Draw to Learn Science

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BACKGROUND

It is well established pictures improve memory recall better than words alone[6][7] and our pedagogy capitalize on this effect through the use of illustrations, diagrams, and photographs in educational materials. Illustrations benefit meaningful learning as they summarize verbal information into a concrete representation, often depict spatial relations that are not easily communicated verbally, encourage engagement, and prompt the learner to identify gaps in their understanding. [1][2]

A developing body of literature explores whether asking students to create their own drawings to represent what they are learning about benefits learning more so than studying provided illustrations[3]. Most studies on drawing-to-learn use lessons about scientific phenomena that have an observable physical presence (e.g., the mechanics of an air pump, the circulatory system), and find that novices learn best when the drawing process is guided by an instructor.[3] But, is the pattern of these effects dependent on the learning material itself?

The present study extends this research to the design of methods that help students learn scientific concepts that do not have a definitive visual representation. For theoretical concepts, it may be less important that students draw exactly what an instructor would produce as these representations are arbitrary. Therefore, student self-generated drawings may improve learning because they allow students to produce personally meaningful representations while more effectively capturing students' thinking.

RESEARCH QUESTION & HYPOTHESIS

When the learning material is theoretical in nature, do student generated drawings improve retention and/or transfer of the material in the lesson more than instructor provided illustrations?

We hypothesize that the learning benefits of illustrations during the reading period will increase as participants generate more of their own drawings (from *a to d*): *a.* Study a provide illustration, *b.* Copy a provided illustration *c.* Complete a provided *d.* Create a novel drawing.

DESIGN

❖ n = 193 undergraduates, 14 excluded, M_{age} = 20.3
❖ 100 low prior knowledge and 79 high prior knowledge learners.
❖ All students read a 1607 word passage about the formation and properties of black holes.
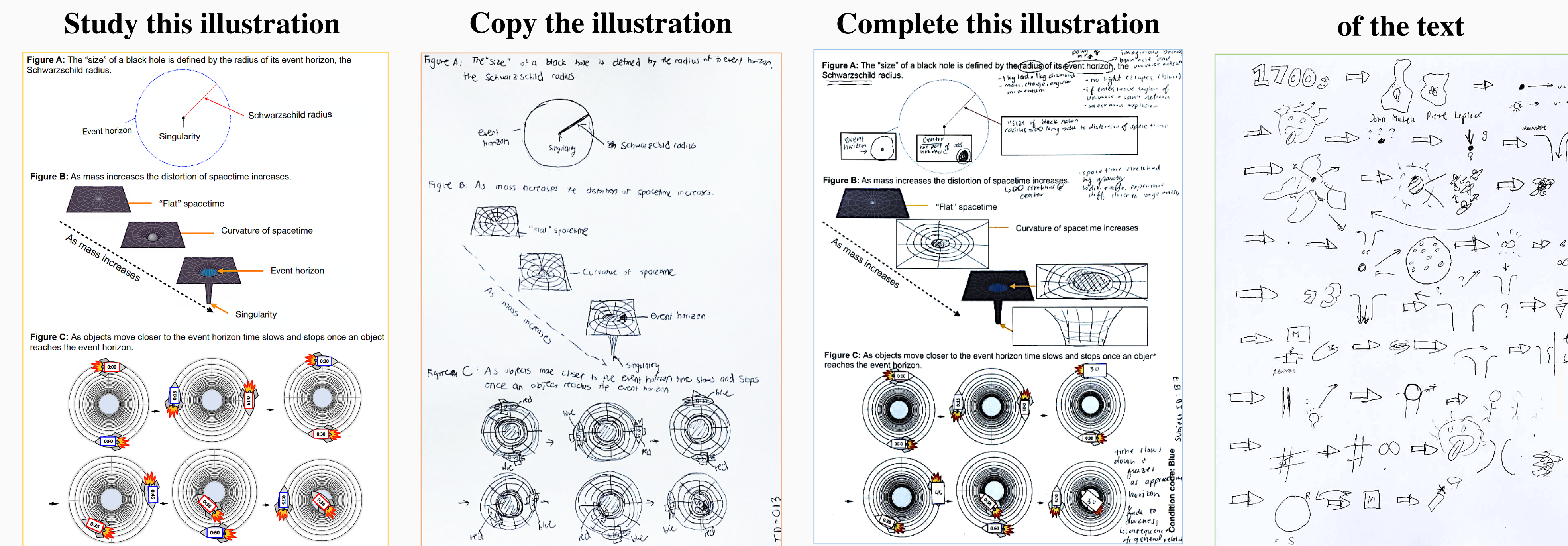
Measures:

