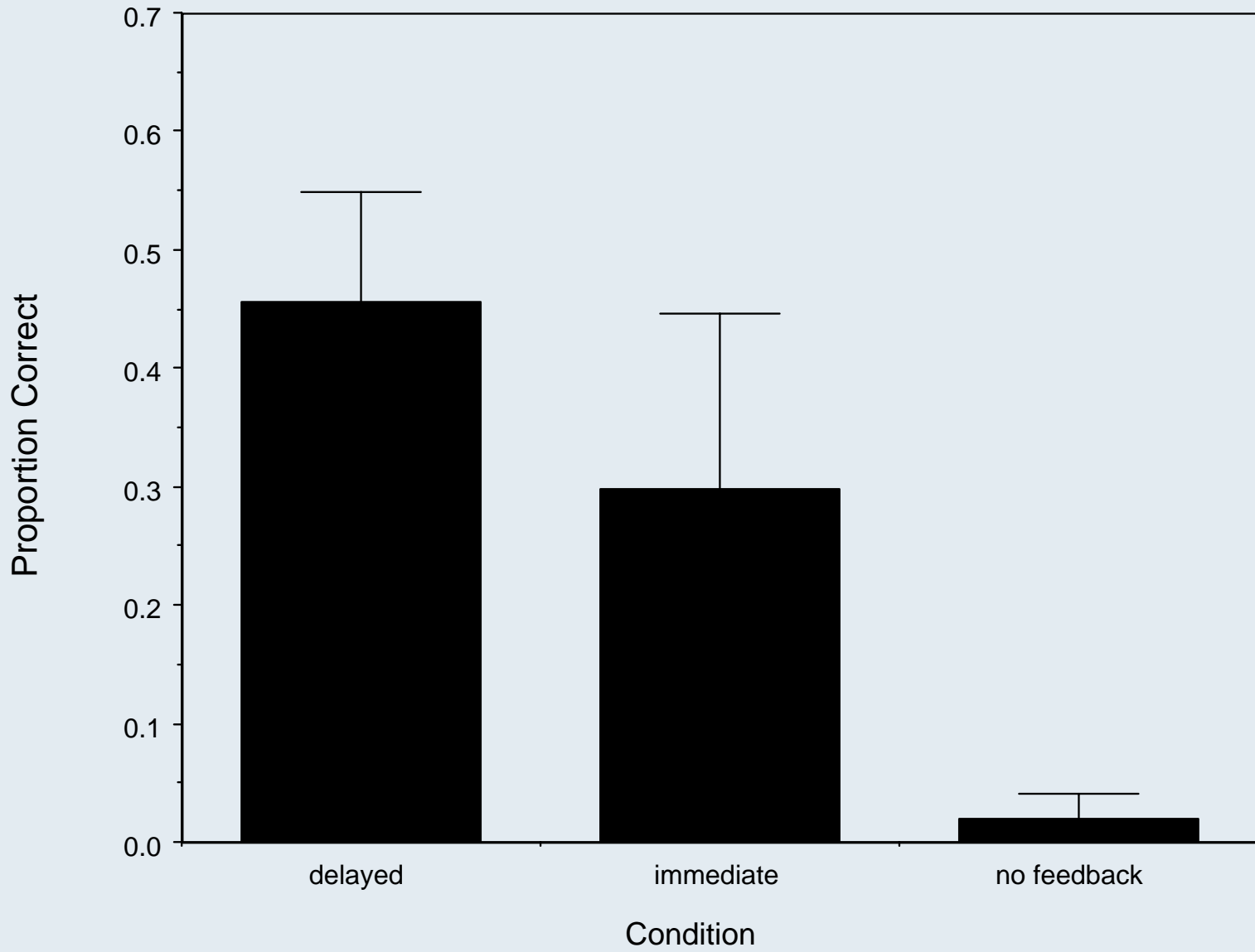
Immediate feedback      delayed test

Delayed feedback        delayed test

No feedback              delayed test



The design of this experiment allowed us to look at the effect of immediate versus delayed feedback, holding constant feedback lag to test (by only using the middle sessions).



# PEDAGOGICAL IMPLICATIONS

We DO need to give feedback, and good feedback that is very specific and that the person fully learns and understands.

