Understanding the beliefs informing children's commonsense theories of motion: The role of everyday object variables in dynamic event predictions

Bib citation:

Hast, Michael and Howe, Christine (2012) Understanding the beliefs informing children's commonsense theories of motion: The role of everyday object variables in dynamic event predictions. Research in Science & Technological Education, 30 (1). pp. 3-15. ISSN 0263-5143

Version: Post-print

Official link: http://dx.doi.org/10.1080/02635143.2011.653876

Understanding the origins of children's commonsense theories of motion: The role of everyday object variables in dynamic event predictions

Abstract

Background: Children are not blank slates when they begin school; they bring prior conceptions about the everyday world with them. These conceptions usually do not comply with accepted scientific views and have to be changed within the process of education. However to do this effectively more needs to be known about the relationship between the everyday world and children's knowledge of scientific principles.

Purpose: This study sought answers to the question which object variables children use when reasoning, and how these variables are associated with outcomes. The reported study addresses these issues in relation to object motion.

Sample, design and methods: UK primary school children (n = 144) aged 5 to 11 years were assessed on their predictions of motion along a horizontal, in fall, and down an incline by using a range of everyday objects by responding to questions where they needed to compare potential motion patterns of the objects.

Results: Round shape and smooth texture of objects were consistently associated with faster motion across age groups as well as across motion dimensions. However, faster horizontal motion was associated with lighter and smaller objects across all ages whereas faster fall was associated with heavier objects. While younger children predicted faster incline motion for

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lighter and smaller objects, there was a shift in conceptions with age, with older children predicting faster motion for heavier and bigger objects.

Conclusions: The overall findings are used to support the development of commonsense theories of motion previously identified, and suggestions for educational practice are made. Specifically, it is suggested that teacher training may need to take these findings into consideration in the development of their programmes.

Introduction

It is widely accepted that children do not come to formal science education as blank slates but instead possess rich prior conceptions about the physical world (cf. Duit, 2009). Children construct this prior knowledge on the basis of their everyday experiences and interactions (Klaassen, 2005; Vosniadou & Ioannides, 1998). Such notions appear to be particularly prevalent in dynamic situations because of the ubiquitous nature of moving objects in everyday life (diSessa, 1996; Planinic, Boone, Krsnik, & Beilfuss, 2006; Tao & Gunstone, 1999). Indeed, because of its ubiquity motion provides an interesting case to evaluate in terms of children's conceptual development and its role in science education.

A problem of learning lies with what knowledge children possess rather than with what knowledge they do not have (Carey, 2000). It is apparent that children develop commonsense theories of motion that are incommensurate with scientific notions (Bliss & Ogborn, 1988; Bliss, Ogborn, & Whitelock, 1989; Hast & Howe, in press; Ogborn, 1985). While such commonsense theories may suffice for survival in the everyday world (cf. Reif, 2008), they are clearly not accurate enough for education purposes. A further problem is that they are highly resistant to change through education (Bloom & Weisberg, 2007; Chi, 2005;

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Duit, Treagust, & Widodo, 2008), even persisting into adulthood and affecting subsequent learning (Reif, 2008; Sherin, 2006).

Although the concept of commonsense theory provides helpful insights into children's developing ideas of motion, a crucial aspect relating to the development of such theories is missing: whether reasoning depends upon the multiplicity of dimensions along which everyday objects can vary (hereafter, termed 'everyday object variables'). Kinaesthetic and sense experiences have been suggested as a possible source of children's prior conceptions (e.g. Wilkening & Huber, 2002), and the origins of commonsense theories of motion are best explained through children's experiences with everyday objects (cf. Klaassen, 2005; Vosniadou & Ioannides, 1998). This highlights the potential relevance of everyday object variables in children's developing theories of motion.

The National Curriculum for England, Wales and Northern Ireland (DfEE, 1999) specifies that children between the ages of 5 and 7 years should be encouraged to use first-hand experiences to respond to questions relating to the physical world. While in Scotland no official specific requirements currently exist, recommendations in place (e.g. SSERC, 2009) follow a very similar approach. Nevertheless, despite such recommendations, there seems to be discordance between what children know in terms of their commonsense theories and what they should know by the end of primary school regarding motion. Due to the high resistance of children's prior conceptions to change and instruction, understanding the origins of conceptions leading to commonsense theories of motion may therefore have a positive impact on teaching strategies. This shortcoming informed the study to follow.

