Solving the Puzzle to Reach the Summit:
Using Metaphor to Gauge Public Perceptions of Science

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Abstract

Skepticism towards science has risen sharply in recent years. Cognitive scientists can help address this issue by illuminating how people conceptualize the scientific process, paving the way for improved communication with the public. We recruited a large sample of lay Americans, as well as academics in the sciences and humanities, to answer a series of questions assessing their views about science. Because metaphors have been identified as useful tools for communicating about complex domains, we asked participants to choose which of two metaphors—*working on a puzzle* or *scaling a mountain*—best captured their beliefs about the scientific process. Results revealed substantial variation in perceptions of science across groups, and we highlight the ways in which scientists seem to conceptualize science differently from non-scientists. Importantly, metaphor preference was associated with particular patterns of thinking, though not always in our originally hypothesized direction. We discuss the implications of these findings.

Keywords: metaphor, science, concepts, public perceptions

Introduction

Scientific research requires a variety of skills and involves a range of tasks and experiences. It can be like *piecing together a puzzle*, in which a diverse set of empirical findings are connected to fill in the details of big-picture scientific theories. And it can be like *climbing a mountain*, in which careful planning and steadfast persistence are necessary to move projects forward. Both of these metaphors—*working on a puzzle* and *scaling a mountain*—capture aspects of the scientific process. In this paper, we use these two metaphors to gauge how people think about science. We recruited a large sample of the general public, as well as academics in the sciences and humanities, to answer a series of questions assessing their views about science, scientific practices, and the priorities of working scientists. They also selected which of the two metaphors (*puzzle* or *mountain*) better represented their beliefs about science, and we explored associations between this choice and broader patterns of thinking about scientific practice.

Understanding how people conceptualize science is important given the widespread anxiety about everything from climate change to vaccines to genetically modified

organisms (Achenbach, 2015). Indeed, recent populist political movements have been accompanied by an increasing distrust in science and data. In a recent US poll, almost half of participants (and over two-thirds of President Trump's base) said they did not trust the economic data being reported by government agencies (Ryssdal, 2016). There is also concern in the scientific community about the quality of science education and the lack of public investment in science: "An overwhelming majority of scientists [over 75%] see the public's limited scientific knowledge as a problem for science," according to another recent poll (Funk & Rainie, 2015).

The lack of support for science represents a direct threat to addressing important real-world situations like climate change and, potentially, the stability of societal institutions at large (Otto, 2016). As one recent *Washington Post* article concluded, "This is how a democracy crumbles: not with a bang, but with data trutherism" (Rampell, 2016).

Recent work in the cognitive sciences has explored how to improve communication with the public for specific scientific issues like climate change and public health (Flusberg, Matlock, & Thibodeau, 2017; Thibodeau, Perko, & Flusberg, 2015). Metaphors have been identified as useful communication and explanatory tools, as they can help people make sense of complex issues by relating them to more familiar domains, leveraging the schematic knowledge people already have in order to reason about new and complicated subjects (Thibodeau, Crow, & Flusberg, 2016). To date, however, little research has investigated the role of metaphor in thinking about the scientific process itself (but see Thibodeau, 2016, and Harwood, Reiff, & Phillipson, 2005).

In addition to addressing practical concerns about public perceptions of science, therefore, the present work also has theoretical implications, as cognitive scientists (particularly cognitive linguists) often treat metaphor as a window into how people think (e.g., Fairclough, 2013; Lakoff & Johnson, 1980). That is, *puzzle* and *mountain* metaphors for science seem to have different entailments, which may suggest that people who talk about science as a *puzzle* think about the scientific process differently than people who talk about science as a *mountain*. On the other hand, some have

questioned this approach because of the assumptions that are made about the nature of *thinking* simply from observing patterns of language use (Keysar & Bly, 1995; McGlone, 2011; Murphy, 1996, 1997).

One of the few studies to address this issue in the context of reasoning about science involved structured interviews with scientists aimed at identifying (a) key characteristics of scientific inquiry and (b) metaphors that scientists use to conceptualize these issues (Harwood et al., 2005). The goal was to improve science education by encouraging science teachers to use metaphors in the classroom more deliberately. The results indicated that scientists' descriptions of the scientific process emphasized five key characteristics: open-mindedness, putting yourself in your work, utilizing resources, problem solving, and making connections. These characteristics were then matched to conceptual metaphors that the scientists used in the interviews. For example, a *puzzle* metaphor was often used to emphasize how scientists seek to make connections; an *artist* metaphor was used to stress the importance of being open-minded; a *gardening* metaphor was used to talk about immersing oneself in their work.