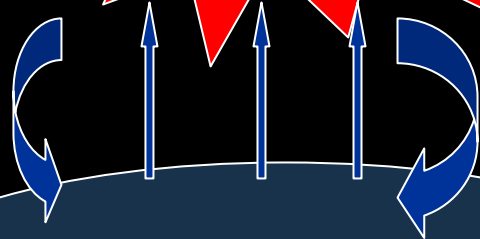
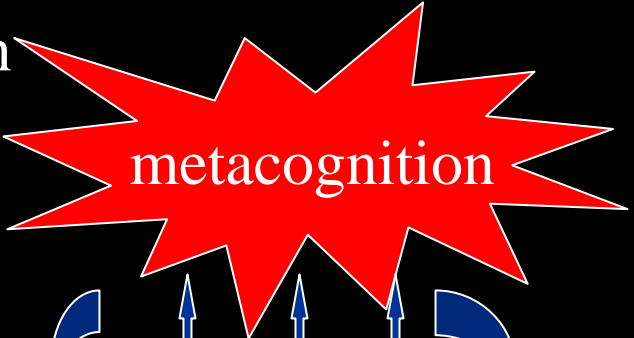
BUT, we may not have to give that feedback immediately.



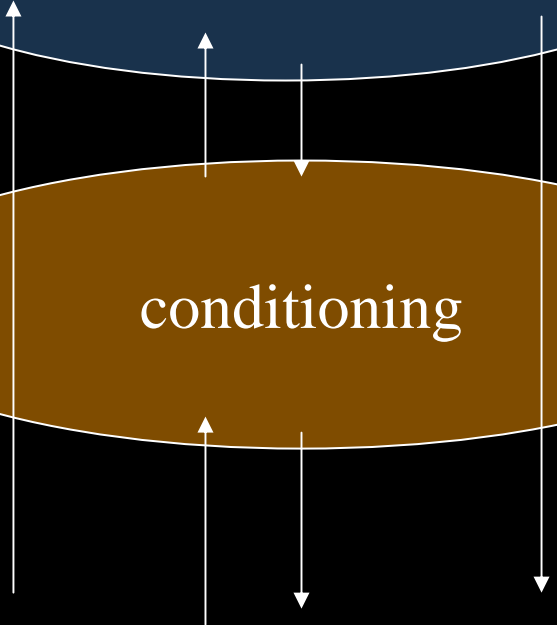
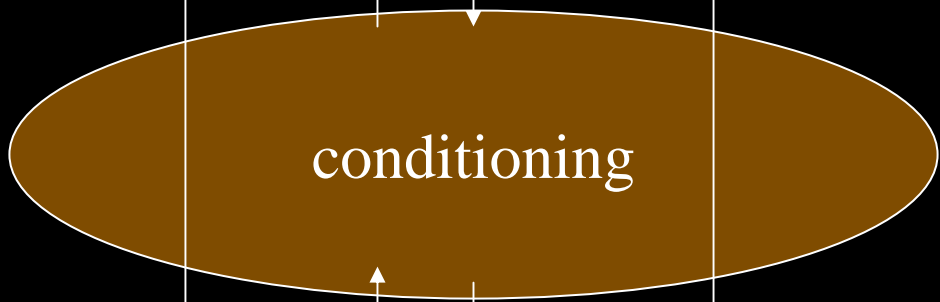
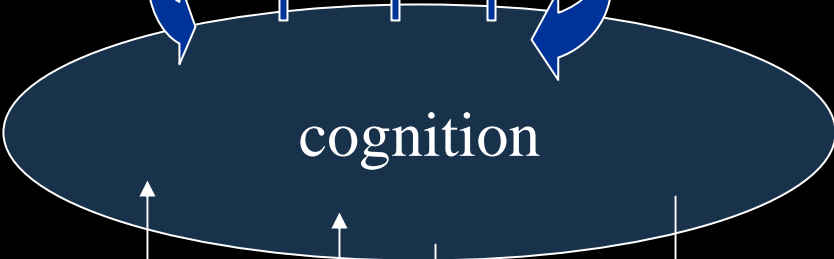
# METACOGNITION

Metacognition entails knowing about our cognitions, including our memories and our learning.

The reflection on  
the question



The question  
itself



Judgments of Learning (JOLs) are a metacognitive assessment and they usually correlate well with later performance.

