Seeing Like a Geologist: How Expertise and Context Impact Frame-of-Reference Judgments

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SEEING LIKE A GEOLOGIST, MEASURING LIKE A PSYCHOLOGIST

Frame of reference is vital to the interpretation of geologic data (e.g., plate motion), strike and dip, navigation, and visualization with diagrams and outcrops (Kastens and Ishikawa, 2006; Groom et al., 2015). For example, when viewing a map of plate motion relative to the United States, you will observe a different pattern than a map of absolute plate motion (Groom et al., 2015). Geologists use frame-of-reference thinking when interpreting geologic scenes, such as examining structural changes (i.e., fault movement) within an outcrop. Presently, there is a lack of empirical data to understand the impact of frame of reference in the geosciences. This study offers preliminary data on the impact of geologic expertise on frame-of-reference thinking with and without geologic context.

Psychologists describe two distinct frames of reference for diagram interpretation: environmental (i.e., describing objects' locations based on the axis of the environment or scene) and object (i.e., describing an object's location based on the intrinsic features of another object) (Carlson-Radvansky and Irwin, 1993). Psychological literature demonstrates that most people will use an environmental frame of reference (Friederici and Levelt, 1990; Carlson-Radvansky and Irwin, 1993). Friederici and Levelt (1990) support the idea that situational conditions can impact the frame of reference that a person uses, suggesting that frame-of-reference thinking is context dependent.

We propose that geologic training influences a geologist's frame-of-reference judgments and may be a predictor of geologic expertise. Geologic training focuses on the object level of the scene, putting equal importance on the parts as the whole. For example, introductory geology students learn that the top and bottom contact of an individual sedimentary layer has meaning, even when the layer is folded or tilted. In other words, the term "above" has special geologic meaning in context and does not always refer to the top of a diagram. For example, when discussing "above," advanced stratigraphic features, including onlapping or offlapping layers and topset, foreset, and bottom beds may cause miscommunication. The draped manner of these layers and unique patterns that emerge may change the understanding of "above" for novices or experts. We also propose that expert geologists will preference an object frame of reference when interpreting geologic diagrams. Novices' recent training with introductory concepts, such as Steno's laws, may cause equal rates of object responses for geologic and non-geologic settings.

These proposed ideas imply that frame-of-reference judgments may be a predictor of geologic expertise and could be used to evaluate where people fall on the expert-novice spectrum. Understanding the relation between expert and novice frame-of-reference judgments has implications for the classroom and field; students and faculty may utilize the same terminology to discuss different features, causing a misunderstanding.

Here, we report the results of a pilot study that examines the proposed impact of geologic training on frame of reference by asking the following questions: (1) does geologic expertise impact the frame of reference geologists use when deciding where "above" is in a scene?; and (2) does the context of the scene impact frame-of-reference thinking?

METHODS

A survey was administered at the 2017 Geological Society of America Annual Meeting at the Michigan State University Geocognition Research Laboratory booth. The survey included four frame-of-reference questions and a demographic survey. The demographic survey collected data on geologic experience. The frame-of-reference questions included two geologic scenes and two non-geologic scenes. The non-geologic scenes were modeled after Carlson-Radvansky and Irwin (1993), with a donkey on a hill with two flies, one placed in each reference frame (Fig. 1A). Participants were prompted: "Circle the fly above the donkey."

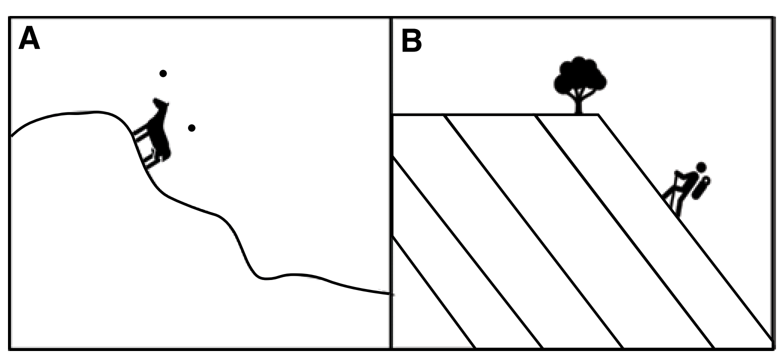

Figure 1. Diagrams with the non-geologic (A) and geologic (B) scenes have objects placed in the object and environmental reference frame.

GSA Today, v. 30, https://doi.org/10.1130/GSATG423GW.1.

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To evaluate whether context influences frame of reference, a parallel item depicted a geologic scene with tilted sedimentary beds exposed on the side and top. A hiker and tree were placed above the limestone layer in the object and environmental frames of reference, respectively (Fig. 1B). Participants were prompted: "Circle the object that is above the limestone layer."

