Class-sourcing data: A simple strategy for impactful classroom research projects

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Background

My goals when teaching undergraduate experimental methods:

- Students get some experience:
  - designing experiments
  - collecting data
  - writing up manuscript

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Theorem

Let $N = \#$ of these goals that can be fully realized in one course.
Then $N \leq 2$

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Proof.

(due to S. Lang) This proof is left as an exercise for the interested listener. $\square$

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My goals with mentoring undergraduate research:

- Get them involved in my research area
- Replication studies

Combine the two!

Basic idea: how could I replicate a common paradigm in mathematical cognition (e.g., response time measurements) that tests the effects of problem format and problem size on arithmetic performance?

Classroom implementation:

- Each PSYC 3435 student administers the experiment to 4 different participants
- Minimal time investment for each student $\rightarrow$ large data set!

Class experiment

Basic idea: how could I replicate a common paradigm in mathematical cognition (e.g., response time measurements) that tests the effects of problem format and problem size on arithmetic performance?

Why do this?

- Quick and easy data collection
- Students get to play detective and try to solve a puzzle
- Beginners get practice with technical aspects of experimental methods without worrying about the design

Class experiment

Basic idea: how could I replicate a common paradigm in mathematical cognition (e.g., response time measurements) that tests the effects of problem format and problem size on arithmetic performance?

Problem: Don't response time studies require computer software for precise timing?

- Yes and No
- Solution: shift from measuring time per problem to measuring # problems in a given time period

Class experiment

6 + 2		8 + 3	
2 + 9		6 + 4	
5 + 2		2 + 7	
3 + 8		7 + 3	
3 + 3		2 + 5	
2 + 2		3 + 6	
3 + 2		4 + 4	
2 + 8		4 + 3	
7 + 2		9 + 2	
3 + 4		6 + 3	
3 + 7		4 + 6	
5 + 4		5 + 5	
3 + 5		4 + 2	
4 + 5		8 + 2	
3 + 3		5 + 3	
2 + 3		2 + 4	

Form A

7 + 7		9 + 8	
6 + 9		9 + 6	
8 + 7		9 + 3	
8 + 8		5 + 6	
6 + 8		6 + 7	
8 + 6		5 + 8	
3 + 9		8 + 9	
9 + 9		4 + 7	
6 + 5		7 + 4	
7 + 8		9 + 4	
9 + 7		8 + 5	
5 + 9		8 + 4	
4 + 9		7 + 5	
4 + 8		9 + 5	
7 + 9		6 + 6	
7 + 6		5 + 7	

Form B

Class experiment

two + two		four + three	
seven + two		four + five	
eight + two		four + four	
eight + three		three + four	
three + three		two + three	
two + six		two + eight	
three + six		six + two	
two + five		six + four	
three + five		seven + three	
three + seven		four + two	
five + three		three + eight	
two + four		five + four	
six + three		two + nine	
two + seven		nine + two	
three + three		four + six	
five + five		three + two	

Form A

seven + nine		four + seven	
seven + eight		six + six	
seven + seven		six + eight	
four + eight		nine + nine	
five + seven		eight + six	
five + six		eight + five	
nine + six		six + seven	
six + nine		nine + seven	
four + nine		eight + four	
seven + four		five + eight	
five + nine		seven + five	
nine + five		eight + seven	
eight + nine		nine + eight	
three + nine		nine + four	
six + five		seven + six	
eight + eight		nine + three	

Form B

Procedure

Class mental arithmetic experiment:

- Each student administers the experiment to 4 different participants
- Independent variables:
  - Problem size (small vs. large)
    - Small (product less than or equal to 25)
    - Large (product greater than 25)
    - Form A = small, Form B = large
    - within-subjects manipulation
  - Format (digits vs. words)
    - between-subjects manipulation

Procedure

Class mental arithmetic experiment:

- Each student administered the experiment to 4 different participants
- Dependent variables (measures):
  - Number of problems completed
    - directly related to reaction time (i.e., as reaction time decreases, number of problems completed increases)
  - Number of errors