Although people can do these metacognitive tasks with great facility and considerable accuracy, there has been little evidence, until recently, that they are causal in determining study behavior, and, more to the point, that they are efficacious.

Remember Cassandra





The question we, therefore, address is:  
Do people use their metacognitions to **control**  
their learning in an effective way?

Let us first ask, what is the relation between metacognition and study choice and study time allocation.

We will then turn to whether this is an effective choice.

The literature, until recently, supported the idea that people selectively study the most difficult items, resulting in a negative correlation between Judgments of Learning (JOLs) and study choice or time allocation.

This led to the

## Discrepancy-Reduction Model of Study-Time Allocation

which says that people allocate the most study time to items that they know least: i.e, low JOL's are associated with long study times.

BUT

What about the labor in vain effect?

And, what about



Piaget

Atkinson

Berlyne

Hebb

Vygotsky

For these two reasons, we entertain a

**Region of Proximal Learning Model**

The earlier studies were all conducted in a paradigm in which one item was given at a time, and there were no time limits or tradeoffs.

The materials were nearly always easy.

We put time constraints on the learner, and used a range of difficulty and found data supporting a

**Region of Proximal Learning**

family

tragedy

kneecap

?

?

?

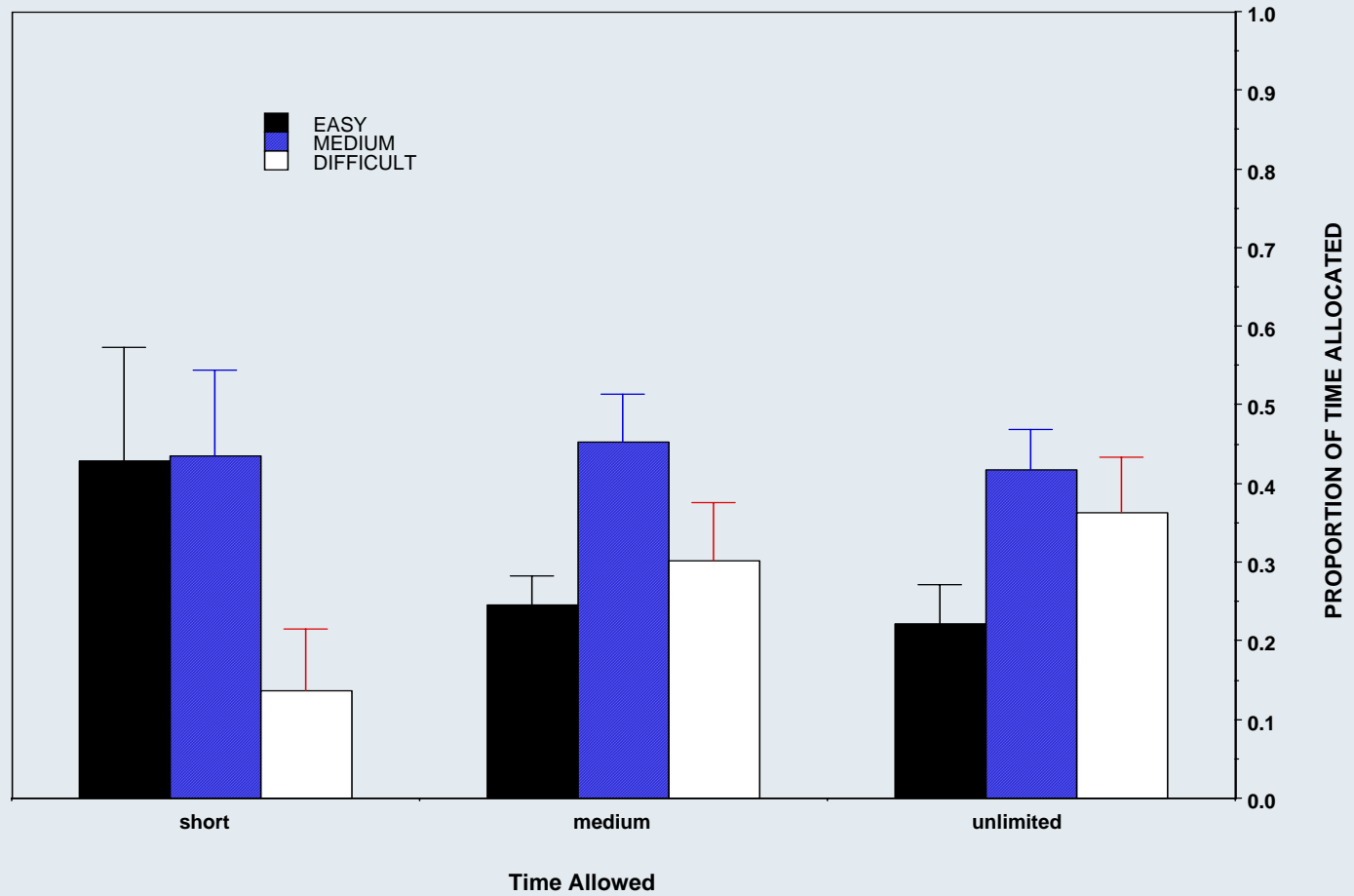
familia

desgracia

choquezuela

Metcalf, JEP:Gen, 2002

B

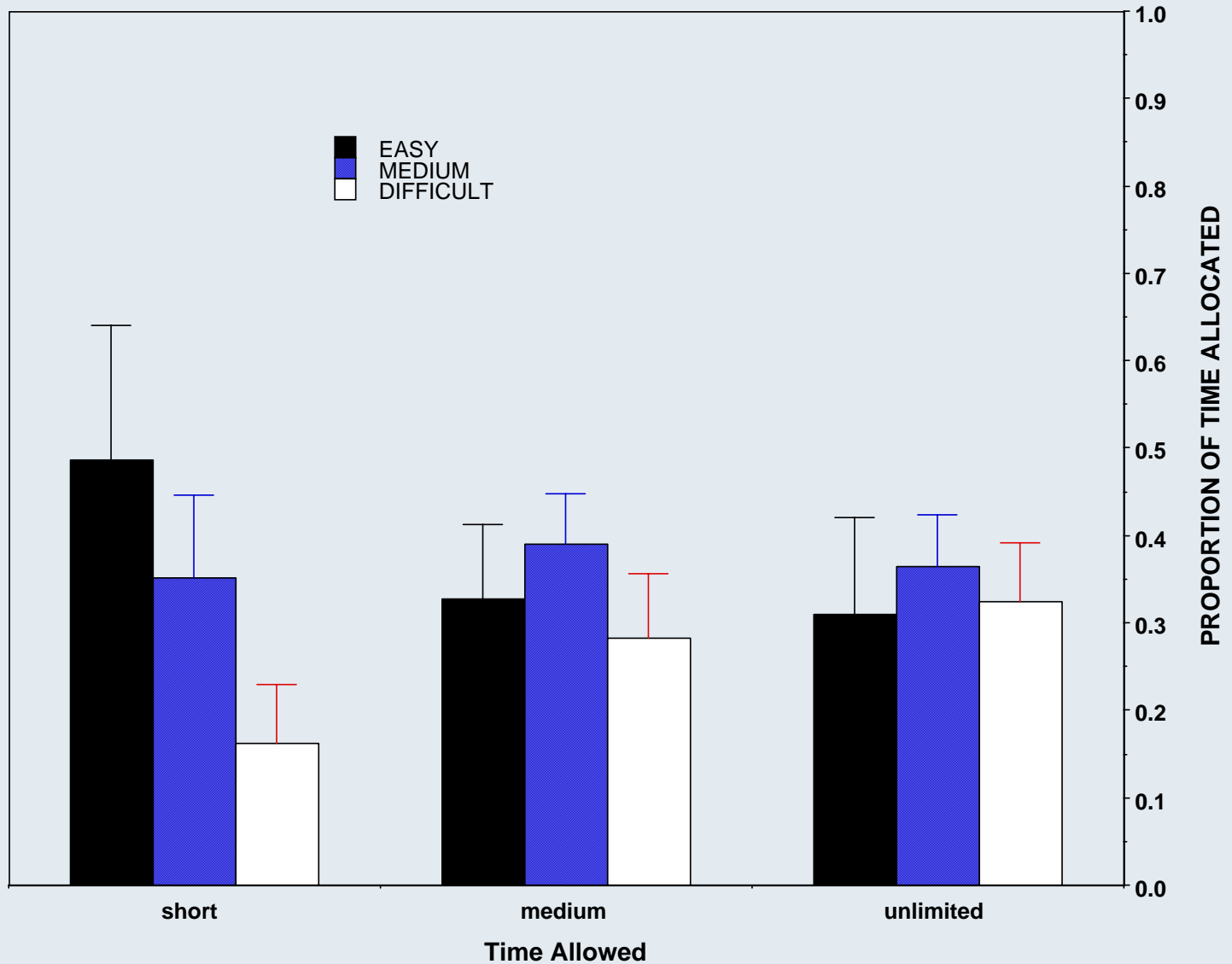


Kids do basically the same thing

# Kids' time allocation (a bit more towards the easy items than adults)

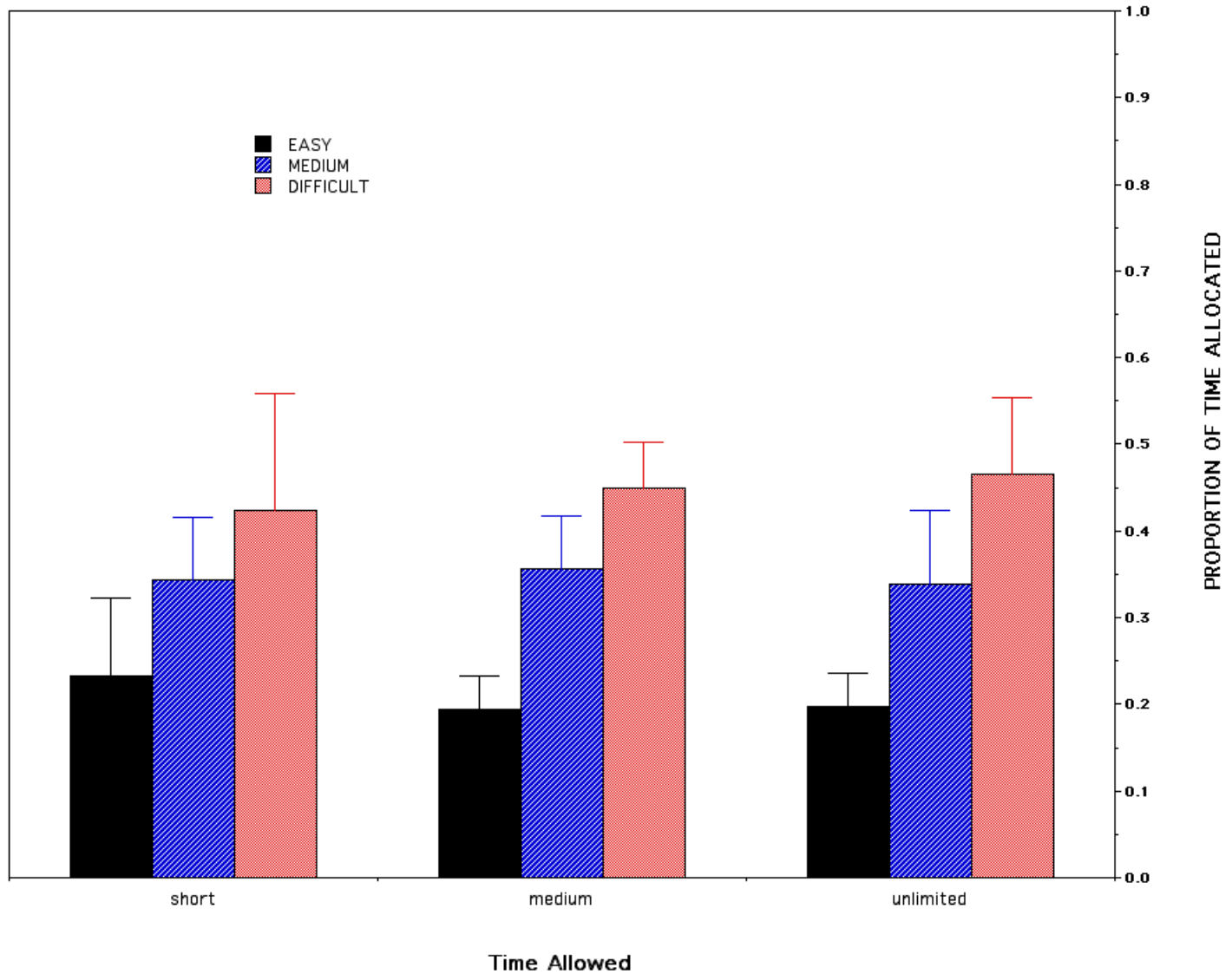
FIGURE 3, RIGHT PANEL

B



Experts, whose Region of Proximal Learning should be towards the more difficult items (since they already know the easy items) shift their study time allocation in that direction.