As regards motion in fall, previous research is relatively consistent, with mass identified as the predominant object variable that is relied upon during reasoning. Faster descent is largely associated with heavy objects across a range of ages (Baker, Murray, & Hood, 2009; Chinn & Malhotra, 2002; Gunstone & White, 1981; Hast & Howe, in press;

Nachtigall, 1982; Sequeira & Leite, 1991; van Hise, 1988). With horizontal motion, there is less consistency. Faster motion sometimes seems to be associated with lighter objects in older participants (Maloney, 1988) and sometimes with heaviness (Howe, 1991, as cited in Howe, 1998; Inhelder & Piaget, 1958). The latter work however suggests that children up to 12 years view heaviness as a hindrance to horizontal motion. Hast and Howe (in press), too, reported that children up to 12 years associate faster horizontal motion with lightness. In addition to mass, object variables such as size, texture and bounciness feature in the literature (Howe, 1991, as cited in Howe, 1998), although not as prominently. The limited research into incline motion also shows signs of inconsistency, but here with stronger hints of age-related change (Hast & Howe, in press; Howe et al., 1992, as cited in Howe, 1998; Inhelder & Piaget, 1958). Again, mass was a significant variable, alongside size.

Overall, object mass features heavily in reported studies concerned with conceptions of motion, in concordance with Galili's (2001) notion of mass – after space and time – being the most fundamental concept affecting general knowledge of physics. However, the use other variables has been noted, too. Similar to Hast and Howe (in press), who tested children on object motion along a horizontal, in fall *and* down an incline, the present study recognises that testing the same children on horizontal, fall and incline motion provides the clearest information of relevance to commonsense theory. Although Hast and Howe have already closed an important gap in the literature by focusing on all three dimensions, their focus was specifically on the importance of mass differences alone, not taking into account other object variables. This shortcoming is therefore addressed in the present study. Accordingly, the study tests all children on all three dimensions. In addition, age-related changes will help to clarify teaching strategy development. Therefore the study that follows also examines conceptions across a broad age range, that is, 5 to 11 years.

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In short, the research to follow attempted to establish a clearer picture of children's understanding of natural object motion in the interests of developing the commonsense theories of motion. Given the approach used in current teaching and learning recommendations insight was to be provided into the possible origins of such theories by examining understanding of motion using a range of everyday objects, which would be familiar to children and which they could relate to. Particular consideration was given to the relevance of these variables for the psychological differentiation of horizontal, incline and falling motion and the development of conceptions across a broad age range.

Method

Overview

To clarify the everyday origins of children's commonsense theories of motion a range of everyday objects were used, since these best reflect the sources of conceptions children bring to the classroom. Whether responses were made correctly or incorrectly according to scientific rules was not relevant. Instead, the justifications for decisions were the focus of attention, assessing the variables that feature in justifications, and how these relate to faster or slower motion. In order to establish a complete picture relating to commonsense theories of motion children had to predict motion along a horizontal, in fall and down an incline. To provide a stronger account the same children responded to all tasks. The study thus involved a mixed design with four age groups (between-participants) spanning the primary school age range and all participants responded to all three dimensions and all object comparisons (within-participants).

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Participants

Participants were recruited from a state primary school located in a suburban area of Cambridge, United Kingdom. The sample was drawn from those children whose parents did not object to their participation, and who, when they were non-native speakers of English, were identified by class teachers as capable of understanding the research instructions. This amounted to 144 children (80 girls), including 36 Year 1 children (20 girls; age *M* = 5.47 years, *SD* = 0.33), 36 Year 2 children (21 girls; age *M* = 6.48 years, *SD* = 0.29), 36 Year 4 children (21 girls; age *M* = 8.34, *SD* = 0.35) and 36 Year 6 children (18 girls; age *M* = 10.51, *SD* = 0.23).

Design and materials

The materials consisted of 12 everyday objects, which are shown in Figure 1. The objects were a yellow glass marble (approximately 1.5cm in diameter), a red billiard ball (approximately 5cm in diameter), a red toy car (approximately 7cm length x 3cm width x 2cm height), an orange toy truck (approximately 8cm length x 3cm width x 4cm height), a standard golf ball (approximately 4cm in diameter), a standard squash ball (approximately 4cm in diameter), a standard tennis ball (approximately 7cm in diameter), an orange (approximately 7cm in diameter), a hammer (approximately 32cm length x 13.5cm head width), a rock (approximately 5cm diameter x 3.5cm height), a feather (approximately 13cm length x 3cm width), and a leaf (approximately 13cm length x 9cm width). Being perishable, the orange and leaf needed to be exchanged every few days, but care was taken to match old and new objects by size and shape as much as possible.