1. Vividness of Visual Imagery Questionnaire (VVIQ)[4] – 16 items
2. A validated cognitive load questionnaire[5]

Multiple choice test: two versions of a 13 question multiple choice test were created – students were randomly assigned to complete one as a pre-test and the other as a post-test.
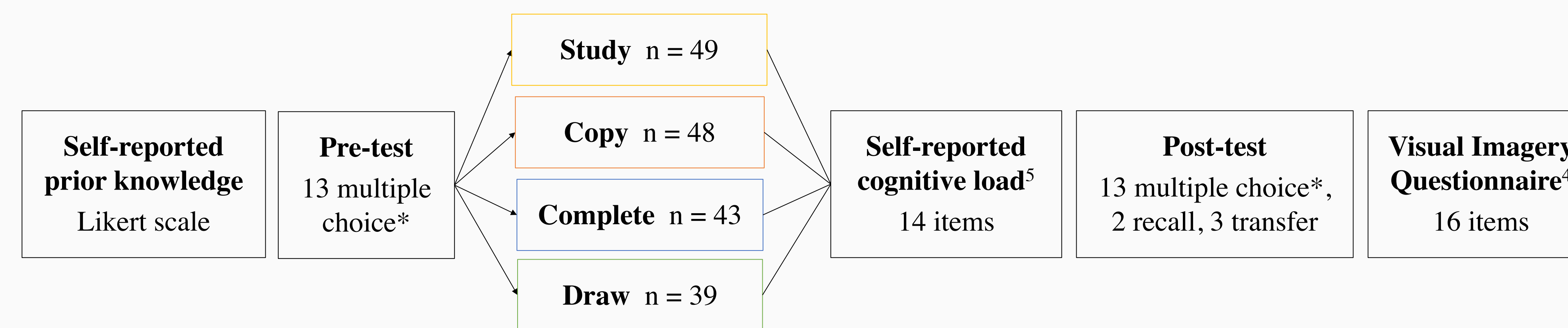
Retention & Transfer tests:

❖ "How do black holes form?"
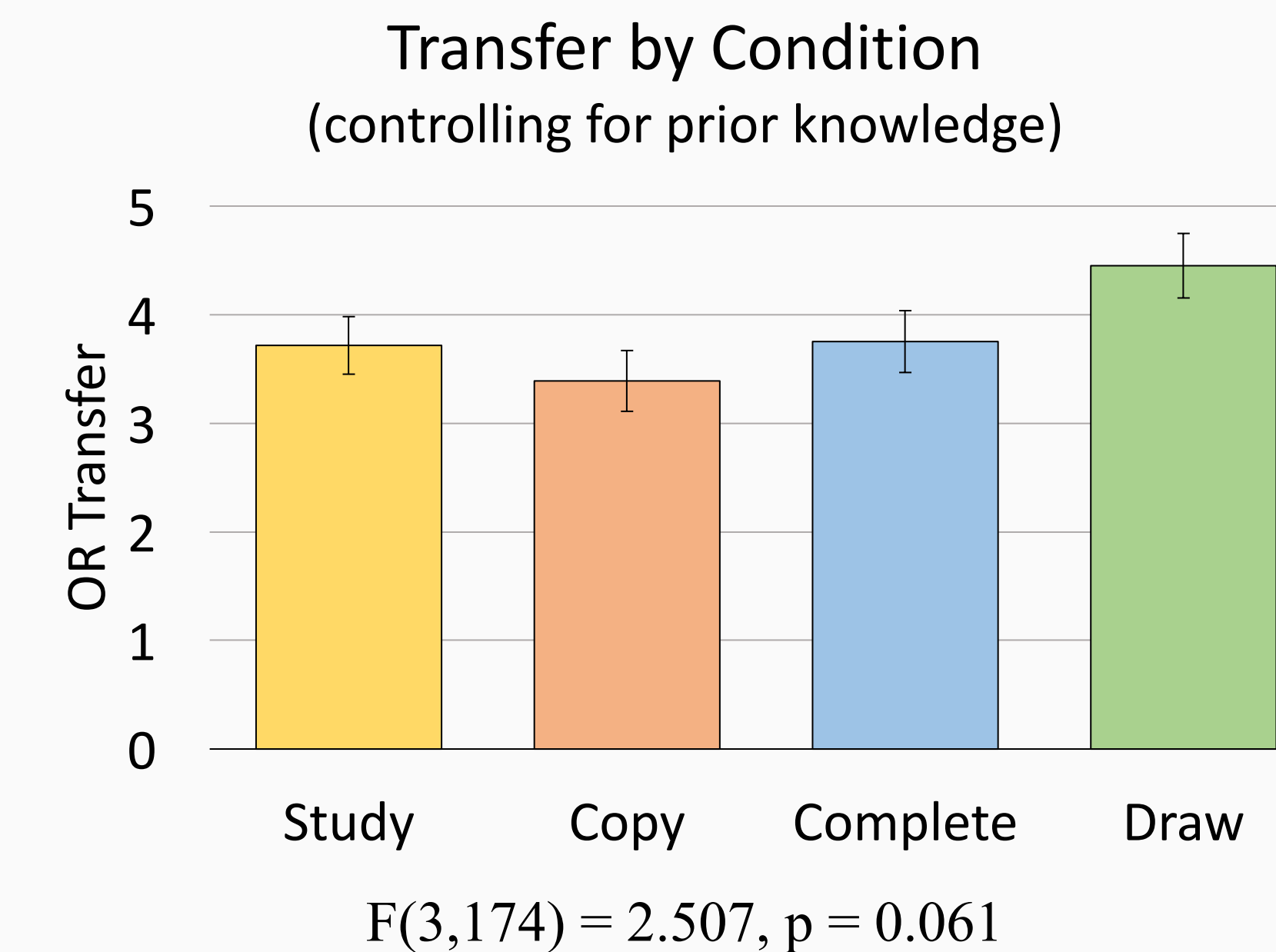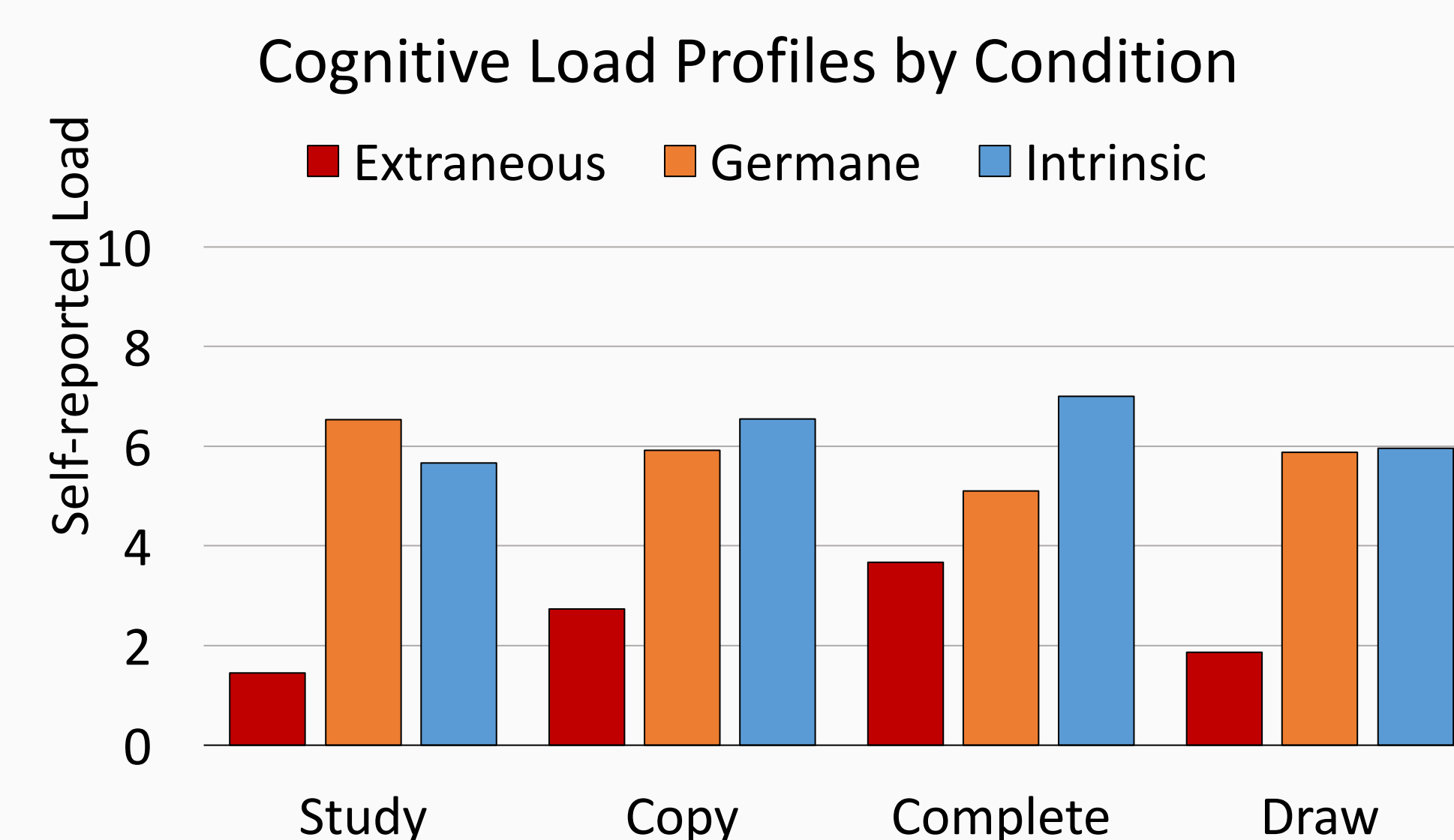