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DEVELOPING COMMONSENSE THEORIES OF MOTION: THE EMERGENCE OF MISCONCEPTIONS

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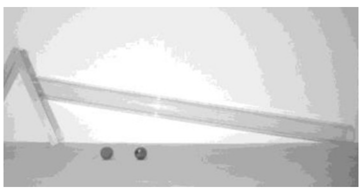
How developmental psychology underpins our understanding of knowledge formation and conceptual change in early science education has been of concern for some time now, fostering a strong partnership between the two disciplines. In particular, there has long been interest in the development of knowledge that stands in conflict with accepted scientific views, often posing challenges for educational instruction. To explore this, the work presented here is a review of past and current studies I have conducted in the field of early understanding of rudimentary scientific concepts relating to the everyday world. Specific focus is placed on the construction of so-called commonsense theories of motion and the role played by object and motion dimension properties in contributing to this early conceptualization. Further, consideration is given to some of the nonverbal underpinnings of such constructions by addressing recent work into tacit knowledge and the role of relative object weight in preschool search tasks. Potential implications for educational practice are discussed, as well as relevant directions for future research.

Keywords: early science, object motion, object properties.

CHILDREN'S CONSTRUCTIONS OF THEORIES OF MOTION

My research over the last years has been influenced by some of the oldest philosophical discussions around the laws that govern the physical world, leading all the way back to Aristotle, if not further. Many of these so-called commonsense theories that are based on personal experiences result in conceptions that are misaligned from accepted scientific views, and these often persist into adulthood. Based on this, I have been particularly intrigued to explore children's ideas about what factors they believe to be pertinent to object motion, and what commonsense theories, as a result, they develop. To date, this has focused on two key elements in their reasoning – the role played by various object variables and the understanding of different motion dimensions. These are aspects of physical science that many school curricula cover during early stages of education, providing a clear justification for exploring at what level and in what way intuitive knowledge about object motion and accepted scientific views in the classroom meet.

By initially working with primary school children aged 5 to 11 years it became evident that their understanding of object motion was dominated by the particular concept of object weight, more so than any other type of variable – for example, heavy objects, by virtue of their heaviness, are deemed to fall faster than lighter objects, but lighter objects are believed to roll faster along horizontal surfaces because of their lightness (Hast & Howe, 2012). Continued research also unveiled that object weight also impacts on children's understanding of speed change (Hast & Howe, 2013a). A central question at this stage was also whether ideas about object motion in the three dimensions are interrelated or independent from another in children's thinking. Both above studies indicated that the same children reason differently when it comes to considering objects' behavior in fall, along horizontals or down slopes. What is more, when using the same objects children consider the central role of object weight to still matter but to be constrained or facilitated according to the particular dimension in which the objects move (Hast & Howe, 2013b; also see Figure 1 for a summary of some of the main results). Consequentially, the notion was developed that children's constructions of commonsense theories of motion begin early, that these theories have a certain degree of robustness to them, and that they outline an understanding of the laws of the physical world that is incommensurate with accepted scientific views – thus presenting a challenge for the science classroom on a number of levels.



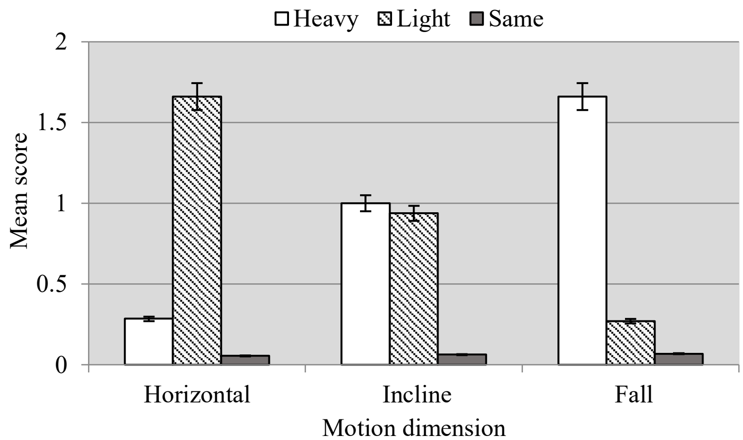


Figure 1. Apparatus used for "incline" condition in Hast and Howe (2013b), left, and overall predictions made by children in each condition about which ball would be faster, right.

However, subsequently it became clearer that children's reasoning is not informed by three separate dimensions but merely by two – noted through absence or presence of surface support – and that children appear to use these theory fragments either independently or in interaction with one another (Hast, 2014a, 2016). Collectively, this work was able to show that commonsense theories of object motion develop early in childhood, as they are present by the age of 5 years at the latest, and that these theories are constructed on the basis of both motion dimension and object variables. This certainly has implications for early science education, since one of its core purposes is to engage with and, where necessary, challenge the knowledge that children bring into the classroom. For instance, it raises questions about in what order certain topics should be taught, how conceptual change can be facilitated, and when this should be done. An answer to the first question might be that aspects of fall and horizontal motion should be taught first, and then of motion down inclines (cf. Hast & Howe, 2013b). But is there opportunity to foster conceptual change, and when should this be addressed?