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The 12 objects were separated into three groups, one group per motion dimension, with four objects in each group. Objects that resembled each other within a group were paired (marble and billiard ball, toy car and toy truck, golf ball and squash ball, tennis ball and orange, hammer and rock, feather and leaf). Markedly different pairs were then placed together in groups. Except where allocation to a particular group did not make sense because motion would not occur (e.g. the feather in horizontal motion), group allocation was at random. The horizontal motion objects were the glass marble, the billiard ball, the toy car and the toy truck. The incline motion objects were the golf ball, the squash ball, the tennis ball and the orange. The fall objects were the hammer, the rock, the feather and the leaf.

[Insert figure 1 about here]

Three different questionnaires (one to be used per child) were used to guide the tasks and for the researcher to note responses to questions. There were three separate sections within each questionnaire – one concerned with motion along a horizontal, one concerned with motion in fall, and one concerned with motion down an incline. Objects within each group were compared with each other in every possible combination, providing six object comparisons per group and 18 comparisons overall. Thus there were 18 questions. Each child was expected to answer all questions. Equal numbers of children per age group were selected at random for each questionnaire.

Procedure

The interviews took place in an open and publicly accessible area of the children's school. Upon arrival, each child was given general information about the study – that the

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researcher had brought some toys and there were going to be some questions about them. To begin with, the child was introduced to the four objects relevant to the first questionnaire section. The child was allowed to handle the objects and was encouraged to notify the researcher when an unknown object was encountered, in which case the researcher would explain what the object was. The objects could be handled at any time but the child was prevented from carrying out any relevant actions when responding to the questionnaire items, that is, rolling the balls across the table or deliberately letting them fall were not permitted. Two of the objects were then selected, in accordance with the first question on the questionnaire.

For the horizontal motion objects, the child was given the following first instruction (object pairs are examples; italics were stressed by the researcher in speech): "Imagine you are playing on the floor, you are holding the car with one hand and the truck with the other hand *right next* to each other, like this [researcher demonstrated this action with hands]. If you push them both *as hard as each other* across the floor at the *same time*, do you think one of the two will roll faster, or do you think they will both roll as fast as each other?" Depending on the child's choice, the researcher then asked, "*Why* do you think the truck (or the car) will roll faster?" or "*Why* do you think they will roll as fast as each other?"

For the incline motion objects, the child was given the following first instruction: "Imagine you are on a hill, you are holding the tennis ball with one hand and the orange with the other hand *right next* to each other, like this [researcher demonstrated this action with hands]. If you let both of them go at the *same time*, do you think one of the two will roll down the hill faster, or do you think they will both roll as fast as each other?" Depending on the child's choice, the researcher then asked, "*Why* do you think the tennis ball (or the orange) will roll faster?" or "*Why* do you think they will roll as fast as each other?"

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For the fall motion objects, the child was given the following first instruction: "Imagine you are standing up, you are holding your arms out at the *same height*, like this [researcher demonstrated this action with hands] and you have the hammer in one hand and the feather in the other hand. If you let both of them drop at the *same time*, do you think one of the two will fall faster, or do you think they will both fall as fast as each other?" Depending on the child's choice, the researcher then asked, "*Why* do you think the hammer (or the feather) will fall down faster?" or "*Why* do you think they will fall down as fast as each other?"

For each section the initial description of the situation was only given with the first comparison and not repeated for subsequent items. For each question, there was a choice between three response possibilities: The child could select one of the two objects over another, or state that both would behave the same. In addition, the child was asked to provide justifications, that is, state why choices had been made. At the end of each section the objects were removed and the child was given the option either to take a short break or to continue with the next section. Each interview lasted approximately 20 to 25 minutes.

Results

Data were collected in the form of justifications; multiple justifications could be given for each questionnaire item. Five main justification types were identified: references to the objects' mass, size, shape or texture, or any other justifications. With the exception of the final group of responses, each of the justification types was broken down into two sub-variables. Thus, mass was separated into 'heavy' and 'light', size was separated into 'big' and 'small', shape was separated into 'round' and 'uneven', and texture was separated into 'smooth' and 'rough'.