Procedure

Data sheet:

			Form A		Form B	
Participant	Format	Order	Completed	Errors	Completed	Errors
1	Digits	A – B				
2	Digits	B – A				
3	Words	A – B				
4	Words	B – A				

Previous research

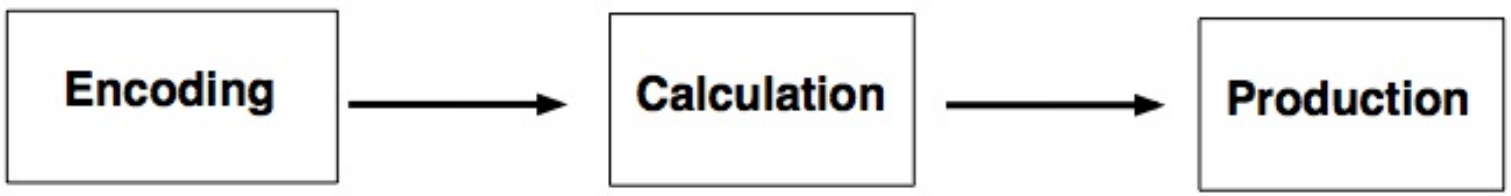
Many studies have investigated mental arithmetic in the past 20 years. Here's what they always find:

- The problem-size effect
  - Participants complete more small problems than large problems
  - Participants make fewer errors on small problems than large problems
- The problem-format effect
  - Participants complete more digit problems than word problems
  - Participants make fewer errors on digit problems than word problems

Our Present Study

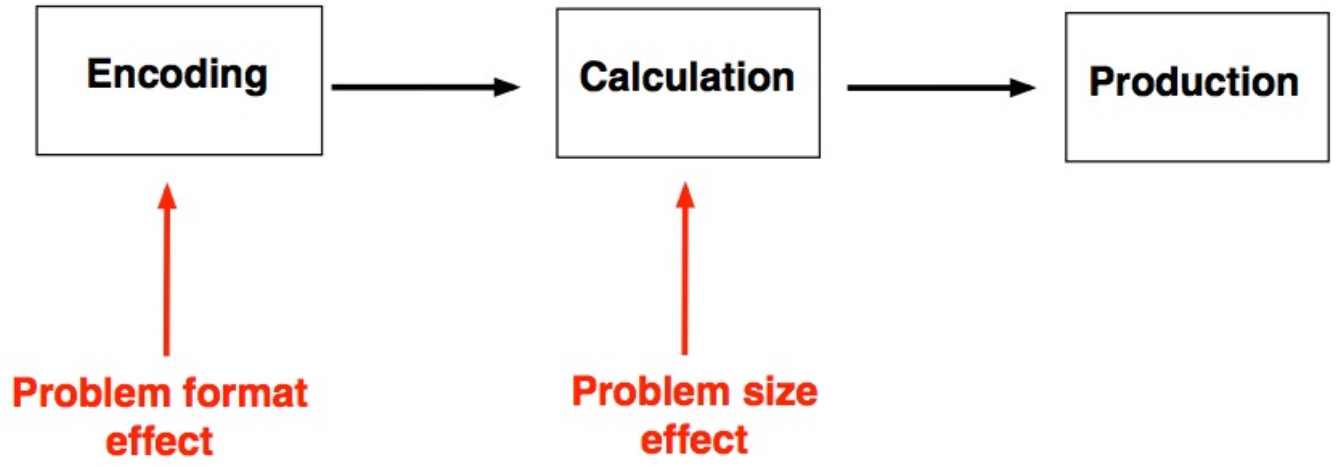
The point of our class experiment is to examine whether there is an interaction between problem-size and problem-format.

