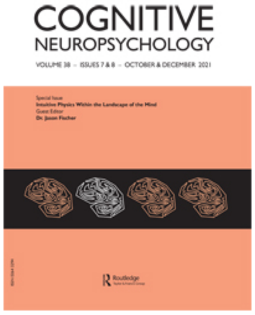


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# The building blocks of intuitive physics in the mind and brain

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INTRODUCTION

# The building blocks of intuitive physics in the mind and brain

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**ABSTRACT**
There has been a recent wave of interest in understanding the mental processes underlying *intuitive physics* – our ability to apprehend the physical structure of the world and anticipate how objects will behave as a scene's dynamics unfold. While work to uncover the neural mechanisms of intuitive physics is just in its beginnings, vibrant lines of neuropsychological research are investigating the many facets of cognition intimately linked with the 'physics engine in the mind'. This special issue brings together a collection of papers that delve into the interactions between intuitive physics and related domains such as audiovisual scene analysis, action planning, and decision making, providing a view of the larger landscape of mental processes that allow us to predict how physical events will unfold in the next moments and plan our behaviors accordingly.

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What do you see in Figure 1(a)? Some familiar items grab the eye: a full dinner plate complete with corn, tomatoes, and an orange for dessert, along with a glass of Grenache to complement the course. Before examining those items in detail, though, perhaps you *felt* something else on first glance – a sense that the scenario is precarious and bound to fall into disarray in short order. If you saw this scene from across the room, you might wince in anticipation of shattered glass and wine splashed across the table, or you might hurry over to stabilize the tray before it falls.

Consider some further questions:

- Was your reaction to the physical arrangement based on your recollection of mechanical principles from Introductory Physics?
- Did you think through the various physical relationships among the objects before getting a sense that the arrangement might be unstable?
- Would a two year old have the same reaction you did? Would a housecat?

Our daily lives play out in a world governed by the laws of physics. Every action we take has an intended physical consequence, and many of our decisions hinge on assessments of physical properties and dynamics (*"Are these stairs too slippery to walk down safely?"*; *"Does this chair seem durable enough to last a few years?"*). Physical reasoning is at the heart of explicit decisions like these, but more often our physical inferences proceed silently in the background. While we're thinking about whether any dinner guests have food allergies and whether to use the floral print placemats or the beige ones, we're performing impressive feats of physical reasoning by stacking dishware and rearranging items in the fridge. These collective abilities to apprehend the physical structure of everyday scenes and infer how their dynamics will play out in the immediate future are termed *intuitive physics*.

For such a fundamental aspect of daily mental life, the scientific study of intuitive physics has only picked up steam over the past decade, with a relatively small (but foundational) collection of studies carried out in the preceding fifty years. We are currently in the midst of a wave of new work to uncover the mental algorithms and neural mechanisms underlying intuitive physics, but the findings of early studies of intuitive physics remain some of the most stunning. For example, McCloskey and colleagues (McCloskey et al., 1980) asked college students to diagram the

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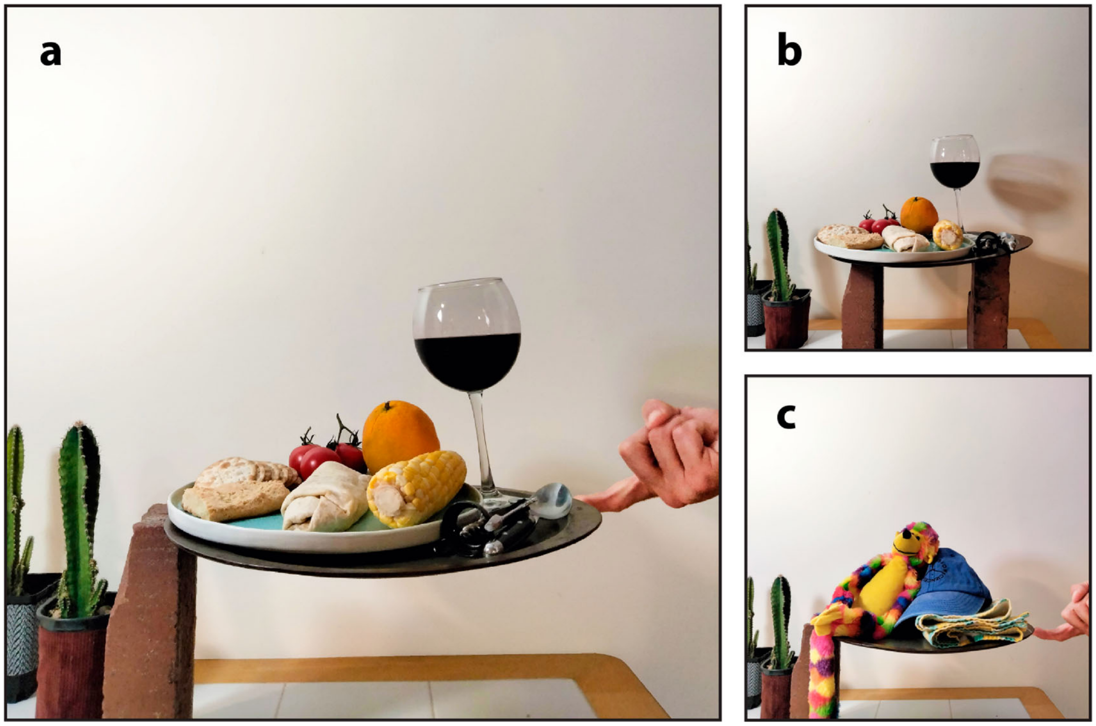