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Kolmogorov-Smirnov tests on normality of distribution showed that distributions for all datasets deviated significantly from normality, implying that assumptions for parametric tests were not met. Mean scores were therefore analysed using Friedman's ANOVAs and post hoc Wilcoxon signed-rank tests, with Bonferroni corrections applied (all significance thresholds $p \leq 0.0125$). Effects of gender were analysed with Mann-Whitney tests. Effects of age and of question order were analysed with Kruskal-Wallis tests and post hoc Jonckheere-Terpstra tests. No significant gender or question order effects were found, therefore these factors are not considered further. All data were analysed using PASW (Predictive Analytics Software, formerly SPSS) Statistics version 18.

With 18 questions, a maximum score of 18 was obtainable for each justification type used by children in their predictions. There was significant variation in mean scores for justification types, $\chi^2(4, n = 144) = 219.15$, $p < 0.001$. Mass ($M = 6.62$, $SD = 3.61$) was used as a justification significantly more often than size ($M = 3.70$, $SD = 2.25$), $T = 7$, $r = -0.55$. Mean scores for size and shape did not differ significantly. Shape ($M = 3.20$, $SD = 2.08$) was used significantly more often than texture ($M = 2.56$, $SD = 1.95$), $T = 3$, $r = -0.02$. Texture was used significantly more often than other reasons ($M = 0.97$, $SD = 1.49$), $T = 6$, $r = -0.05$.

Specifically, faster motion was significantly associated with: a) heaviness ($M = 4.72$, $SD = 2.60$) over lightness ($M = 1.90$, $SD = 2.29$), $T = 8$, $p < 0.001$, $r = -0.68$; b) roundness ($M = 3.18$, $SD = 2.09$) over unevenness ($M = 0.02$, $SD = 0.11$), $T = 10$, $p < 0.001$, $r = -0.80$; c) smoothness ($M = 2.21$, $SD = 1.80$) over roughness ($M = 0.35$, $SD = 0.75$), $T = 8$, $p < 0.001$, $r = -0.67$. No significant association was found between faster motion and either bigness or smallness. There was a significant interaction of age with the use of mass as a justification, $H(3) = 77.37$, $p < 0.001$, usage increasing with age, $J = 6118$, $z = 8.01$, $r = 0.67$. There was also a significant interaction of age with the use of size as a justification, $H(3) = 15.57$, $p < 0.001$, usage decreasing with age, $J = 3125$, $z = -2.75$, $r = -0.23$. There was, thirdly, a

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significant interaction of age with the use of shape as a justification, $H(3) = 32.71$, $p < 0.001$, usage increasing with age, $J = 5344$, $z = 5.26$, $r = 0.44$. Finally, there was a significant interaction of age with the use of texture as a justification, $H(3) = 36.59$, $p < 0.001$, usage increasing with age, $J = 5165$, $z = 4.63$, $r = 0.39$. However, there was no significant interaction of age with the use of other justifications.

Figure 2 shows the mean scores by age group for motion along the horizontal, that is, the mean number of responses indicating that a particular variable was associated with faster motion. With six questions addressing horizontal motion, a maximum score of 6 was obtainable. There was significant variation among mean scores for justification types, $\chi^2(4, n = 144) = 237.80$, $p < 0.001$. Mean scores for size and shape did not differ significantly. Both size ($M = 2.13$, $SD = 1.40$), $T = 4$, $r = -0.35$, and shape ($M = 2.13$, $SD = 1.45$), $T = 4$, $r = -0.37$, were used significantly more often than mass ($M = 1.33$, $SD = 1.38$). Mass was used significantly more often than other reasons ($M = 0.51$, $SD = 1.16$), $T = 5$, $r = -0.43$. Other reasons were used significantly more often than texture ($M = 0.14$, $SD = 0.57$), $T = 3$, $r = -0.26$. Use of mass increased with age, $J = 5110$, $z = 4.56$, $r = 0.38$, use of shape increased with age, $J = 4953$, $z = 3.91$, $r = 0.33$, and use of texture increased with age, $J = 4230$, $z = 2.91$, $r = 0.24$. Size and other reasons did not vary significantly with age.

Specifically, faster motion was significantly associated with lightness ($M = 1.10$, $SD = 1.30$) over heaviness ($M = 0.23$, $SD = 0.60$), $T = 6$, $p < 0.001$, $r = -0.50$. The same difference was observed at all age levels, but it was only statistically significant for Year 1, Year 2 and Year 6 children (all $p < 0.05$). Faster motion was also significantly associated with smallness ($M = 1.56$, $SD = 1.30$) over bigness ($M = 0.57$, $SD = 1.00$), $T = 6$, $p < 0.001$, $r = -0.48$. The same difference was observed at all age levels, but was only statistically significant with Year 1, Year 2 and Year 6 children (all $p < 0.05$). Faster motion was significantly associated with roundness ($M = 2.11$, $SD = 1.46$) over unevenness ($M = 0.01$, $SD = 0.07$), $T = 9$, $p < 0.001$, r

