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Any way the wind blows: Children's inferences about force and motion events

Nathan R. George [a,*], Tilbe Göksun [b], Kathy Hirsh-Pasek [c], Roberta Michnick Golinkoff [d]

[a] Gordon F. Derner School of Psychology, Adelphi University, Garden City, NY 11530, USA
[b] Department of Psychology, Koç University, Istanbul 34450, Turkey
[c] Department of Psychology, Temple University, Philadelphia, PA 19122, USA
[d] School of Education and Departments of Psychology and Linguistics, University of Delaware, Newark, DE 19716, USA

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ABSTRACT

Göksun, George, Hirsh-Pasek, and Golinkoff (2013) used *force dynamics*, or the semantic categories defined by spatial arrays of forces, to study the development of preschoolers' predictions about the outcomes of forces working in concert. The current study extends this approach to problems requiring inferences about causal factors. In total, 30 5- and 6-year-old children were asked to identify and coordinate forces to achieve a result. Problems varied in the number and orientation of forces, mirroring spatial arrays characteristic of categories like *prevent* (i.e., opposing forces). Children successfully inferred causes of single- and dual-force events, performing best when problems reflected the spatial arrays of forces described in language. Results support force dynamics as a valuable framework for the development of force and motion representations.

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Introduction

The mobile child is a mecca of force, whether kicking a ball around a playground, hurling toys during a tantrum, or pulling on his mom's shirt as she tries to leave the room. Although each of these

* Corresponding author.
E-mail address: ngeorge@adelphi.edu (N.R. George).

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forces affects the world, the primary approach in the psychology of causal perception has been to consider forces in isolation (e.g., Baillargeon, 1994; Cohen, Rundell, Spellman, & Cashon, 1999; Leslie, 1982, 1984; Oakes & Cohen, 1990; Rakison & Krogh, 2012; Saxe, Tenenbaum, & Carey, 2005; Saxe, Tzelnic, & Carey, 2007). This approach overlooks the tapestry of forces that contribute to the outcome of an event. Whether the child *keeps* his mother from leaving or she exits *despite* the child's efforts depends not only on the strength of the child's tugging but also on its relation to the force of the mother walking. As children's causal knowledge develops, they must learn to interpret their own actions and the forces around them in this broader context.

Defined as the interaction between entities in space resulting from multiple forces (Talmy, 1988; Wolff, 2003, 2007), force dynamics theory encompasses not only simple cause–effect relations but also these scenarios in which two or more forces affect the trajectory of an entity in an event. The semantic categories of force dynamics such as *enable* and *prevent* yield a useful framework with which to look beyond isolated causes and allow for a more systematic and complex view of interacting forces in space. Recent research shows that the development of children's predictions about single- and dual-force events is captured well by these categories, with representations building from single-force *cause* events to more complex *enabling* and ultimately *preventative* interactions (Göksun, George, Hirsh-Pasek, & Golinkoff, 2013). We extend this analysis by considering another facet of children's representations of caused motion: inferring causers from effects. Inferring causers in the world, such as the presence and direction of wind from the curved path of a golf ball in flight, is an essential aspect of navigating and accurately conveying information about force and motion. We ask whether the patterns observed in children's predictions extend to their ability to infer causers from observed effects. Our aim is to show that inferences about caused motion, much like predictions, emerge categorically in a manner supported by one force dynamics framework developed from the linguistic literature.

Force dynamics

Research in event perception traditionally emphasized the perception of causality from a Michottean perspective (Michotte, 1963), studying direct causal events in which an object in motion (i.e., an agent) contacts a stationary object (i.e., a patient), causing the patient to immediately move along the agent's trajectory. The spatiotemporal contiguity between the paths of the two objects creates the perception of causality, a finding consistently supported and extended (e.g., to state change events) by work with both adults (e.g., Choi & Scholl, 2006; Fugelsang, Roser, Corballis, Gazzaniga, & Dunbar, 2005; Schlottmann, Ray, Mitchell, & Demetriou, 2006) and infants (e.g., Cohen & Amsel, 1998; Leslie & Keeble, 1987; Muentener & Carey, 2010; Newman, Choi, Wynn, & Scholl, 2008; Rakison & Krogh, 2012; Saxe et al., 2007). These studies are typically in support of a physicalist account of causal perception, in which the transmission of some physical quantity (e.g., energy, momentum) is considered necessary and sufficient for the perception of causal interactions (Shultz, 1982). Although such conclusions reflect a valid part of causal knowledge, they oversimplify the complexity of everyday causal interactions by overlooking additional factors relevant to the perception of causality, and specifically of caused motion. For example, a vital component of a causal motion event, *trajectory,* has received relatively little attention in the literature but is influential in adults' causal perception (Straube & Chatterjee, 2010; Wolff, 2007). Moreover, the environment often contains multiple kinetic forces working in concert, and theories of causal perception must scale up to consider how these defining features of causation are perceived in the context of these complex yet commonplace occurrences.

At least one framework addresses the limitations of previous physicalist accounts of causality. Built from the work of Talmy (1985, 1988) and Jackendoff (1990) in the domain of language, the *force dynamics model* asks how language might offer a window into the spatial arrays of coordinated forces that underpin caused motion events (Wolff, 2003, 2007). This model of force dynamics expands our view of caused motion, suggesting that we distinguish among conceptual categories of causal interactions: *cause* (one force that moves an object), *enable* (a secondary force that promotes the motion in the intended direction), *prevent* (a secondary force that hinders the motion in the intended direction), and *despite* (a secondary force that hinders the motion in the intended direction but is overcome by the primary force) (Wolff, 2007). For example, when a boat is moving toward a port, a secondary force,

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