One possibility is that these metaphors can encourage non-scientists to think about the scientific process in a way that is more consistent with how scientists think about scientific inquiry (Harwood et al., 2005). However, an alternative possibility is that the meaning of these metaphors will be different for scientists and non-scientists. That is, the knowledge and experience that people have with science may influence how they interpret metaphors for the scientific process. A recent investigation into how different groups of people understand militaristic metaphors in biology like *invasive species* suggests support for the latter possibility (Larson, Nerlich, & Wallis, 2005): a metaphor that means one thing to scientists can mean something else to non-scientists.

Therefore, the present study represents an important empirical step in comparing how different groups of people interpret metaphors for the scientific process. Do people actually think about science in a way that is consistent with the metaphor they would use to talk about it?

Experiment

Methods

Participants A sample of 518 people representing the general public was recruited from Amazon's Mechanical Turk (60% female; M_{age} = 35). A second sample of academics was recruited from the faculty listings of college and university websites in the United States, drawn from a list of top research and liberal arts institutions. We created a list of 2,000 academics, roughly half representing the sciences (i.e. faculty working in Physics, Chemistry, or Biology Departments), and half representing the humanities (i.e. faculty working in English, History, or Philosophy Departments). An email asking for voluntary participation in the survey, yielded responses from 156 academics (93 from the sciences and 63 from the humanities).

Although we were primarily interested in comparing how scientists and the general public think about science, we were also interested in understanding *why* these groups may think differently. Including the group of academics from the humanities helps to address this question. Like scientists, this sample is highly educated, familiar with working on projects that can take long periods of time, and conduct their work in a college or university setting. On the other hand, like participants from the general public, this sample may not be as familiar with the day-to-day experience of conducting scientific work. As a result, including the humanists allows us to investigate why the general public might hold views about science that are different from scientists. For instance, are differences related to more general factors like education level or related to factors more directly tied to being immersed in scientific work?

Materials & Design All participants were asked to choose between two metaphors for science. The instructions for this judgment read, "We are interested in how people think about science. Which of the following metaphors best captures how you view the process of working on a scientific project?" The order of the two options—*Working on a puzzle* or *Scaling a mountain*—was counterbalanced.[1]

These two metaphors for science were chosen because of their use in prior work (Thibodeau, 2016), and because they are commonly used by scientists to talk about the scientific process (Harwood et al., 2005). Thibodeau (2016), for example, found that metaphorically framing a scientist's work as a *puzzle* led people to value "testing completely novel theories" over "using methods that are simple for others to follow," whereas framing the scientist's work as a *climbing a mountain* led people to value using simple methods over testing novel theories.

All participants were also asked to rank six aspects of the scientific process in order of importance, three of which were designed to be more consistent with the entailments of the *puzzle* metaphor and three of which were designed to be more consistent with the entailments of the *mountain climbing* metaphor (see Table 1). The relationship between the entailments and metaphors was based on prior work (Harwood et al., 2005; Thibodeau, 2016), and experimenter intuition; one goal of the study is to test whether different groups of people have similar intuitions about the relationship between the entailments and metaphors. The order of the statements was randomized across participants.[2]

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[1] In pilot testing we found no effect of subtle wording differences for these metaphorical phrases (i.e. "Working on a puzzle" versus "Solving a puzzle"; "Climbing a mountain" versus "Scaling a mountain"). In every case, about 90% of participants from the general public chose *puzzle*.

[2] Of note, the order of the metaphor preference judgment and the entailment ranking tasks was counterbalanced for the sample from the general public. Since there were no differences in how people responded on the two orderings, we did not counterbalance these tasks for the academics.

We compare how the three populations (General Public; Scientists; Humanists) rank the statements overall, and we test whether people who prefer the *puzzle* metaphor for science rank the *puzzle*-congruent statements as more important than the *mountain*-congruent statements (and vice versa for the *mountain* metaphor).

Table 1. Tasks related to the scientific process that were ranked by participants.

Actions and Behaviors Related to Science	Metaphor
1. Find creative ways to study important research questions	Puzzle
2. Seek insight from diverse sources	Puzzle
3. Find connections between seemingly unrelated ideas	Puzzle
4. Make a detailed research plan	Mountain
5. Persist in the face of setbacks	Mountain
6. Revise theories in light of new data or counter-evidence	Mountain

Finally, participants were asked to complete the 40-item Scientific Attitude Inventory II (SAI II), which is designed to measure attitudes related to science along six dimensions (Moore & Foy, 1997; see Table 2). This instrument has been used to measure perceptions of science among students and the general public, and to predict who is likely to pursue a career in a STEM field (e.g., Bathgate, Schunn, & Correnti, 2014; Moore & Foy, 1997).