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= -0.77. The same pattern was observed in all four age groups (all $p < 0.001$). Finally, faster motion was significantly associated with smoothness ($M = 0.14$, $SD = 0.57$) over roughness ($M = 0.00$, $SD = 0.00$), $T = 2$, $p < 0.05$, $r = -0.17$. Among Year 6 children, faster motion was significantly associated with smoothness ($M = 0.31$, $SD = 0.82$) over roughness ($M = 0.00$, $SD = 0.00$), $T = -2$, $p < 0.05$, $r = -0.34$. Year 1, Year 2 and Year 4 children made no reference to texture.

[Insert figure 2 about here]

Figure 3 shows the mean scores by age group for motion in fall, that is, the mean number of responses indicating that a particular variable was associated with faster motion. Again with six relevant questions, a maximum score of 6 was obtainable. There was significant variation in mean scores for justification types in fall motion predictions, $\chi^2(4, n = 144) = 338.99$, $p < 0.001$. Mass ($M = 4.38$, $SD = 2.02$) was used as a justification significantly more often than size ($M = 0.57$, $SD = 0.87$), $T = 10$, $r = -0.81$. Mean scores for size and other reasons did not differ significantly. Other reasons ($M = 0.41$, $SD = 0.82$) were used more often than texture ($M = 0.10$, $SD = 0.34$), $T = 4$, $r = -0.35$. Mean scores for texture and shape did not differ significantly. Use of mass increased with age, $J = 6049$, $z = 8.12$, $r = 0.68$, and use of size decreased with age, $J = 2617$, $z = -5.27$, $r = -0.44$. Shape, texture and other reasons did not vary significantly with age.

Specifically, faster motion was significantly associated with heaviness ($M = 3.83$, $SD = 1.95$) over lightness ($M = 0.55$, $SD = 0.91$), $T = 9$, $p < 0.001$, $r = -0.77$. The same pattern was observed at all four age levels (all $p < 0.001$). Faster motion was also significantly associated with bigness ($M = 0.50$, $SD = 0.86$) over smallness ($M = 0.07$, $SD = 0.26$), $T = 5$, $p < 0.001$, $r = -0.43$. The same difference was observed with Year 1, Year 2 and Year 4

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children (all $p < 0.05$). Year 6 children showed an association of faster motion with smallness over bigness but this difference was not significant. Faster motion was significantly associated with roundness ($M = 0.06$, $SD = 0.23$) over unevenness ($M = 0.00$, $SD = 0.00$), $T = 3$, $p < 0.05$, $r = -0.24$. The same difference was observed at all age levels. Finally, faster motion was significantly associated with smoothness ($M = 0.08$, $SD = 0.31$) over roughness ($M = 0.01$, $SD = 0.08$), $T = 3$, $p < 0.05$, $r = -0.22$. Year 2 children made no reference to texture, and while smoothness was associated with faster motion at all other age levels, in no case were the differences statistically significant.

[Insert figure 3 about here]

Figure 4 shows the mean scores by age group for motion down an incline, that is, the mean number of responses indicating that a particular variable was associated with faster motion. Once more, a maximum score of 6 was obtainable. There was significant variation in mean scores for justification types in incline motion predictions, $\chi^2(4, n = 144) = 188.78$, $p < 0.001$. Texture ($M = 2.33$, $SD = 1.74$) was used as a justification significantly more often than shape ($M = 1.02$, $SD = 1.09$), $T = 6$, $r = -0.53$. There were no significant differences over use of shape, size and mass, but all three were used significantly more often than other reasons (all $p < 0.001$). Use of mass increased with age, $J = 5401$, $z = 5.83$, $r = 0.49$, use of shape increased with age, $J = 5221$, $z = 5.04$, $r = 0.42$, and use of texture increased with age, $J = 4955$, $z = 3.88$, $r = 0.24$. Size and other reasons did not vary significantly with age.

