Spatial Thinking and Reasoning
Across the College Curriculum

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As a spatial cognition researcher, I have long believed that spatial thinking is at the core of a large and diverse set of disciplines, and that mechanisms of spatial thinking like reference frames may serve as a valuable connecting entity that enable us to address important research questions in an inter-disciplinary manner. Reference frames are representations that are imposed on space, thereby providing structure by assigning orientation, direction, scale and distance to the space, and offering a means for locating people and things within the space. These parameters may be set by different sources of information, including people interacting in the space, environmental features within the space, or objects contained within the space. Moreover, multiple reference frames may be imposed simultaneously that configure different parts of the space, or that configure the space at different levels of granularity. This flexibility may be beneficial for the cognitive system because it enables representations that can be set up with respect to particular tasks and goals. It also therefore requires a set of skills that can operate on these varied representations, including the ability to translate between the different types of reference frames that are derived from different sources; the ability to coordinate reference frames at different levels or scales of space; the ability to effectively communicate locations of people and things within the space with respect to different frames of reference; and the ability to navigate within the space with respect to different reference frames. The importance of these processes and accordingly the skills required to master these processes should not be understated, because reference frames as mechanisms of spatial thinking appear within a wide set of disciplines, including engineering, linguistics, perception, anthropology, education, psychology, medicine, and architecture. This ubiquity suggests that reference frames are a central mechanism for thinking about space, and further that spatial thinking may be facilitated through training in the processes that operate on reference frames, with positive consequences that cut across these varied disciplines.

In my lab, reference frames serve as a central common element for ongoing collaborative inter-disciplinary projects. For example, in a project with Dr. Panos Antsaklis at Notre Dame (Aerospace/Mechanical Engineering), we are examining how spatial thinking and the allocation of spatial attention to the environment may change as a function of off-loading key cognitive functions from the human driver to the automatic control systems of the car. We are particularly interested in the phenomenon in which drivers steer toward a stopped vehicle on the side of a road when their attention is diverted to that location. One possible explanation is that the driver is trying to align their heading which may be encoded egocentrically with the location of the roadside object which may be encoded allocentrically. We are interested in solutions to this
phenomenon that may involve the car monitoring the heading and when a drift is detected, invoking an alert system or making automatic steering adjustment.

As another example, in a project with Dr. Marge Skubic at Missouri (computer science/engineering) we are designing an interface to facilitate the linguistic interaction between humans and robots in an eldercare setting in which a robot serves as an assistive device for the elderly. The focus is on the production and comprehension of spatial descriptions, and translating between the reference frames that are selected by the human to represent and communicate spatial locations, and the reference frames that are used by the robot to store location information about the environment and to navigate.

Other projects in the lab that involve reference frames include developing a diagnostic tool to identify whether patients suffering from apraxia (an inability to reach to a target) have deficits in the encoding of space according to egocentric or allocentric reference frames, and identifying how people judge how “roomy” a car feels, which requires a coordination between the representation of the space around the body with a representation of the interior space of a car. Finally, I have worked extensively with Tim Shipley at Temple/SILC and Christoph Hoelscher at University of Freiburg/SFB and Ruth Conroy Dalton at Northumbria on projects that include an examination of the reference frames that are used during navigation in new buildings, and a determination of how they are coordinated with the organization of the building and the strategies that participants employ.

A focus on reference frames as a key spatial skill was also readily apparent at CogSci2011 which was entitled “The expanding space of cognitive science,” and for which Tim, Christoph and I served as program chairs. One of our symposia explored spatial thinking across a variety of fields including architecture, medical visualization training, cartography, geography and geosciences.

Given my research background in spatial thinking with a focus on reference frames, my history of inter-disciplinary research, and my interest in promoting the examination of spatial thinking across a variety of disciplines, I have a keen interest in this workshop, and would welcome the opportunity to share my ideas and skills at facilitating cross-discipline discussion and collaboration. I could envision reference frames serving as an organizational tool across a curriculum, and would be interested in more formally discussing the underlying spatial skills and devising a means for including training in these skills across a range of disciplines. I have been formally trained and certified to teach K-8, and taught 4th grade for 2 years before graduate school; therefore, I have some practical experience at implementing curricula. I have also been teaching at the university level since 1994.