Stages of arithmetic processing:



Predictions

Dehaene & Cohen (1995) – additive model of mental arithmetic



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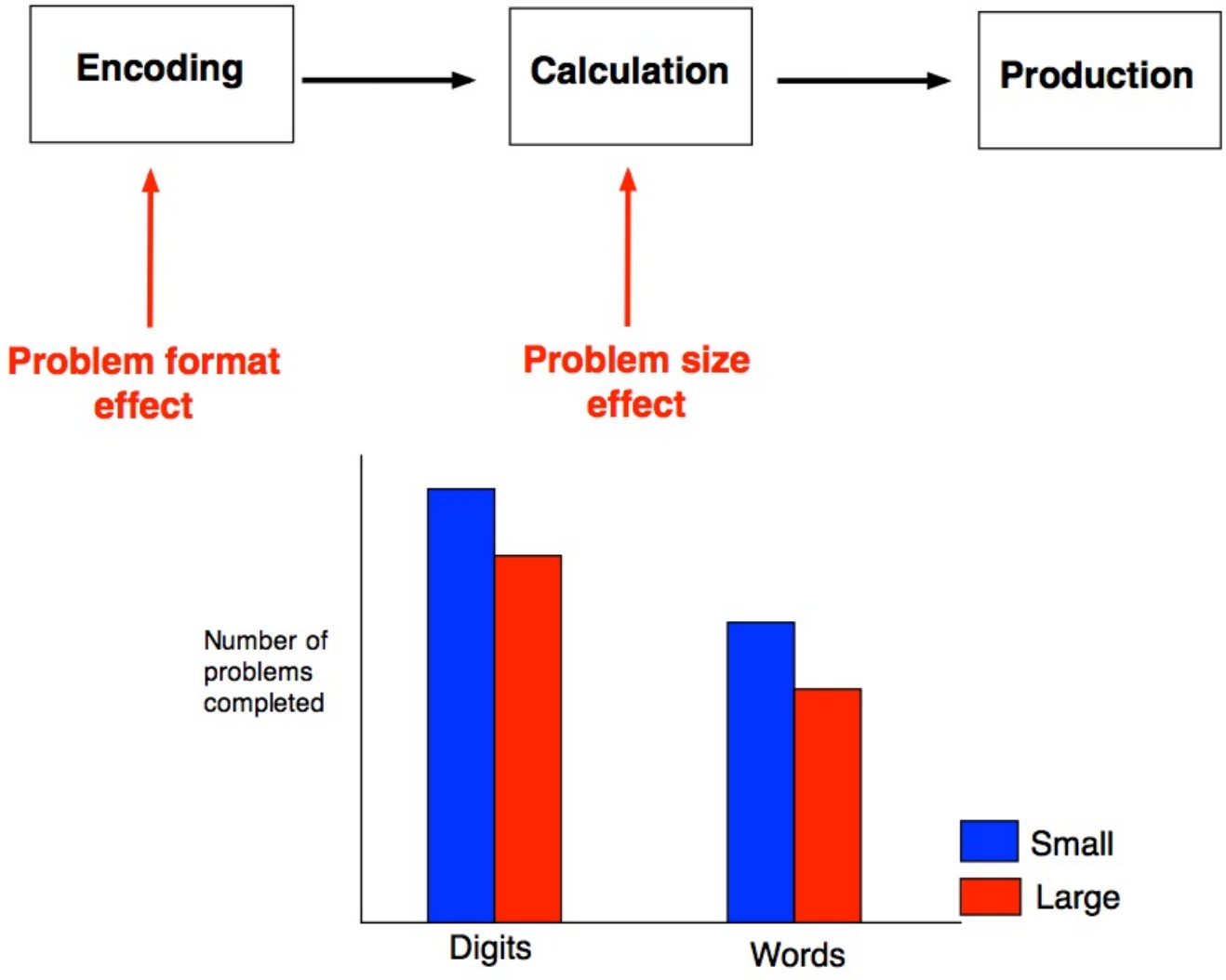
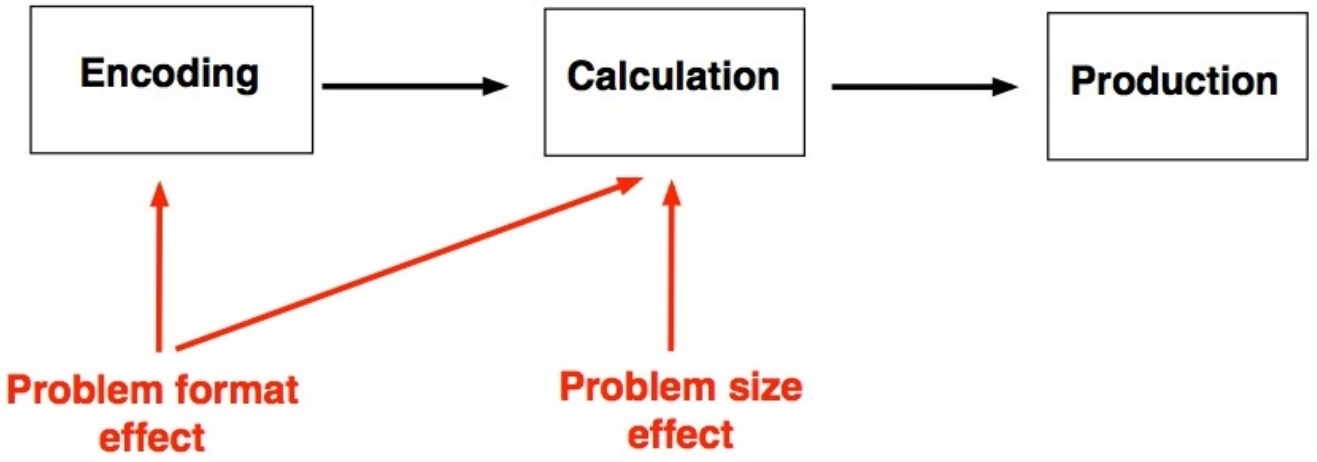