Specifically, faster motion was significantly associated with heaviness ($M = 0.66$, $SD = 0.92$) over lightness ($M = 0.25$, $SD = 0.92$), $T = 5$, $p < 0.001$, $r = -0.41$. The same pattern was observed among Year 2, Year 4 and Year 6 children, but it was only statistically significant with Year 4 and Year 6 children (all $p < 0.05$). Among Year 1 children there was

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an association of faster motion with lightness over heaviness, but this difference was not significant. Faster motion was significantly associated with bigness ($M = 0.59$, $SD = 0.99$) over smallness ($M = 0.36$, $SD = 0.75$), $T = 6$, $p < 0.001$, $r = -0.54$. Among the three older age groups, the preference was for big objects moving faster (all $p < 0.05$) but Year 1 children showed a significant preference for smaller objects moving faster, $T = 4$, $p < 0.001$, $r = -0.60$. Faster motion was significantly associated with roundness ($M = 1.01$, $SD = 1.08$) over unevenness ($M = 0.01$, $SD = 0.08$), $T = 8$, $p < 0.001$, $r = -0.66$. The pattern was constant across age groups (all $p < 0.05$). Finally, faster motion was significantly associated with smoothness ($M = 1.99$, $SD = 1.65$) over roughness ($M = 0.34$, $SD = 0.75$), $T = 8$, $p < 0.001$, $r = -0.65$. The same difference was observed among Year 2, Year 4 and Year 6 children (all $p < 0.001$). Among Year 1 children there was an association of faster motion with roughness over smoothness, but this difference was not significant.

[Insert figure 4 about here]

Discussion

This study was an attempt to establish what general beliefs primary school children hold about the speeds of different everyday objects following three kinds of motion, as support to understanding children's development of commonsense motion theories (Bliss & Ogborn, 1988; Bliss, Ogborn, & Whitelock, 1989; Hast & Howe, in press; Ogborn, 1985). It was not concerned with whether children's predictions about object motion were consistent with accepted scientific views, but instead addressed the variables that affect these predictions, and how predictions and variable use compare across different motion types.

Predictions were classified as being made on the basis of mass, size, shape, texture, or any other reasons. Overall, it would appear that the results are in accordance with Galili's (2001) notion of mass being an important variable in reasoning about the physical world. Almost half of all justifications in this study were mass-based. Nevertheless, the frequency of references to mass varied with motion types. With motion in fall, mass accounted for almost all justifications. However, with horizontal motion mass only accounted for a quarter of justifications, and with incline motion for less than that. Instead, horizontal motion justifications were dominated by size and shape, and incline motion justifications by texture, with size and shape used as frequently as mass.

While the general use of shape and texture as means of justification is interesting per se, since it highlights that mass and size are not the only important variables in children's reasoning about motion, the specific role these variables play within reasoning is not particularly surprising. Faster speed was almost always associated with the roundness and smoothness of objects, suggesting even the youngest children tested here have a very good understanding of how these variables function. But given the relatively widespread everyday experience with round objects such as balls and marbles with little, if any, deviation from scientific views (due to factors such as very low friction coefficients), the consistent understanding and application to scenarios is perhaps not unexpected.

However, where mass and size are concerned, a different picture emerges. The results suggest that in terms of these variables horizontal motion and vertical motion are understood differently from each other at an early age and that the differentiation remains constant across the primary school age range. Given the substantial literature on understanding of object fall (Baker et al., 2009; Chinn & Malhotra, 2002; Gunstone & White, 1981; Hast & Howe, in press; Nachtigall, 1982; Sequeira & Leite, 1991; van Hise, 1988), it does not come as a surprise that children mainly associated faster motion with heavier objects across all ages,

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although children in the youngest age group also referred to size reasonably often, with faster motion associated with bigger objects. Horizontal motion, on the other hand, was associated with lighter and smaller objects, again fairly consistently across age groups. This observation is also in concordance with previous work (Hast & Howe, in press; Howe, 1991, as cited in Howe, 1998).

Regarding mass and size there was even less consistency for incline motion. While younger children predicted faster motion for lighter and smaller objects, there was a clear shift in conceptions, with older children predicting faster motion for heavier and bigger objects. This, too, is consistent with prior work (Hast & Howe, in press; Howe et al., 1992, as cited in Howe, 1998). It is interesting to note, though, that for incline motion scenarios the reliance on shape and texture was as frequent as the reliance on mass and size. However, it is unclear whether this is due to the developmental instability noted in Hast and Howe (in press), whereby beliefs change with age, or due to a heightened appreciation of variables of the particular objects over objects in the other groups. A combination of the two seems rather likely.