TACIT RECOGNITION OF OBJECT MOTION

To begin addressing the notion of the nature of the commonsense theories outlined above – which includes their potential malleability in the context of conceptual change – my work has examined children's underlying understanding of object motion. That is to say, based on a plethora of studies with nonverbal infants there seemed good indication that children could potentially verbally state one prediction yet could, underlying, hold models that represent something else about the same phenomenon. Different studies that I conducted, again with 5- to 11-year-olds, have thus shown that there is indeed a difference between expressed beliefs about object motion and recognition of dynamic events (Hast & Howe, 2015, 2017; also see Figure 2 for a summary of the results). Children would explicitly predict one outcome – such as that heavy objects will fall faster than light ones because they are heavier – but would be able to accurately identify this as incorrect if shown through simulated events (and pick out those events that actually corresponded to the correct outcomes, even if these had not been predicted).

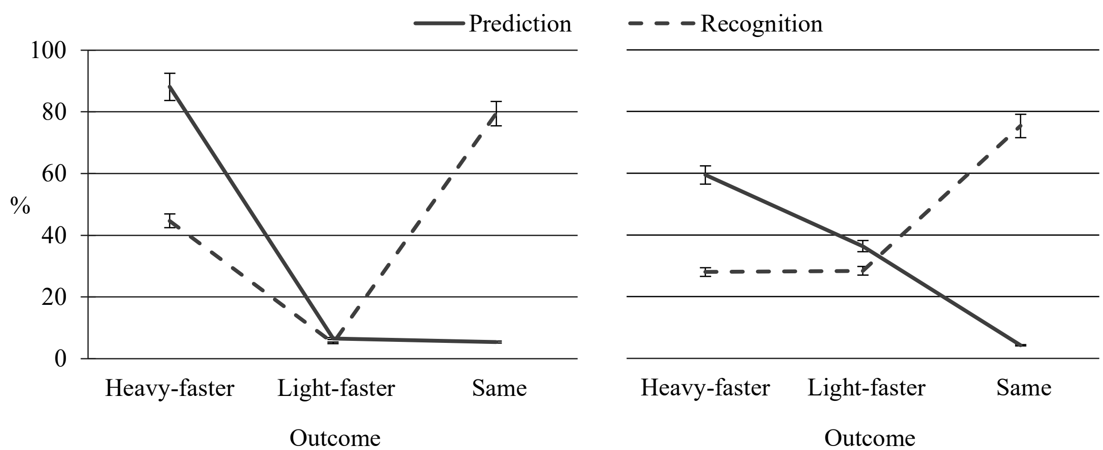


Figure 2. Overall outcomes of children's predictions and recognition of objects in fall (Hast & Howe, 2015), left, and of objects rolling down inclines (Hast & Howe, 2017), right.

Most notably, the predictions that children make in such tasks are clearly informed by their rigid beliefs about object properties, yet their ability to recognize and reject dynamic events to a high degree of accuracy suggests an intuitive grasp of such dynamic events does not draw on such object property beliefs. The work has given rise to the proposition that underlying tacit knowledge structures around object motion are stable, quite possibly from infancy onwards, but that expressed theoretical constructions are subject to change over time without impeding those underlying structures. This was particularly notable in the exploration of children's understanding of motion down inclines (Hast & Howe, 2017). In the context of education it is worth examining this in more detail. I devised a dual pathway model outlining the relationship among knowledge representations, with the significant difference being external contributors such as discourse, education and personal experiences (Hast, 2014b; also see Figure 3), but further research would do well to examine the specific contributor processes in more detail.

Applications of the theoretical work to classroom practice have already shown that utilizing underlying knowledge recognition principles has significant potential in promoting conceptual change in this field when working with primary school age children, and even adults (see Howe, Devine, & Taylor Tavares, 2013; Howe, Taylor Tavares, & Devine, 2016). However, it is important to not only consider the direct implications for child learning but also for classroom teaching. A recent qualitative examination of generalist primary school teachers' perceptions on the use of such intervention tools to guide conceptual development in the early science classroom (Hast, 2017a) has shown positive attitudes embedded within a model centered on trust and responsibility of learning. However, it also raised some concerns about the feasibility of incorporating such tools into practice, especially for teachers who lacked the necessary knowledge or confidence to teach physical science topics. Addressing these concerns will require a deeper understanding of teaching practice but also a clearer view of the underpinnings of the conceptions children bring to the classroom.

