Even though we can't see or touch time, we are able to construct mental representations that allow us to reason about it. How do we do this? One possibility is that our knowledge about abstract concepts like time is grounded in experiences with more concrete domains (Lakoff & Johnson, 1980). For example, we have deep experiential knowledge of space, and we understand time by mapping it onto this knowledge. But how do we learn these space-time mappings? Some work has suggested that prelinguistic infants show overlapping associations for spatial length and duration, one aspect of time (Srinivasan & Carey, 2010). Other work has suggested that cultural practices such as writing direction (Bergen & Lau, 2012) or cultural focus (de la Fuente et al., 2014) influence the way we map time onto space in our minds.

Another possibility for how we learn culturally-specific mappings between space and time is through patterns in language. It is common across many languages to use spatial metaphors for time (e.g. look *forward* to the future), and research has shown that in many cases, the way we talk about time is consistent with our mental representations of time (Boroditsky, 2011). For instance, Mandarin includes vertical metaphors for time, and behavioral experiments reveal that Mandarin speakers associate time with vertical space (Boroditsky, Fuhrman, & McCormick, 2011). By contrast, speakers of English, which does not commonly talk about time vertically, show no evidence of vertical representations.

Although there is correlational evidence that metaphors for time in language predict speakers' non-linguistic space-time associations, this kind of data cannot tell us whether language reflects pre-existing mental representations, or **whether language is a causal force that shapes the way we think about time**. If metaphors in language can indeed shape thought, then learning to use a new set of metaphors should change the way people think about time. Therefore, in the proposed experiments, participants will learn vertical metaphors before completing a nonlinguistic temporal task to examine their representations of time. The studies proposed here build on work from an experiment that I have already conducted.

Experiment 1: Participants were taught to use metaphors describing temporal sequences as occurring vertically (e.g. *lunch is higher than dinner)*, and then practiced by filling in the metaphoric word in 90 sentences. Next, they did a sequential image task: they saw two related images, one at a time, and pressed a key to indicate whether the second image came at an earlier or later time point than the first. Crucially, the response keys were arranged vertically so that the "earlier" response key was either congruent or incongruent with the metaphor the person learned, manipulated between blocks and within-subjects.

I found that when key mapping and metaphor were congruent, people were significantly faster to make a sequential decision than when the mapping and metaphor were incongruent. This suggests that linguistic metaphors for time have a causal influence on mental representations. The following experiments address questions arising from Exp. 1.

Future Experiments - Experiment 2: My first goal is to explore the mechanism through which metaphor shapes representations. **Does the representation rely on internal language use,** such that the person must be subvocally thinking of the words "higher" or "above" while completing the task, **or is the representation mediated by non-linguistic spatial representations?** To answer this question, I will use the same paradigm as in Exp. 1, but the sequential image task will be paired with verbal and spatial interference tasks. The difficulty of the interference tasks will be calibrated for each person to ensure that they are matched for difficulty (following Frank et al., 2012). To ensure participants are not subvocally generating the metaphors, they will remember a string of letters while completing the sequential image task. In other trials, they will remember a spatial arrangement of blocks to tax their spatial working

memory. If metaphor's effect on mental representation relies on language use in the moment, verbal interference should eliminate the difference between congruent and incongruent trials; otherwise, the difference should remain. Similarly, if the representation induced by language is primarily spatial, spatial interference is likely to eliminate the effect, but otherwise, the difference between congruent and incongruent trials should remain.

Experiment 3: The previous experiments rely on an explicitly taught new metaphor: participants are told that they are learning a new way of talking about time and undergo a thorough training session. However, this is not how we learn space-time metaphors in natural language. **Would a more natural, subtle instantiation of a new metaphor also give rise to new spatial representations of time?** In order to test this, we will embed vertical metaphors in a passage about sequences of life events. For example: "There is a group of people who say that when a person is born, he is at the very *top* of a mountain. As time goes on, he gradually *descends*…" After reading this passage, participants will complete the sequential image task from Exp. 1 to see if the more natural, implicit exposure to space-time metaphors is sufficient for inducing a particular spatial representation of time.

In the studies above, effects of learning new metaphors are measured in response-time association tasks. If learning new metaphors indeed creates productive new representations and cognitive habits, then it should be possible to see these effects across a range of other dependent measures. For example, **would learning new metaphors guide people's interpretation of ambiguous visual scenes** that yield a different interpretation if examined from bottom to top as opposed to top to bottom? Would learning to place the future or the past above (in more visible space) **make that time period seem more prominent or important** in people's minds? Might eye-tracking reveal that when hearing about sequences, **people look up or down depending on where those events are represented** by the metaphor?

Broader Impacts: At first glance, metaphor may seem to be merely a rhetorical flourish, but metaphors are widespread and form a foundation for many of the abstract concepts we reason about. They pervade education (e.g., the immune system *defends* the body from *invading* viruses), policy (the economy needs to be *jump started*), and business (climbing the corporate *ladder*). The relationship between metaphor and thought has been applied by scholars in diverse fields including military intelligence (IARPA Project), law, and politics. Overall, this work deepens our understanding of the rich set of relationships between language and thought.

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