As with the rank order task, we use responses from the SAI II to compare how the three populations think about science and to test whether certain dimensions of the scale map onto the view that science is like working on *puzzle* versus scaling a *mountain*.

Table 2. Six dimensions of the SAI II and example items..

Dimension	Example Item
Theory	Scientific ideas can be changed.
Limited	Scientists cannot always find the answers to their questions.
Empirical	Scientific questions are answered by observing things.
Goal	Ideas are the important result of science.
Public	Every citizen should understand science.
Interest	I would enjoy studying science.

At the end of the survey, participants from the general public were asked background and demographic questions, including their gender, age, education level, math/science training, political ideology (0, Very liberal, to 100, Very conservative), and personality (the Big Five personality dimensions; Gosling, Rentfrow, & Swann, 2003). Academics were asked to identify as working in the humanities or sciences.

Results

Metaphor Preference Among participants sampled from the general public, 89% preferred the *puzzle* metaphor for science, $\chi^2(1) = 315.09$, $p < .001$. The *puzzle* metaphor was also preferred by 89% of academics, $\chi^2(1) = 92.31$, $p < .001$, although scientists (84%) were marginally more likely to choose the *mountain* metaphor compared to humanists (95%), $\chi^2(1) = 3.71$, $p = .054$.

For the sample recruited from the general public, we tested whether any of the individual difference measures (i.e. gender, age, education level, math/science training,

political ideology, personality) predicted participants' choice of metaphor. The only reliable predictor of participants' choice was age: older participants were especially likely to endorse the *puzzle* metaphor for science, $B = .40$, $SE = .17$, $p = .016$.

Ranking Priorities We first compare how the three populations ranked the six statements about science, focusing on contrasts between scientists and (a) humanists and (b) participants from the general public. Then we test for a relationship between participants' preferred metaphor and their rankings of the statements. For this second analysis, we excluded the humanists because of the small number who preferred the *mountain* metaphor ($n = 3$).

First, a mixed-effects linear model was fit to the rankings with statement (1-6) treated as a within-subjects effect and sample (public, humanists, scientists) treated as a between-subjects effect (Bates, Maechler, Bolker, & Walker, 2014). The model revealed that the samples gave different rankings to the statements, $\chi^2(5) = 209.91$, $p < .001$.
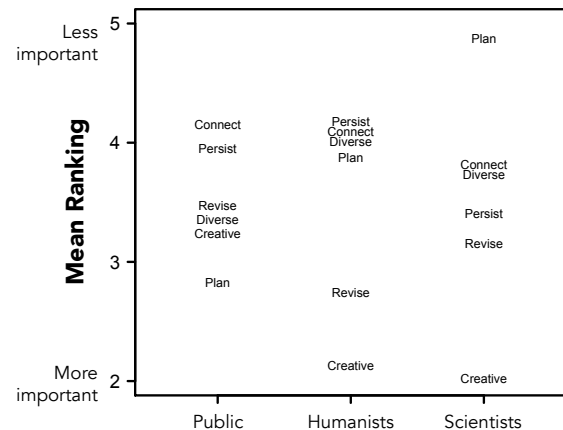

Figure 1. Mean ranking of six statements about science by sample: of the general public, academics working in the humanities, and academics working in the sciences.