**Figure 1.** Our intuitive sense of physical stability. (**a**) Why is this person balancing a tray with one finger? No one knows for sure, but we all agree it's a bad idea. (**b**) That's better. (**c**) Also better than the scenario in **a**, this time because the consequences of a topple would be less dire.

path an object would take when it was released from circular motion (e.g., when a ball bearing propelled through a spiral-shaped tube exited the other end). They found that people's reports were often starkly at odds with how natural physical dynamics would play out. A substantial portion of participants – even those who had completed coursework in physics – drew a curved path as though the tube imparted an impetus to the ball that sustained its curvilinear motion for the extent of its flight. Over time, more examples of faulty physical reasoning were documented. Research participants often report than an object dropped by someone in motion will fall straight downward (Caramazza et al., 1981), and they markedly overestimate the mass of a moving object that strikes a stationary one (Gilden & Proffitt, 1989). Qualitative errors in physical reasoning are still being discovered (Ludwin-Peery et al., 2020), and they present a nagging puzzle: how is it that people can give wildly incorrect responses in scenarios like those above and yet deftly interact with the world in their daily activities? Some possible answers are emerging from fresh perspectives on the mental algorithms underlying our physical inferences, including the ideas put forward by a number of papers in this special issue. But the overarching goal in assembling this special issue goes beyond just investigating the mechanisms of physical inference. As the body of work on intuitive physics grows, it is increasingly apparent that it comprises an integrated collection of processes that take their inputs from multiple sensory modalities and interface with a wide range of other mental systems. The central aim of this special issue is to bring together a collection of work from the facets of perception and cognition that inform – and are informed by – intuitive physics. These studies might not otherwise be found in the same journals alongside one another; however, collectively they give a broad-scale view of how intuitive physics is situated within the mind and brain.

A number of papers in this special issue grapple with the puzzle laid out above: why do people's physical judgments sometimes seem to be fundamentally mistaken while at other times they reveal an accurate and nuanced implicit understanding of physical behaviour? In this issue, Bass et al. (Bass et al., 2021) build on the recent proposal that we perform physical inference via forward simulation of object behaviour under Newtonian laws (Battaglia et al., 2013; Ullman et al., 2017). This notion might seem to be at odds with the various misconceptions that people display when describing how physical events will play out, but a simulation need not be perfect – the veracity of the output is constrained by the quality and contents of the inputs. Bass et al. (Bass et al., 2021) show that if we assume people don't always simulate ALL elements in a scene (particularly the ones they're not asked directly about by the experimenter), the outcomes of noisy Newtonian simulations can match the pattern of errors in participants' reports. Ahuja et al. (Ahuja et al., 2021) further show that the traces of simulation can be found in the visual cortex – mentally simulating a scene leads to activity in motion processing brain regions that matches the pattern of neural response in these regions when an individual is actually viewing the physical dynamics.

Another source of errors in physical reasoning could come from the format in which people express their predictions. In the bulk of intuitive physics work so far, participants are asked to make categorical judgments or provide explicit descriptions of physical behaviour rather than producing natural actions that are guided by physical predictions. In this special issue, Fischer & Mahon (Fischer & Mahon, 2021) argue that intuitive physics is embedded within a mental system for evaluating and selecting first-person actions on the world based on their anticipated physical consequences. Under this view, systematic errors can arise in explicit judgments of physical outcomes when queried in a format that does not match the native egocentric, action-oriented representations produced by our physical inferences. Indeed, the findings of Neupärtl et al. (Neupärtl et al., 2021) provide direct evidence that physical predictions expressed through natural actions accord better with Newtonian laws than those expressed through arbitrary responses. The distinction becomes particularly apparent in studies that experimentally distinguish between cases where people must reason de novo about the physical outcomes of actions from those where people can draw on semantic knowledge about familiar scenarios. Tessari et al. (Tessari et al., 2021) highlight the distinct routes used for reproducing familiar actions based on semantic representations in long-term memory vs. novel actions that must be prepared via online visuomotor transformations, and they shed light on the processes that modulate route selection. Likewise, engaging with familiar vs. unfamiliar tools draws on distinct neural processes that rely on stored semantic information vs. online mechanical reasoning, respectively. In their review of intuitive physics in neurodegenerative diseases, Baumard et al. (Baumard et al., 2021) highlight how the two systems can by differentially affected in different clinical populations.