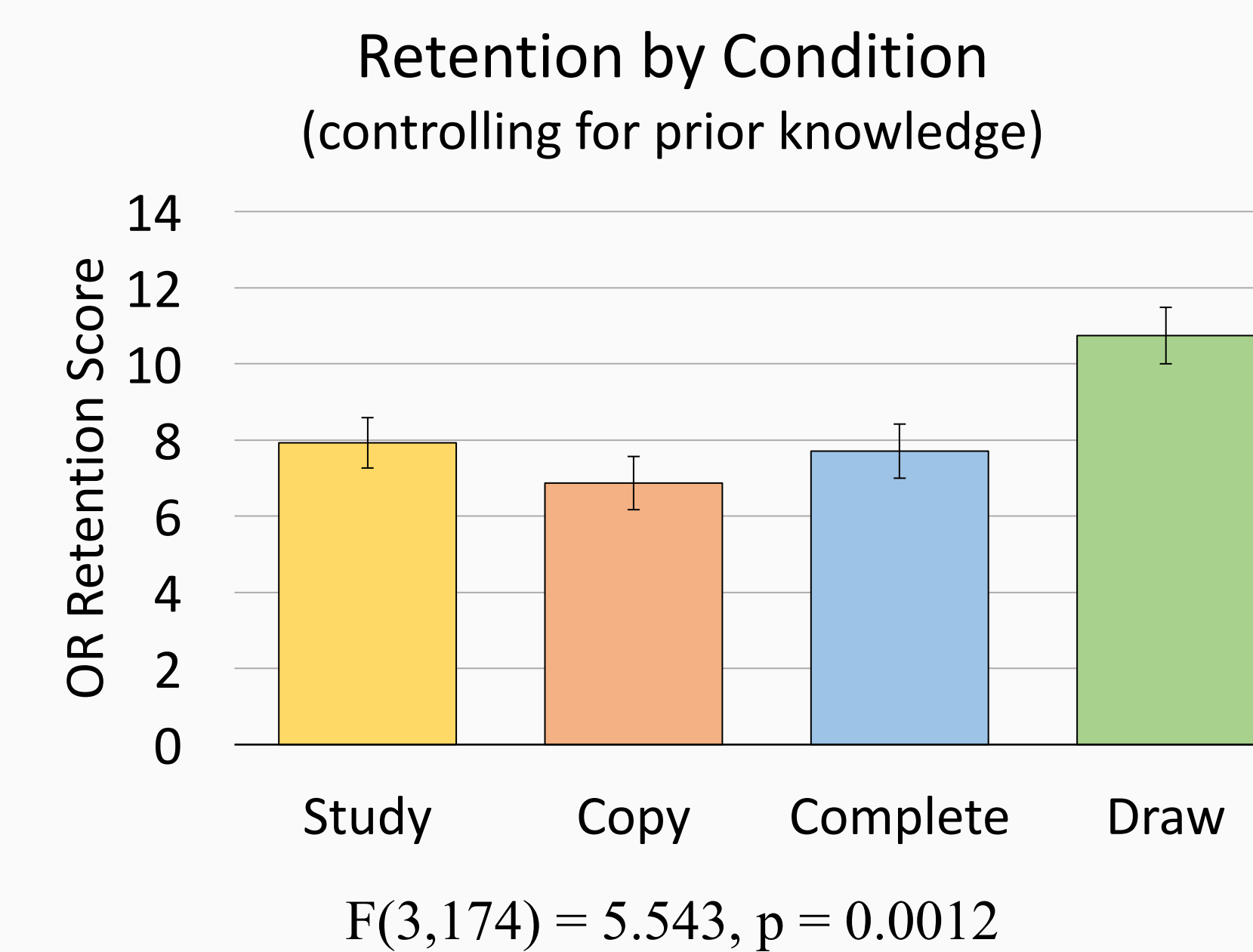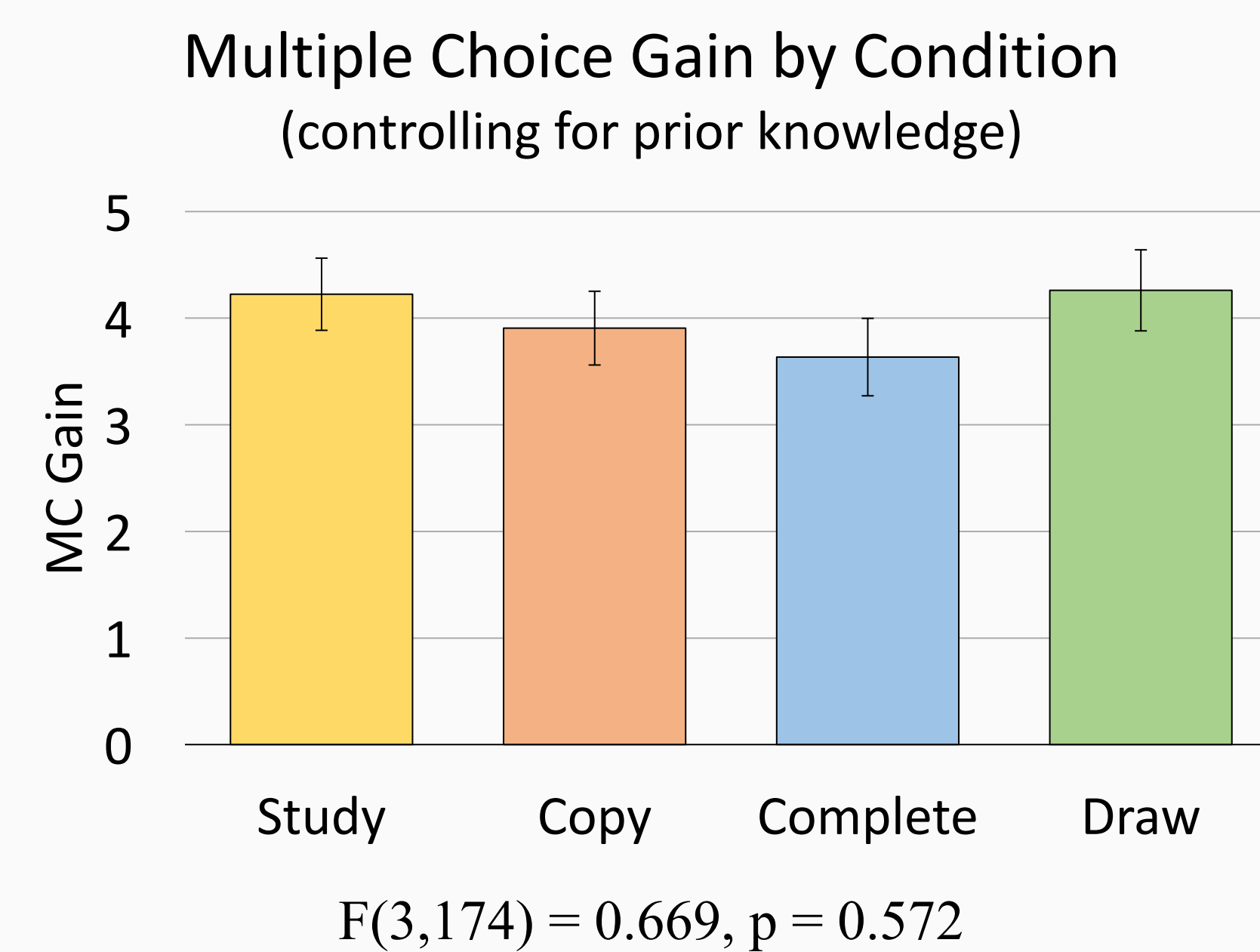❖ "A supernova explosion produces a neutron star. Why didn't it make a black hole?"