# Experts



# How do people allocate study time according to RPL?

- 1) They first try to eliminate those items that they know they know.
- 2) Among those items that they do not know, they attempt to study in the order easiest to most difficult.
- 3) They stop studying an individual item when their  $j$ ROL, that is, their perceived **rate** of learning approaches zero.

BUT, is this efficacious?

To investigate Nate Kornell and I have been using a paradigm in which we ask people to choose which items they want to study (or restudy), and then we either honor or dishonor their choices.

With general information questions,  
they declined study on those items  
they knew already, consistent with  
RPL.

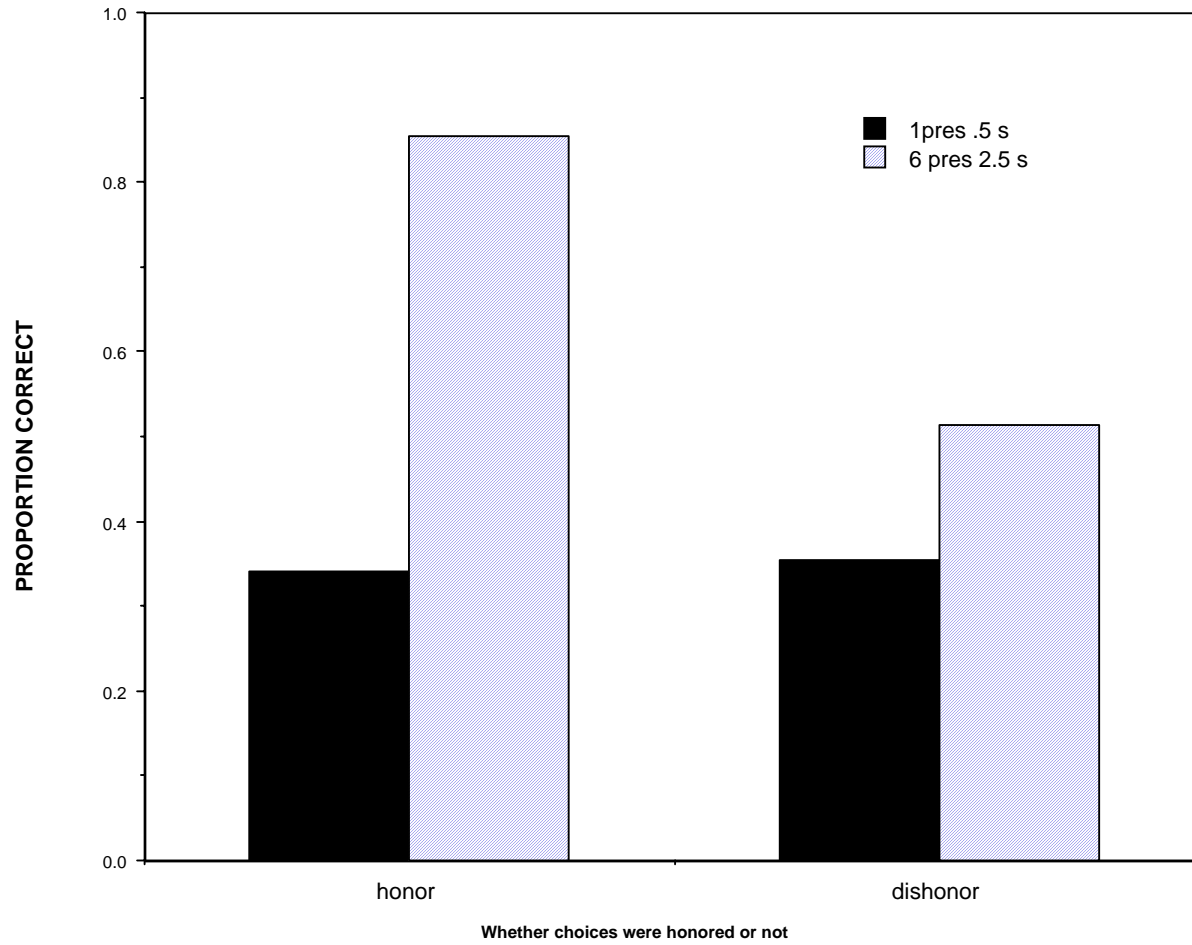
When given a final test on all of the items, they scored better when we had honored their choices.