Participant responses were categorized as an object or an environmental reference frame. For example, if the participant selected the fly perpendicular to the donkey's back or the hiker, then they were coded as the object reference frame. The demographic survey was scored based on participants' number of undergraduate courses, graduate courses, degrees, and years worked. An expert is a typical geology faculty member or senior-level employee, an intermediate is equivalent to a graduate student or early-career employee, and a novice is a typical undergraduate student.

RESULTS

The results focus on the use of an object frame of reference for two reasons: (1) we proposed that geologic training would focus geologists on the objects within the scene, and (2) a high rate of use of an object frame of reference will show a deviation from the expectations of the psychological literature.

Testing research question 1, our study divided frame of reference use by geologic expertise, then by the type of scene. Our results show that all levels of expertise used an object frame of reference at least 35% of the time (Fig. 2). For the geologic scenes, experts and intermediates used an object frame of reference to answer the prompts over 75% of the time. Novices answer ~60% of the time for both scenes.

For research question 2, we tested each level of expertise using a chi-square test. No significant difference was found in novice responses based on the context of the scene, X^2 (1) = 0.254, ρ = 0.614. Context is important at higher levels of expertise. Intermediates [X^2 (1) = 20.422, ρ = 0.000] and experts [X^2 (1) = 6.798, ρ = 0.009] both switch from an object reference frame for the geologic scenes to an environmental reference frame for the non-geologic scenes.

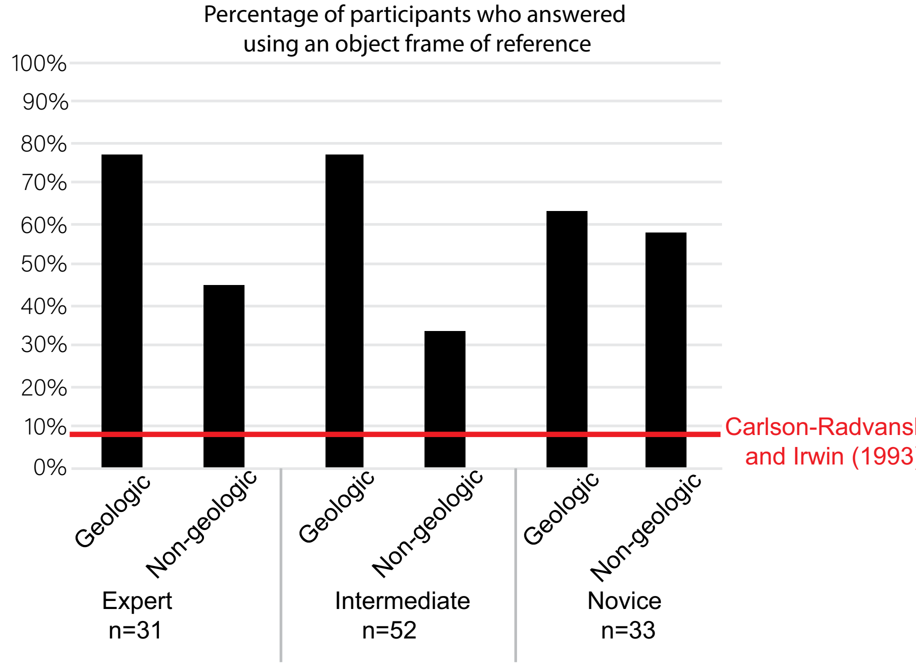

Figure 2. Percentage of participants who responded using an object frame of reference by expertise and context. The red line represents Carlson-Radvanksy and Irwin's 1993 object response rate.

FUTURE WORK AND LIMITATIONS

This pilot study is limited by a small number of survey items. However, we gathered data with a higher number of participants compared with the cited literature (Carlson-Radvansky and Irwin, 1993). Comparison with previous studies is limited, because modern use of technologies (e.g., GPS) may yield poorer frame-of-reference thinking (Ishikawa et al., 2008). Future work should test if the forced-choice response format in this study primed participants and yielded a higher object-centered response rate than an open-ended task. Since frame of reference is a component of spatial thinking, expanding the study to include other science, technology, engineering, and math disciplines and a general audience would be valuable to understanding the context of these findings. This study concludes that explicit frame-of-reference training may prevent confusion between faculty and students, increasing the rate novices move along the expert-novice spectrum, and provides the basis for continued research to further understand its relationship with geology.

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Manuscript received 25 Oct. 2019
Revised manuscript received 14 Feb. 2020
Manuscript accepted 27 Mar. 2020