Figure 1 illustrates how participants from the three groups ranked the statements overall. One pattern to note is that scientists tended to show more agreement on how the statements were ranked (Kendall's $W = .25$) than participants from the general public ($W = .07$) or humanists ($W = .21$). For instance, "planning" was ranked as the most important aspect of science by the general public, with 53% of participants from this sample ranking it first or second. In contrast, "creativity" was ranked as the most important aspect of science by scientists, with 76% of participants from this sample ranking it first or second. On the other end of the spectrum, "finding connections" was ranked as the least important aspect of science by the general public (46% ranked it fifth or sixth), while "planning" was ranked as the least important aspect of science by scientists (66% ranked it fifth or sixth). This suggests that scientists, as a group, have a more consistent conception of the scientific process than the general public; the humanists showed an intermediate level of consistency.
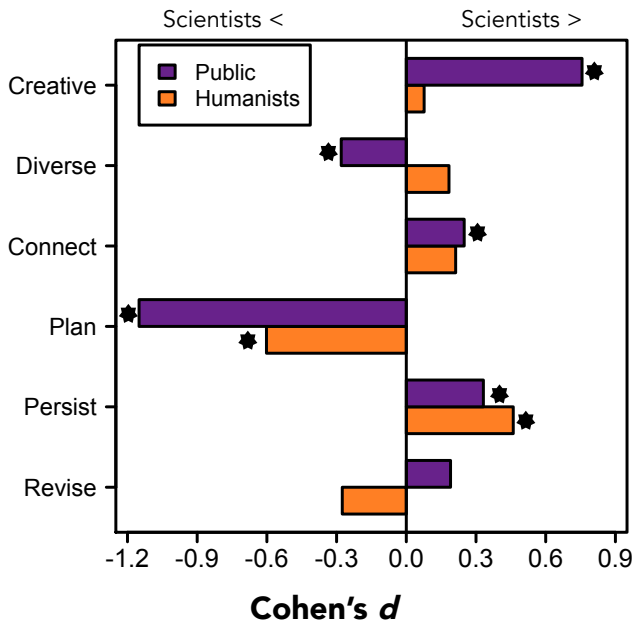
Figure 2. Comparing rankings of scientists to those of people from the general public and humanists with a measure of effect size (Cohen's *d*). Bars that extend to the right indicate that scientists ranked the statement as more important (purple: compared to participants from the general public; orange: compared to humanists); bars that extend to the left indicate that scientists ranked the statement as less important. Stars indicate a statistically significant difference between scientists and the comparison group.

Figure 2 shows how scientists ranked the statements compared to the other two groups of participants by plotting a measure of effect size (Cohen's *d*). As shown, scientists tended to place less emphasis on planning than humanists, $t(154) = 3.69$, $p < .001$, or participants from the general public, $t(609) = 10.21$, $p < .001$. On the other hand, scientists tended to place more emphasis on persistence than humanists, $t(154) = 2.82$, $p = .005$, or participants from the general public, $t(609) = 2.95$, $p = .003$. The two groups of academics ranked the other four statements similarly. Scientists and the sample from the general public ranked three of the remaining four statements differently: scientists placed less emphasis on seeking diverse sources of insight, $t(609) = 2.49$, $p = .013$, but more emphasis on finding connections between seemingly unrelated ideas, $t(609) = 2.21$, $p = .027$, and creativity, $t(609) = 6.72$, $p < .001$; these two groups placed similar emphasis on revising theories in light of new data.

A second analysis tested whether people who considered science to be more like a *puzzle* ranked *puzzle*-congruent statements as more important than people who considered science to be more like *mountain climbing*. A mixed-effects linear model was fit to the data with predictors for statement type (*puzzle*- or *mountain*-congruent), metaphor choice (*puzzle* or *mountain*), and sample (scientists versus general public), which revealed an interaction between the statement type and metaphor choice, $\chi^2(1) = 4.07$, $p = .044$. Contrary to our initial hypothesis, preference for the *puzzle* metaphor was associated with prioritizing the *mountain*-congruent statements (and vice versa). This pattern was consistent across both groups of participants (i.e. there was no 3-way interaction between statement type, metaphor choice, and sample), $\chi^2(1) = 1.39$, $p = .239$ (see Figure 3). Of note, the analysis also revealed an interaction between sample and statement type, $\chi^2(1) = 38.44$, $p < .001$, such that scientists tended to rank the *puzzle*-congruent statements as more important, regardless of preferred metaphor, than participants from the general public.
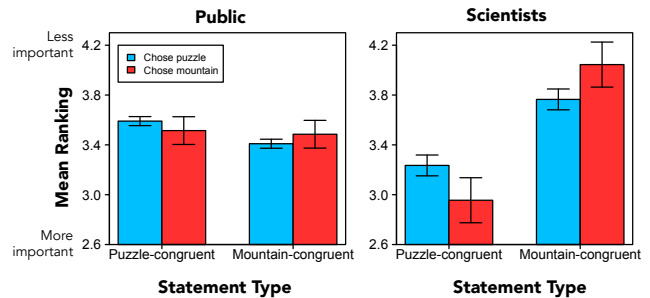

Figure 3. Mean ranking of statements by type (*puzzle*- or *mountain*-congruent) and metaphor chosen (*puzzle* or *mountain*) for the two samples analyzed (from the general public and of scientists).