With new learning, of highly related pairs of items, they, again, eliminated those they knew. When we honored their choice they did better.

We did the same thing with unrelated items, related items and items on which they had so little time that they could not possibly learn them.

Their choices were consistent with RPL, and honoring them resulted in enhanced learning.

### LARGE DIFFERENCES IN THE AMOUNT OF INITIAL LEARNING



Finally, we conducted an experiment in which after presenting the items, and having participants make JOLS, we tested them.

The computer then eliminated those items the participants already knew.

They then made their choices.

If people were homing in on their Region of Proximal Learning (and we had eliminated the items they knew already) they should choose their highest JOLs for restudy.

And, indeed they did.

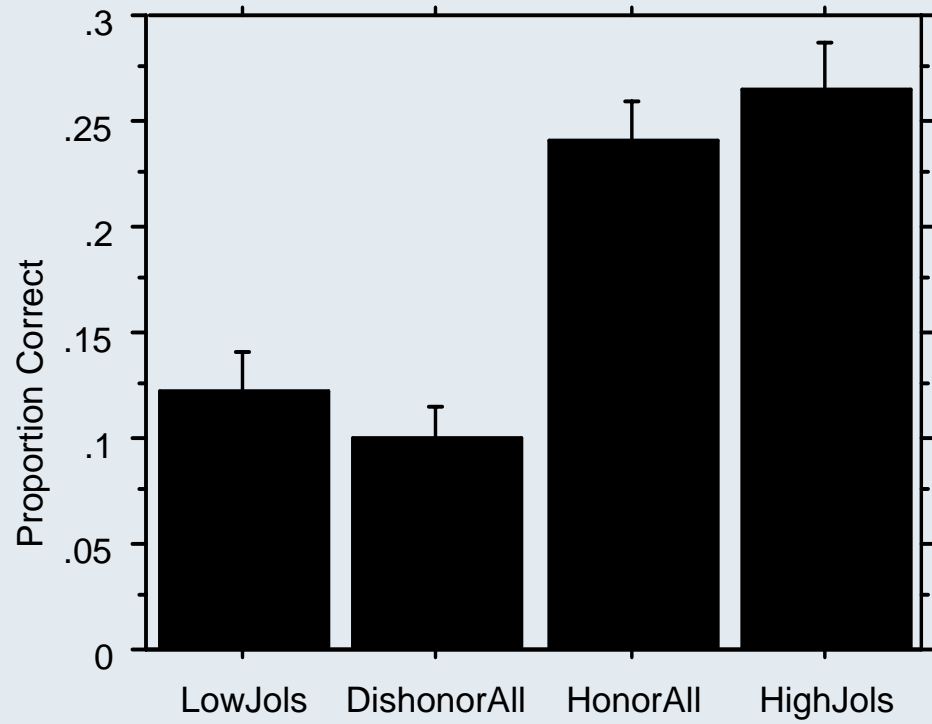
We had 4 conditions:

Honor their choices

Dishonor their choices

Give them their highest JOLs

Give them their lowest JOLs



The data clearly support the Region of Proximal Learning Model, both in terms of what people chose, and that those choices are efficacious.

# PEDAGOGICAL IMPLICATIONS

‘Desirable difficulty’ is determined by the student’s own Region of Proximal Learning. Materials that are already mastered are not in the region (they’re too easy), but neither are the MOST difficult materials.

The region lies just beyond what the learner has already mastered.

# Conclusions

- (1) Having students self generate the answers rather than passively presenting the answers to them has a large effect.
- (2) It makes no difference if the person makes errors in attempting to generate their answers, as long as they are given corrective feedback.
- (3) Feedback matters enormously. Delay, within reason, may help not hurt.
- (4) Learning is optimized when the to-be-learned materials are within the individual's own Region of Proximal Learning. People spontaneously choose to devote their efforts to that region.