Predictions

Campbell (1999) – interactive model of mental arithmetic



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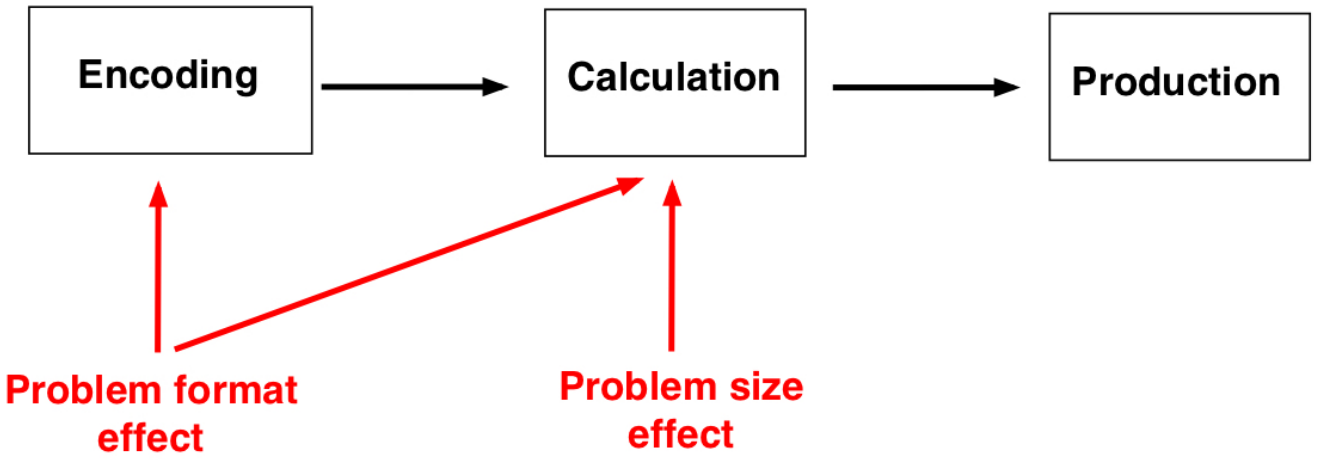
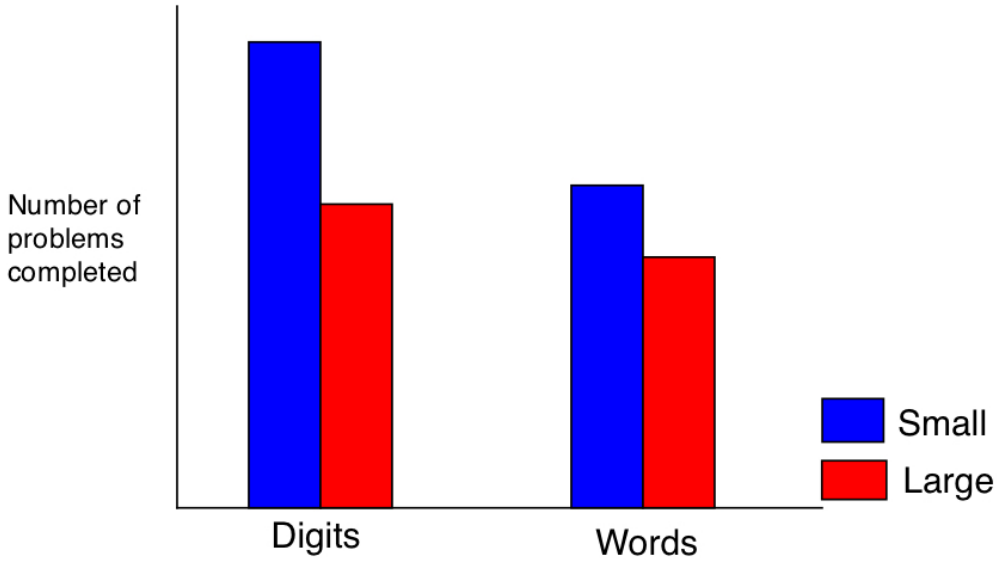