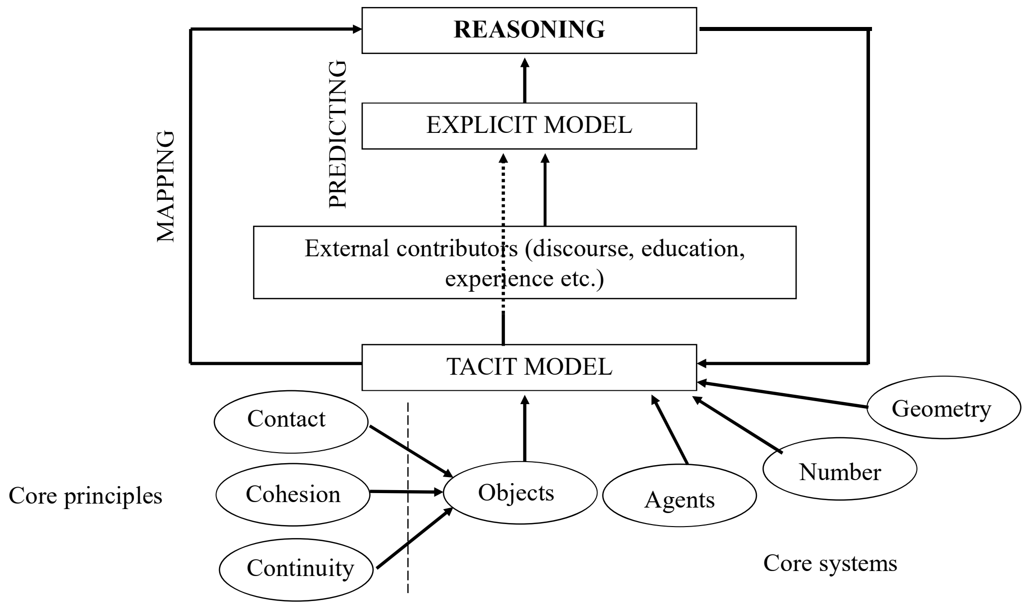


Figure 3. A dual pathway of reasoning about object motion (adapted from Hast, 2014b).

INDICATION FOR RISE IN MISCONCEPTIONS AMONG TODDLERS

More recently my work has, as a result, turned to examining potential beginnings of scientific misconceptions that may contribute to a clearer understanding of the development of commonsense theories of motion. To do so, I turned to working with toddlers aged 2 to 3½ years (Hast, 2018). Past work has consistently demonstrated a so-called gravity bias during this age: When a ball is released into a tube that goes down not in a straight line but in a curved shape, then they will search for the ball immediately beneath the tube rather than where it actually is. To illustrate, using the image on the left in Figure 4, if the ball is dropped into entry A at the top, then the ball will end up in drawer 2 at the bottom, but younger toddlers will be more likely to start searching in drawer 1 immediately beneath entry A. By 4 years of age they typically overcome this bias. But does having information about the relative heaviness or lightness of a ball influence toddlers' search behavior in any way – does the gravity bias, as outlined above, stay for longer or disappear sooner, and do they make fewer or more gravity error searches?

The results of this particular experiment showed that giving toddlers relative information about objects – that is, they are given both a heavy and a light ball to handle – impacts their search behavior. Most notably, they make more search errors guided by a gravity bias when they have relative information about the heaviness of an object and fewer errors in the context of relative lightness (see Figure 4) – but not if the relative information cannot be established. This pattern also only started to show significant effects with toddlers aged around 3 years and above, rather than sooner.

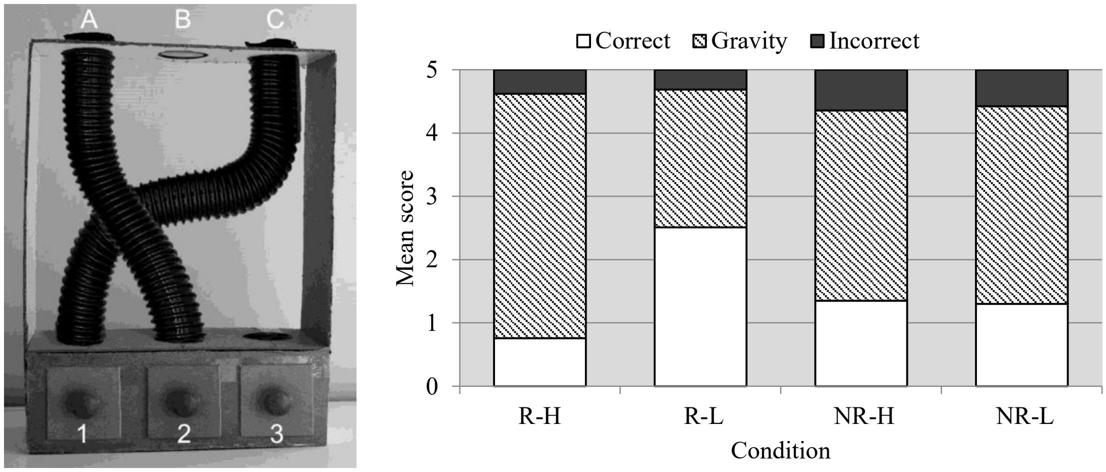


Figure 4. Apparatus used in Hast (2018), left, and overall outcomes of search behaviour, right.

