Facilitation of spatial skills necessary in performing geologic transformations

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Have you ever seen a car that has been in an accident and tried to imagine what happened? Often it is possible to work backwards from the current shape of an object to deduce what happened to it, e.g., a head on collision with a tree. This reasoning requires a spatial cognitive skill - a mental transformation of an object. Mental transformation refers to the ability to alter an internal representation of an object in order to imagine what that object used to look like before some event or what it might look like in the future.

We are studying how people develop this skill. One avenue of our research has been to study mental transformation in experts. Strong mental transformation skills are essential in the field of geology. Geology is a historical science that takes what is observable and tries to deduce what has happened over time to result in the current state of affairs. In particular, geologists use the present spatial relations to figure out what transformations have occurred. This mental reasoning may take place at many scales, from tectonic to microscopic. For example, field geologists study the deformational history of rocks and regions by studying the spatial configuration of geological features in an outcrop and how they fit with other observations in a surrounding area. Just as the bent and rent metal of a car tells a story, so too the geological history is revealed by the bends and breaks, folds and faults, in rocks. (see fig. 1).

Figure 1a Folds

Figure 1b Faults

The current line of research aims to understand how expert geologists reason about mental transformations. Geologists self-report that they look at an outcrop and play back in their mind the sequence of transformations, mentally animating the transformations from the present spatial configurations back to horizontal sedimentary layers. An initial study examined if geologists are objectively able to make such mental transformations, and, if they are, is the skill domain specific or domain general. Previous studies of chess expertise (Chase & Simon, 1973) suggest that expert reasoning is domain specific, in which case geologists should only be able to perform mental transformations on objects that have been altered in geologically relevant ways. In contrast, if geologists are able to perform mental transformations on any object independent of the type of alteration it suggests they have a domain general skill.

Geologists (n=16) were compared to two control groups from other academic fields. All groups had the same level of education (Ph.D.). One control group came from another science that requires spatial reasoning (Chemists, n=14) and one that requires verbal reasoning (English Professors, n=10). The participants were presented with words that were transformed in one of three ways, and asked to identify the word. To make the task more demanding additional characters were added in between each letter of the word (see fig. 2). Words were broken up into pieces along diagonal lines. These pieces were translated as if faulted (see fig. 3) or were randomly displaced (see fig. 4).

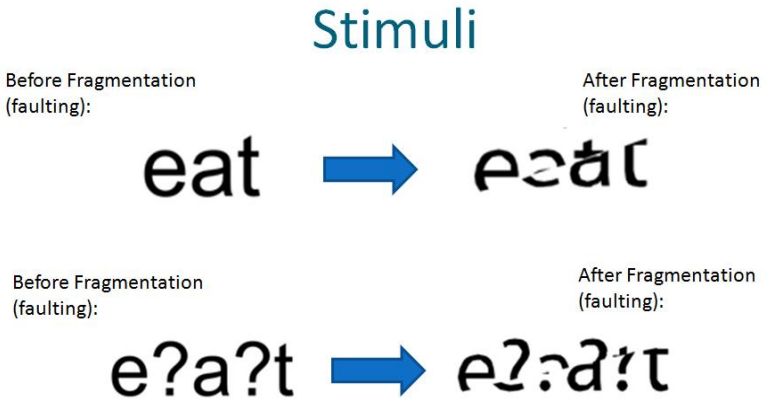

Figure 2

Figure 3

Figure 4

Geologists were significantly better than both control groups suggesting the geologists have a domain general ability to make mental transformations that is superior to novices (Shipley et al, 2009). One explanation for this skill is that geologists are particularly good at disembedding - finding and attending to specific structures within a complex array. We tested this with another set of words where the transformation separated all of the pieces making it easier to see which pieces belonged together and thus mentally undo the transformation (see fig. 5).

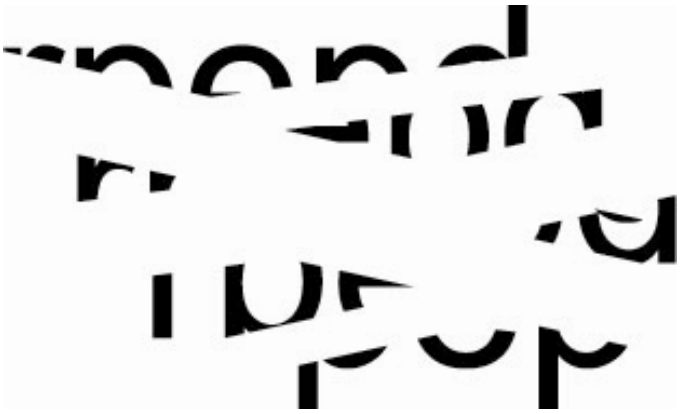

Figure 5

All three groups performed better on these words, however Geologists still outperformed both control groups. This finding suggests that while disembedding is helpful for this task, it is not the sole explanation for the Geologist's skill.

Geologists report that students often have trouble mentally transforming spatial structures. By characterizing this skill, we should be able to help educators provide students with strategies for visualizing such transformations. However, it is not yet clear what about geoscience education produces this skill. Future studies will examine how mental transformation skills develop, and study its importance for student retention and achievement.

References:

Chase and Simon. (1973). Perception in Chess. *Cognitive Psychology*, 4.

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