People who preferred the *mountain* metaphor were particularly likely to rank "finding connections" ($M = 3.69$, $SD = 1.52$) as more important than people who preferred the *puzzle* metaphor ($M = 4.15$, $SD = 1.53$), whereas people who preferred the *puzzle* metaphor were particularly likely to rank "planning" ($M = 3.09$, $SD = 1.91$) as more important than people who preferred the *mountain* metaphor ($M = 3.44$, $SD = 2.00$).

This finding is consistent with the view that the two metaphors capture structured ways of thinking about the scientific process that are different from one another. People who reported thinking science was a *puzzle* ranked the statements in a systematically different way than people who reported thinking science was a *mountain*. However, the finding is inconsistent with how we had mapped the entailments of the metaphors onto the statements, suggesting that the intuitions of language researchers may differ from how metaphoric language is used and understood in the real world.

It is also possible that behaviors on the two tasks—choosing a metaphor and ranking the statements—were complementary. People may have had a sense of the limitations of their preferred metaphor, which they expressed in the rank-order task (or vice versa). For instance, a participant may believe that finding connections and planning are both vital to the scientific process. Such a belief may lead this participant to choose the *puzzle* metaphor as more appropriate (because it captures the value of finding connections) and also to rank planning highly (since it is captured less well by the *puzzle* metaphor). In

other words, participants may consider many aspects of science to be important, not just those that are consistent with the entailments of a single metaphor. This may lead them to express a preference for one metaphor, as required by our forced-choice task, and then to emphasize inconsistent entailments in the rank-order task.

Scientific Attitude Inventory A similar set of analyses was applied to data from the SAI II. First, we found differences in the extent to which participants endorsed the six dimensions measured by the survey, $\chi^2(5) = 1637.2$, $p < .001$: participants agreed most strongly with statements about the necessity of adopting an empirical mindset, followed by statements about the importance of public outreach, about an interest in doing scientific work, that the scope of science is limited to observable phenomena, and finally, that the end goal of science is ideas (rather than a tangible product like technology).
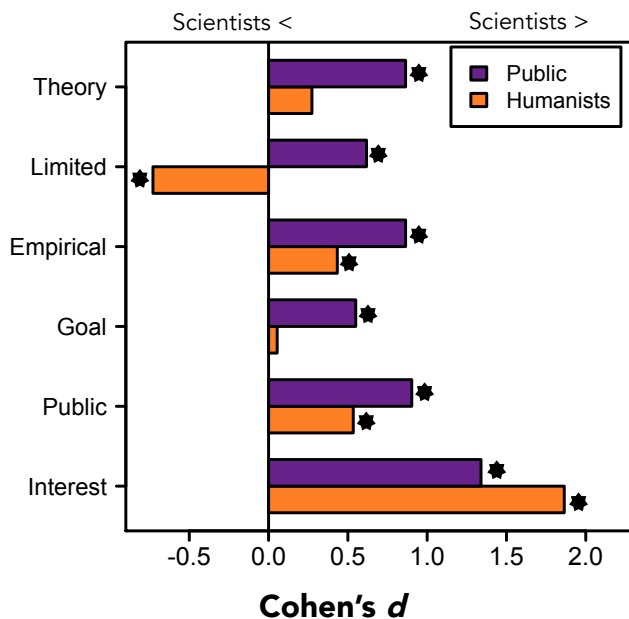

Figure 4. Comparing ratings of scientists to those of people from the general public and humanists with a measure of effect size (Cohen's *d*). Bars that extend to the right indicate that scientists rated the dimension as more important (purple: compared to participants from the general public; orange: compared to humanists); bars that extend to the left indicate that scientists rated the dimension as less important. Stars indicate a statistically significant difference between scientists and the comparison group.

Second, the analysis revealed differences in how the three samples rated the statements, $\chi^2(2) = 196.57$, $p < .001$. Overall, scientists tended to endorse the statements more strongly than participants from the general public, $B = .45$, $SE = .03$, $p < .001$, and humanists, $B = .17$, $SE = .04$, $p < .001$. Humanists endorsed the statements more strongly than participants from the general public, $B = .28$, $SE = .04$, $p < .001$.