Now it's the students' turn

Task: decide which model is best supported by our data!

Steps:

1. Run a 2x2 factorial analysis of variance (ANOVA) using JASP (jasp-stats.org)
2. Test for the following effects:
   - Main effect of problem size
   - Main effect of problem format
   - Interaction effect between size and format
3. Write a short APA manuscript explaining what we did and what we found

Results

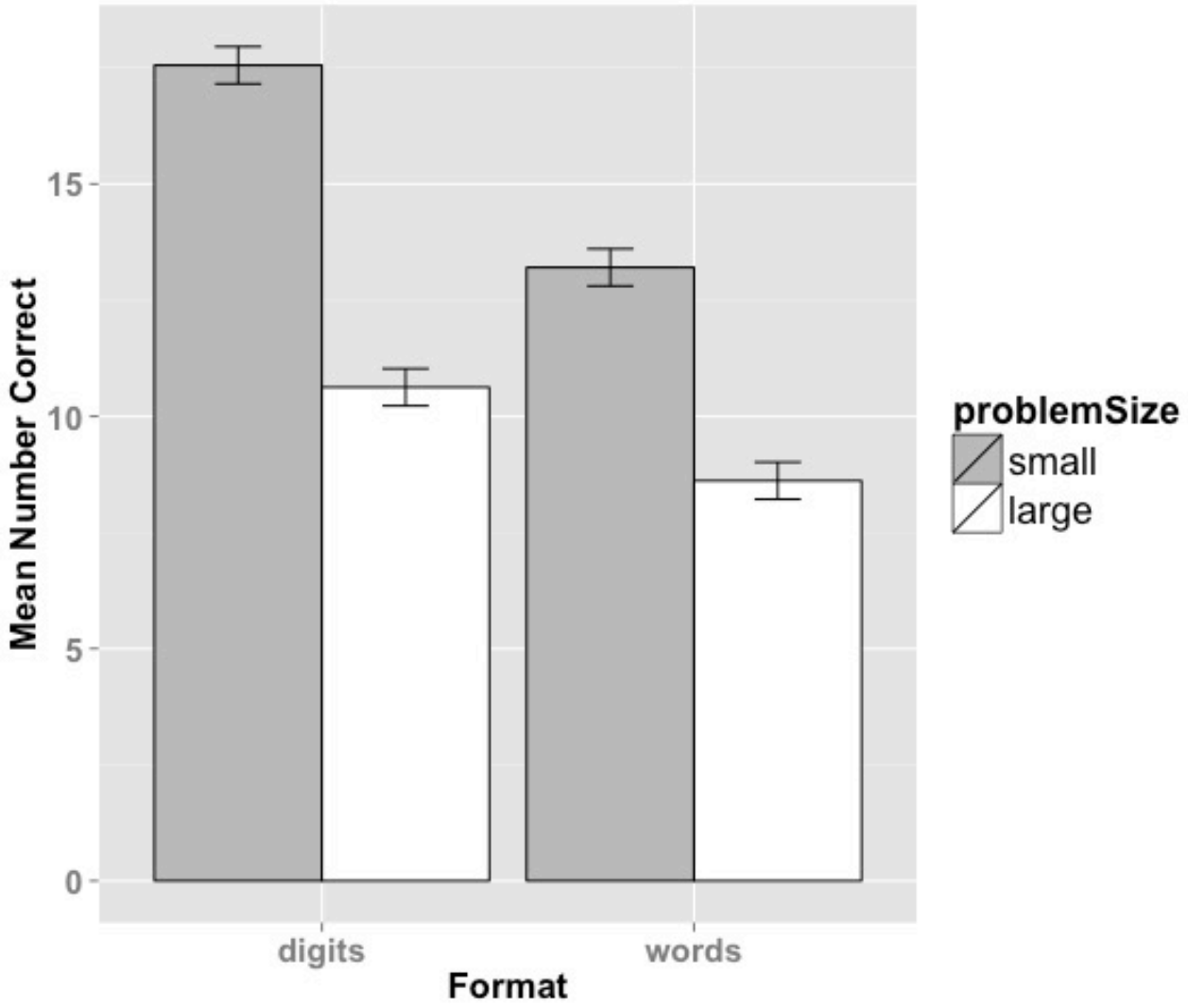
Table 1

Mean number of problems completed by problem size and format

	Small problems		Large problems	
Format	M	SD	M	SD
Digits	17.6	4.9	10.6	4.5
Words	13.2	3.6	8.6	3.7

Note. Overall n=176 with n=88 in each format condition

Results


Mean Number Correct
15
10
5
0
digits
words
Format
problemSize
small
large

Results

The mean number of problems completed was analyzed via a 2×2 factorial analysis of variance (ANOVA), with factors of problems size (small vs. large; within-subjects) and format (digits vs. words; between-subjects).

Source	Df	Sum Sq	Mean Sq	F	p	η_p^2
Problem size	2921.0	1	2921.0	451.6	< 0.001	0.72
Format	890.9	1	890.9	30.7	< 0.001	0.15
Format * Problem size	120.6	1	120.6	18.6	< 0.001	0.10
Error (problem size)	1125.4	174	6.5			
Error (format)	5042.1	174	29.0			

Bonus!

With JASP, we can easily do a Bayesian analysis of variance (Rouder et al., 2012)

Bayesian Repeated Measures ANOVA ▾

Model Comparison

Models	P(M)	P(M|data)	BF_M	BF_{10}	error %
Null model (incl. subject)	0.200	8.588e -53	3.435e -52	1.000	
problemSize	0.200	1.544e -8	6.175e -8	1.798e +44	0.969
format	0.200	4.408e -48	1.763e -47	51330.217	1.108
problemSize + format	0.200	0.002	0.007	1.929e +49	2.373
problemSize + format + problemSize ✻ format	0.200	0.998	2411.216	1.163e +52	2.070

Note. All models include subject.

Model including interaction is favored by a factor ~ 600

Pragmatics

- Easier to grade since everyone is writing up the same results.
- Writing seems better overall.
- Students “buy into” the overall reason for doing the research

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