MATERIALS & METHODS

Study this illustration | Copy the illustration | Complete this illustration | Draw to make sense of the text

Generative learning increases as students produce more of their own drawing

Self-reported prior knowledge — Likert scale → Pre-test 13 multiple choice* → Study n = 49 / Copy n = 48 / Complete n = 43 / Draw n = 39 → Self-reported cognitive load[5] 14 items → Post-test 13 multiple choice*, 2 recall, 3 transfer → Visual Imagery Questionnaire[4] 16 items

RESULTS

Multiple Choice Gain by Condition (controlling for prior knowledge)
$F_{(3,174)} = 0.669$, p = 0.572

Retention by Condition (controlling for prior knowledge)
$F_{(3,174)} = 5.543$, p = 0.0012

Cognitive Load Profiles by Condition
■ Extraneous ■ Germane ■ Intrinsic

Transfer by Condition (controlling for prior knowledge)
$F_{(3,174)} = 2.507$, p = 0.061

DISCUSSION

For the multiple choice gain, we found no significant main effect of drawing condition, prior-knowledge, or their interaction.

For the open response questions, we found a significant main effect of drawing condition on retention but not on transfer. We also found a significant main effect of prior knowledge on retention but not on transfer. No other main effects or interactions reached p>0.05.

Follow up pairwise comparisons using Tukey HSD suggest that the draw condition performed significantly higher on the open response retention questions compared to all other conditions, but study, copy, and complete were no different from one another. Bellow are all significant pairwise comparisons.

Comparison	Difference	P-value	Cohen's d
Draw vs. Copy	4.23	0.0002	0.78
Draw vs. Complete	3.16	0.0134	0.66
Draw vs. Study	2.82	0.0274	0.55

The results suggest that students may benefit from producing their own drawings when learning theoretical concepts.

FUTURE DIRECTIONS

Explore differences in the organization of space of learner-generated drawings (e.g., center-surround, vertical, horizontal, grouping, continuum, proximity). May the use of space of a student's drawing be related to their learning from the passage?

Explore whether this effect holds true with other conceptual concepts (e.g., learning evolution, experimental design).

REFERENCES

1. Ainsworth, S., Prain, V., & Tytler, R. (2011). Drawing to Learn in Science SCIENCE EDUCATION, *333*.
2. Fan, J. E. (2015). Drawing to learn: How producing graphical representations enhances scientific thinking. *Translational Issues in Psychological Science*, *1*(2), 170.
3. Fiorella, L., & Zhang, Q. (2018). Drawing Boundary Conditions for Learning by Drawing. *Educational Psychology Review*, 1-23.
4. Kosslyn, S. M. (1995). Mental imagery. *Visual cognition: An invitation to cognitive science*, *2*, 267-296.
5. Leppink, J., Paas, F., Van der Vleuten, C. P., Van Gog, T., & Van Merriënboer, J. J. (2013). Development of an instrument for measuring different types of cognitive load. Behavior research methods, 45(4), 1058-1072.
6. Mayer, R. E. (2008). Applying the science of learning: evidence-based principles for the design of multimedia instruction. *The American Psychologist*, *63*(8), 760–769.
7. Paivio, A., Rogers, T. B., & Smythe, R. C. (1968). Why are pictures easier to recall than words?!

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