Third, the analysis revealed an interaction between ratings of the dimensions and the three samples, $\chi^2(10) = 199.57$, $p < .001$. As shown in Figure 4, scientists endorsed all six dimensions more strongly than participants from the general public, ps $< .001$. Compared to humanists, scientists more strongly endorsed having an empirical mindset, the view that public support is important, and were more likely to say they enjoyed doing scientific work, ps $< .01$, whereas humanists were more likely to view science as being limited to the study of natural phenomena, $p < .001$. The two groups of academics expressed similar views about scientific theorizing and about the end-goal of scientific work.
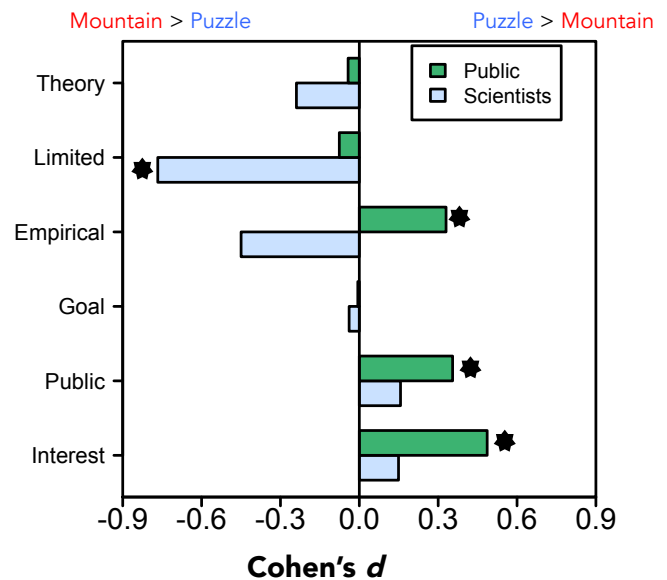

Figure 5. Differences in ratings by metaphor chosen for people from the general public and scientists, illustrated by a measure of effect size (Cohen's *d*). Bars that extend to the right indicate higher ratings among people who preferred the *puzzle* metaphor; bars that extend to the left indicate higher ratings among people who preferred the *mountain* metaphor.

Finally, we tested for a relationship between the metaphor participants preferred and ratings of the dimensions (excluding data from humanists). As illustrated in Figure 5, among scientists, preference for the *mountain* metaphor was associated more strongly with the view that scientific study is limited to natural phenomena, $t(91) = 2.72$, $p = .009$; among the general public, preference for the *puzzle* metaphor was associated with a more empirical mindset, $t(516) = 2.35$, $p = .019$, the view that public support is important, $t(516) = 2.53$, $p = .012$, and a stronger interest in doing scientific work, $t(516) = 3.46$, $p < .001$. These results provide further evidence that the two metaphors capture different ways of thinking about the scientific process, but also suggest that what exactly is captured by the metaphors is different for scientists and non-scientists.

Discussion

Skepticism towards scientific research can be found among the general public as well as politicians on both sides of the political aisle, raising significant concerns about the current quality of science education and communication. As an initial step towards addressing this critical issue, we aimed to illuminate how people think about the scientific process itself, contrasting the beliefs of scientists with those of academics in the humanities and members of the general public, and exploring the role of metaphor in representing broad conceptual viewpoints.

We found several notable similarities and differences in how scientists and non-scientists conceptualized the scientific process. Of particular interest, scientists tended to prioritize persistence more than the two samples of non-scientists, who tended to prioritize planning more than the scientists. This suggests that being immersed in scientific work makes salient the determination needed to complete research projects. Simply hearing about scientific findings in the classroom or the news, on the other hand, may make it seem like scientists spend most of their time planning. In line with this distinction, scientists were more likely than non-scientists to think science was like *scaling a mountain*, although all three groups showed an overall preference for the *puzzle* metaphor.

Individuals who preferred the *puzzle* metaphor tended, counter-intuitively, to value statements about science that were designed to be congruent with the *mountain* metaphor (and vice versa). Preference for the *puzzle* metaphor was also associated with a more empirical mindset, the view that public support is important for scientific progress, and an interest in doing scientific work—but only among the general public, not among scientists. These findings imply that metaphors for science will be interpreted differently depending on one's scientific knowledge and expertise. The findings also highlight the importance of identifying the systems of knowledge associated with metaphor use rather than merely assuming them (Keysar & Bly, 1995; McGlone, 2011; Murphy, 1996, 1997).

Future research in this area should explore additional metaphors for scientific inquiry. For instance, one scientist in the study suggested that science was more like *map-making* or *exploring* than it was like *working on a puzzle* or *scaling a mountain*. Future work should also investigate whether these metaphors can causally influence how people think about the scientific process.

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