A further study that I then conducted with toddlers aged 2, 2½ and 3 years (Hast, 2017b; see Figure 5) similarly showed that relative weight of objects impacted toddlers' search behavior in a task where they could not visually follow the motion. As in the gravity task above, toddlers were more likely to search incorrectly if they had information about the relative heaviness of the ball, and more likely to search correctly if they knew of the relative lightness, but only among the 3-year-olds. For the 2-year-olds this did not play any role. For the 2½ -year-olds only relative lightness mattered.

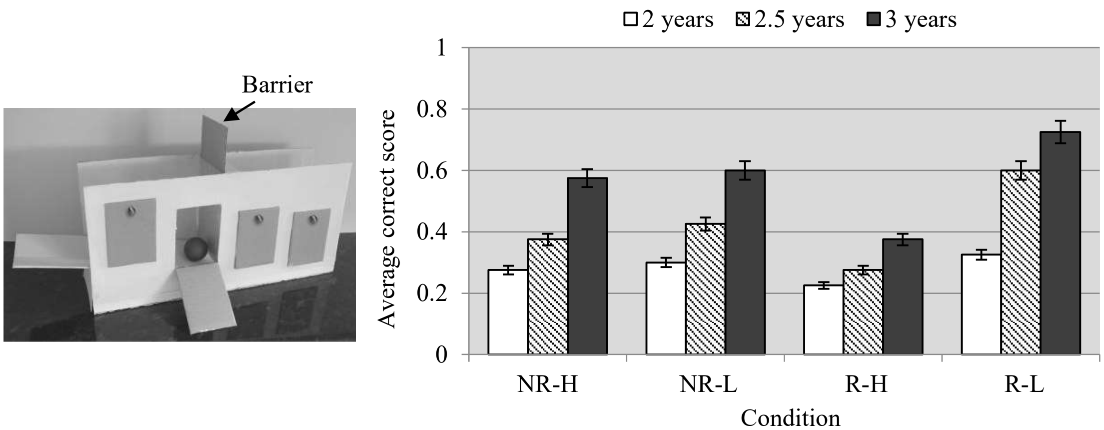


Figure 5. Apparatus used in Hast (2017b), left, and overall outcomes of search behaviour, right.

Both of these recent studies show that already at the preschool level children are incorporating object variable information into their reasoning about object motion. Taken with the previous studies covered in this paper there is thus good indication that children develop explicit understanding, either expressed in their reaching or in their verbal responses, that may give rise at early stages for some of the misconceptions around commonsense theories of motion that dominate the early science education literature. Importantly, while among 5- to 11-year-olds conceptions already seem to be fairly stable and therefore more likely to be resistant to conceptual change, their development seems to begin in the preschool phase and is a gradual process. Understanding this gradual change at the preschool level may not only have implications for the primary science classroom but for the engagement with basic scientific concepts in preschool settings – and, consequentially, for the practitioners in such settings.

CONCLUSION AND FUTURE DIRECTIONS

The various findings outlined in this paper collectively outline the complexity of scientific commonsense theory formation in early childhood that present a challenge in the science classroom. However, they also highlight the positive viewpoints provided through developmental psychology research that demonstrate potential for working towards more effective conceptual change approaches in the early science classroom. In particular, we see that the aspect of object weight plays an early role in the conceptualization of knowledge about motion, and that this already begins at the preschool level. Future research currently in planning is hoping to consider even earlier insight into the nonverbal understanding of conceptual knowledge in this domain, to more fully understand the emergence of misconceptions and, consequently, to move towards more targeted intervention approaches, but it seems clear that the external contributors identified in my dual pathway model (Hast, 2014b) already matter at some point in early development.

In the more applied context of education, this array of research – particularly the more recent developments – may have implications for preschool education. There is no suggestion that science education should be more formalized at that stage. However, more consideration may need to be given to preschool educators' knowledge of such scientific conceptions and how their pedagogy may need to be adapted to incorporate exploratory activities such as the gravity task. In allowing the targeting of conceptions at such an earlier age, misconceptions at the primary school level could potentially be more accessible in and amenable to conceptual change approaches. Future research, in a psychology-education coproduction, must attempt to address this matter.

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