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Beyond ATOM. Space and time in the human mind

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Space and time are closely linked in the human mind, but the nature of this relationship is still debated. According to one proposal, "A Theory of Magnitude" (ATOM; Walsh, 2003, *TiCS*), space and time are linked in the mind by virtue of sharing a common magnitude system located in the right Intra Parietal Sulcus (rIPS). This neural metric has been hypothesized to support representations of magnitude across several prothetic (i.e. quantitative) domains such as brightness, loudness numerosity, space, and time. Evidence adduced to support ATOM comes, most often, from studies showing priming or interference between two or more prothetic domains (e.g., space influencing time judgments), or showing overlap between the neural correlates of magnitude judgments in these domains.

ATOM makes two predictions about the relationship between temporal and non-temporal magnitudes:

1. Relationships between time and other prothetic domains should be roughly symmetric (e.g. space should influence time about as much as time influences space). Although this prediction is left implicit in most of ATOM's formulations, it is difficult to predict any particular asymmetry (e.g. space>time or time<space) on the basis of a single shared magnitude metric.
2. Bigger or more intense stimuli should be perceived to last longer than smaller or less intense ones. This "more of X is more time" relationship is domain-general, and should hold across all prothetic domains. That is, magnitude variations in brightness, loudness, and spatial length (etc.) should all have similar effects on perceived duration.

We challenge these predictions in a series of experiments. First, we show that the relationship between space and time is characterized by a robust asymmetry. Across many experiments, space influences time more than vice versa. This asymmetry is not due differences in perceptual discriminability across domains, or other task related artifacts. Second, we show that space has a privileged link with temporal representations not shared by other prothetic domains. Brightness and loudness are not related to time in the same way that space is, challenging the hypothesis that space-time relationships are the product of a domain-general magnitude system.

In conclusion, we argue that much of the data adduced to support ATOM are better explained by alternative theories of cross-domain relationships: Metaphor Theory, a proposal that predates ATOM by two decades, and A Theory Of Change (ATOC), a new proposal that we recently introduced.