Because the youngest children appeared to rely more on size than older children, and less on mass, it was initially questioned whether they were perhaps using size as a proxy for mass. Indeed, some older studies claimed that young children do not distinguish between size and mass (Gibson, 1969; Piaget & Inhelder, 1974). Smith, Carey and Wiser (1985) have shown, however, that the concept of size is fully differentiated from the concept of mass in early childhood. In fact, these concepts appear to be appreciated and recognised from an early age – studies have shown that by the age of 12 months infants can already differentiate between light and heavy objects (Molina & Jouen, 2002) and that young infants understand when an object is too big to fit into a particular container (Aguiar & Baillargeon, 1998). It seems, therefore, that reliance on size in younger children is not due to an equation of mass with size, but perhaps a reliance on visual aspects of objects rather than on aspects that require physically engagement with objects.

It is, overall, evident from the present findings that children are able to use a range of everyday object variables to explain their motion theories, but that this is sometimes problematic regarding accepted scientific views, particularly where commonly held views are concerned – such as that heavy objects always fall faster than lighter objects; a view dependent on object mass. As far as teaching and learning approaches in science education are concerned, this would, at first glance, suggest that new approaches would need to be developed. Yet everyday experiences are all children can utilise at that age – they cannot run complex experiments, and even if teachers perform experiments for them the children *should* be able to make predictions about what they believe might happen. What, then, is the alternative?

What might certainly be seen as beneficial in the current curriculum structure and other recommendations is that children across the whole primary school age range should be taught to explore similarities and differences between materials and to sort objects on the basis of their properties, as this promotes an understanding of the variables involved in motion. However, the importance of everyday variables is also specifically highlighted in the curriculum by stating that children aged 5 to 7 years should use first-hand experience to respond to questions. While this is certainly helpful in determining prior beliefs and may serve well in analogies to scientific problems, it remains important that teachers are aware of the correct motion principles and can help children to note the fallacy of their beliefs.

Rather than looking at the contribution *children* are making in early science education, it may thus be worthwhile considering the contribution *teachers* make to this approach. The most recent TIMSS evaluation (Martin et al., 2008), for instance, showed that only one third of UK primary school children's teachers interviewed had at some point been

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involved in science-related professional development. And although teacher confidence in teaching science appears to be improving, a further survey found that half of primary school teachers lacked confidence and ability to teach science (Murphy & Beggs, 2005).

It seems, therefore, that reform of teacher training should be a key issue. The benefits of this, in light of the present research, would be twofold. Firstly, teachers – particularly those without a science background – would gain confidence in teaching science topics in the primary classroom. Secondly, they would still be able to encourage the reliance on everyday experiences in their teaching of object motion whilst being able to note any fallacies in children's thinking early enough to correct them. Not only can the issues at stake be tackled early in the learning process – this may, in the long run, also bring primary school children to enjoy science education more and promote a heightened interest in subsequent science-related careers (cf. Martin et al., 2008).

In summary, this study provides further support to the development of commonsense theories of motion by assessing the possible causes leading to prior beliefs based on the everyday world. It is suggested that the relation between these two aspects is not fully understood yet, and that more work will need to be carried out in order to provide a clearer picture. It is clear, however, that the discrepancy between the present findings and current curriculum recommendations require further careful consideration.

Acknowledgements

This study was supported by a doctoral studentship to the first author from the Economic and Social Research Council of Great Britain (ES/F036302/1), which was linked to a research grant held by the second author (ES/E006442/1). The authors thank the Council and the participating children, their teachers and head teachers.

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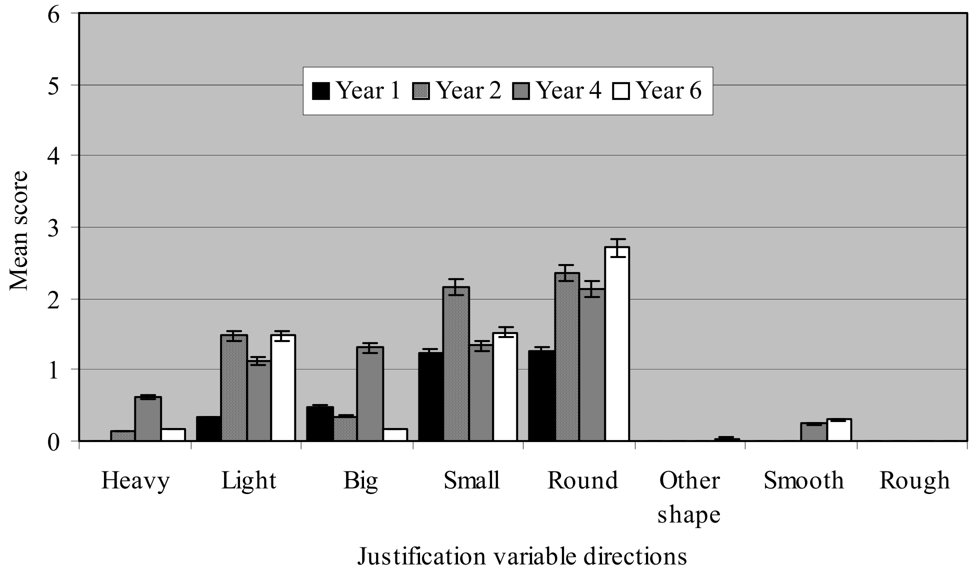

Figure 1. Mean scores for overall faster motion justification directions for motion along a horizontal.