At the foundation of our predictions about physical behaviour is a representation of the physical structure of a scene – the constituent objects and scene elements and the physical properties that dictate how they behave. Two papers in this special issue examine how information about the physical structure of the world is sampled, and both papers look beyond the visual cues that are most often studied. Lowe et al. (Lowe et al., in press) investigate the neural processing of auditory events. In the auditory domain, physical scene and object structure is revealed as events unfold – the dull thud of a heavy door slamming closed or the crisp ring of a wine glass when it bumps the bottle. Lowe et al. (Lowe et al., in press) track these auditory representations in the brain as they evolve over time, transforming from basic representations of acoustic features to semantic representations that can guide physical predictions. Jordan et al. (Jordan et al., 2021) take another angle on studying how physical scene structure is discovered, and they delve into the evolutionary origins of the intuitive physics system at the same time. They investigate whether capuchin monkeys use their interactions with objects to seek out information about unknown physical properties.

The collection of work in this special issue highlights the multifaceted nature of intuitive physics and how broadly it interfaces with other systems in the brain. Studying the intuitive physics system within the larger landscape of cognition will be key to understanding its architecture, and the studies here make important advances in that direction.

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## References

Ahuja, A., Desrochers, T. M., & Sheinberg, D. L. (2021). A role for visual areas in physics simulations. *Cognitive Neuropsychology*, *38*(07-08).

Bass, I., Smith, K. A., Bonawitz, E., & Ullman, T. D. (2021). Partial mental simulation explains fallacies in physical reasoning. *Cognitive Neuropsychology*, *38*(07-08).

Battaglia, P. W., Hamrick, J. B., & Tenenbaum, J. B. (2013). Simulation as an engine of physical scene understanding. *Proceedings of the National Academy of Sciences*, *110*(45), 18327–18332. https://doi.org/10.1073/pnas.1306572110

Baumard, J., Lesourd, M., Guezouli, L., & Osiurak, F. (2021). Physical understanding in neurodegenerative diseases. *Cognitive Neuropsychology*, *38*(07-08).

Caramazza, A., McCloskey, M., & Green, B. (1981). Naive beliefs in "sophisticated" subjects: Misconceptions about trajectories of objects. *Cognition*, *9*(2), 117–123. https://doi.org/10.1016/0010-0277(81)90007-X

Fischer, J., & Mahon, B. Z. (2021). The 'tool processing network' is a part of a domain-specific system for physical reasoning. *Cognitive Neuropsychology*, *38*(07-08).

Gilden, D. L., & Proffitt, D. R. (1989). Understanding collision dynamics. *Journal of Experimental Psychology: Human Perception and Performance*, *15*(2), 372–383. https://doi.org/10.1037/0096-1523.15.2.372

Jordan, E., Völter, C., & Seed, A. (2021). Do capuchin monkeys (sapajus apella) use exploration to form intuitions about physical properties? *Cognitive Neuropsychology*, *38*(07-08).

Lowe, M. X., Mohsenzadeh, Y., Lahner, B., Charest, I., Oliva, A., & Teng, S. (in press). Cochlea to categories: The spatiotemporal dynamics of semantic auditory representations. *Cognitive Neuropsychology*, *38*(07-08).

Ludwin-Peery, E., Bramley, N. R., Davis, E., & Gureckis, T. M. (2020). Broken physics: A conjunction-fallacy effect in intuitive physical reasoning. *Psychological Science*, *31*(12), 1602–1611. https://doi.org/10.1177/0956797620957610

McCloskey, M., Caramazza, A., & Green, B. (1980). Curvilinear motion in the absence of external forces: Naïve beliefs about the motion of objects. *Science*, *210*(4474), 1139–1141. https://doi.org/10.1126/science.210.4474.1139

Neupärtl, N., Tatai, F., & Rothkopf, C. (2021). Naturalistic embodied interactions elicit intuitive physical behavior in accordance with Newtonian physics. *Cognitive Neuropsychology*, *38*(07-08).

Tessari, A., Proietti, R., & Rumiati, R. I. (2021). Bottom-up and top-down modulation of route selection in imitation. *Cognitive Neuropsychology*, *38*(07-08).

Ullman, T. D., Spelke, E., Battaglia, P., & Tenenbaum, J. B. (2017). Mind games: Game engines as an architecture for intuitive physics. *Trends in Cognitive Sciences*, *21*(9), 649–665. doi:10.1016/j.tics.2017.05.012