# Fractions, Decimals, Percentages: Rational Numbers in Cognitive Arithmetic 

Jacob D. Bornheimer ${ }^{1}$ and Jo-Anne LeFevre ${ }^{1,2}$<br>${ }^{1}$ Carleton University, Institute of Cognitive Science ${ }^{2}$ Carleton University, Department of Psychology

## Introduction

In terms of cognition and arithmetic, rational numbers have not been studied as closely as integers. Most studies on fractions and decimals involve comparison tasks, whereas percentages are discussed extremely rarely in the literature. Despite this gap rational numbers are a part of daily life.

In a 2016 pilot, we studied how participants answered mixed rational-whole multiplication questions involving fractions and percentages, formatted as:

$$
x \text { of } y
$$

Where x is a rational number, and y is a whole number. While the design of this pilot was flawed, it raised several interesting questions

1. Are different rational number formats processed differently?
2. How does the problem size effect (PSE) present in rationals?
3. Do these two factors interact?

Because these questions are underexplored in the literature, we conducted a more complete investigation of the processing of differing rational number formats.

## Method

Participants: 36 students ( $50 \%$ female) completed 54 problems presented on a computer screen. Latencies, errors, eye-movements, and solution strategies were recorded. Standard math ability tests were also completed.

Problem Set: The problems took the form ' $x$ of $y$ '. A set of 54 problems was constructed using three variables.

- Three rational number formats (fraction / decimal / percentage)
- Six sizes of proportion ( $0.1,0.25,0.5,0.6,0.75,0.9$ )
- Three sizes of $y$-value $(20,40,60)$

Example questions: $75 \%$ of $40,0.1$ of $20,6 / 10$ of 60

## Results \& Discussion

- No main effect of format, but..
- Small proportion problems were easier as fractions (Fig. 1)
- Largest PSE for fractions (Fig. 1); smallest for percents
- Large proportion problems were more difficult when paired with a larger whole-number operand (Fig. 2)
- The PSE was related to the sizes of both operands
- Effects mediated by conceptual knowledge, rather than speed
- A complication: strategy usage was broad $\rightarrow 5+$ distinct strategies
- Strategy choice varied across formats, and participants also converted between formats on the fly. (Fig. 3)
- When the participants' first fixation was on a fraction, that fixation lasted longer than on a percentage.
- Supports the view that fractions may be more difficult to process than decimals/percentages (DeWolf et al., 2014; Hurst \& Cordes, 2017).

Figures



UNIVERSITY