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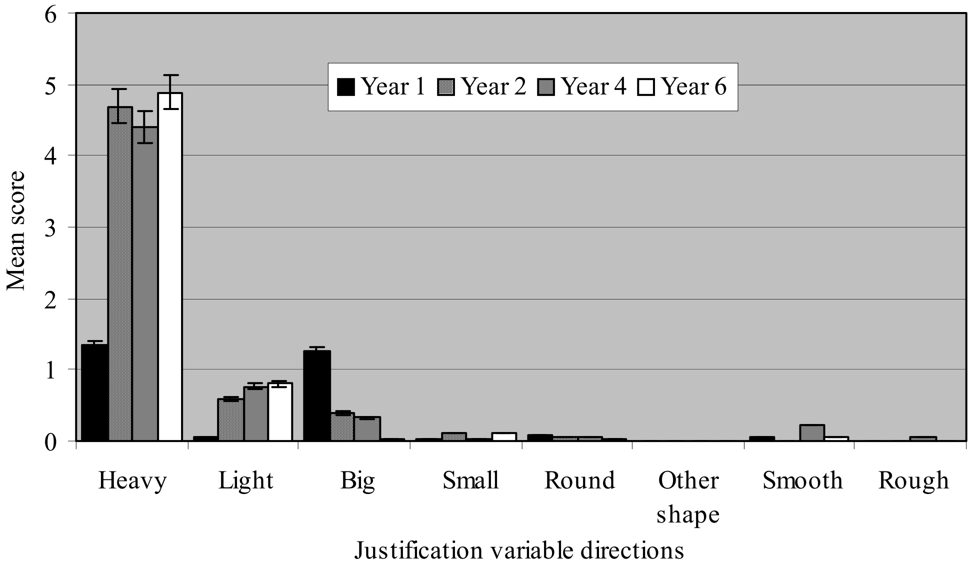

Figure 2. Mean scores for overall faster motion justification directions for motion in fall.

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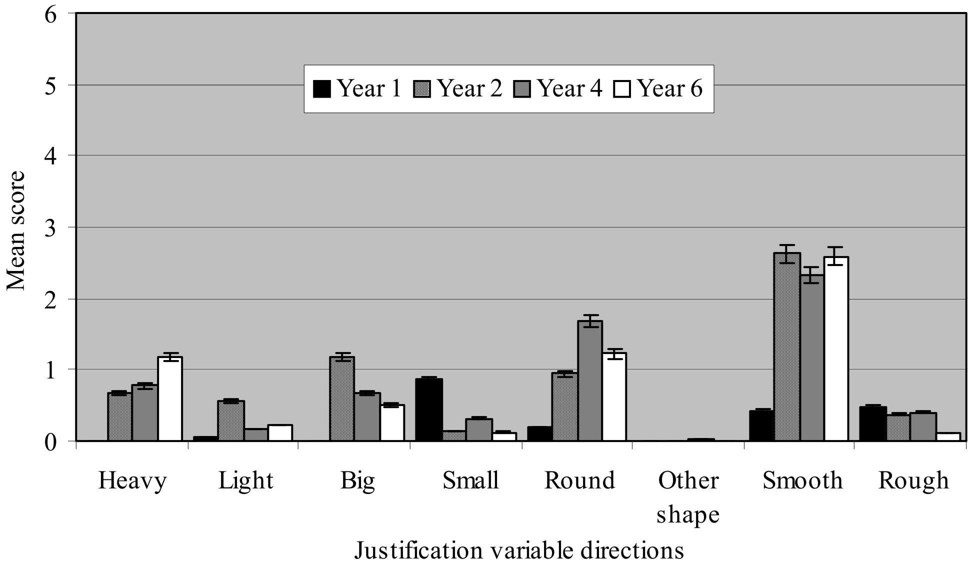

Figure 3. Mean scores for overall faster motion justification directions for motion down an incline.

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