1 **Children's Predictions and Recognition of Fall: The Role of Object Mass**

2

3 **Abstract**

4

5 A small but growing body of evidence suggests that alongside misconceptions in predictions

6 about object motion, adults and children hold relevant underlying conceptions, reflected in

7 recognition, which provide greater understanding of such events. However, the relationship

8 between knowledge retrieved in predictions and in recognition is unclear. One significant

9 element contributing to misconceptions about motion is object mass. This aspect was used to

10 provide further insight into the knowledge relationship. Predictions and recognition of fall in

11 5- to 11-year-old children ($N = 121$) were addressed in the present study. The results suggest

12 that children's recognition of object motion is far better than their expressed anticipation of

13 such events, as they normally recognised correct events as correct and rejected incorrect ones

14 yet predictions were typically in error. Response time data provide additional insight. The

15 findings are discussed in relation to different models of knowledge representations, favouring

16 a hybrid model.

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18 **Keywords:** Conceptual development; everyday physics; object fall; object mass

19

20 **1. Introduction**

21

22   From a young age children hold extensive but largely erroneous beliefs about the physical

23 world, beliefs which they construct on the basis of personal experiences (Klaassen, 2005). A

24 myriad of studies is available (see Duit, 2009, for a comprehensive list), documenting the

25 wide range of misconceptions present in childhood. Among these are beliefs about dynamic

26   events involving objects, a particularly ubiquitous element of the physical world (Planinic,

27   Boone, Krsnik, & Beilfuss, 2006). These beliefs are not isolated ideas but conceptual

28   structures that can be called upon in reasoning and that, despite their limitations, provide a

29   coherent framework for understanding the world. A prominent view is that we hold innate

30   core knowledge about the physical world that is enhanced over time (e.g. Baillargeon &

31   Carey, 2012; but also see e.g. Hood & Santos, 2009, for a wider discussion around the origins

32   of such knowledge).

33   Accessing relevant conceptual knowledge structures in motion prediction tasks that are

34   coupled with explicit explanations – such as planning motion trajectories or deciding the

35   location of an object following an anticipated path – necessitates deliberation, reflection, and

36   a conscious understanding of rules or decisions (Hogarth, 2001; Plessner & Czenna, 2008):

37   an explicit engagement with the structures is required. At the same time, a small but growing

38   field of research suggests infants (Friedman, 2002; Kannass, Oakes, & Wiese, 1999; Kim &

39   Spelke, 1992), children (Howe, Taylor Tavares, & Devine, 2012, 2014; Kim & Spelke, 1999)

40   and adults (Kaiser & Proffitt, 1984; Kaiser, Proffitt, Whelan, & Hecht, 1992; Naimi, 2011;

41   Shanon, 1976) are able to recognise dynamic trajectories that are physically correct and to

42   reject trajectories that appear unnatural to them, even if they are more likely to predict the

43   unnatural events beforehand. Such recognition tasks may merely need to engage underlying

44   tacit knowledge structures (Collins, 2010) – structures set to provide quick responses without

45   conscious awareness, by eliciting feelings of familiarity with events. Although there is some

46   indication that very young children engage in predictive anticipation when evaluating

47   outcomes of dynamic events (e.g. Lee & Kuhlmeier, 2013) it is debatable whether these

48   anticipations can be seen as *explicit* predictions since these children eventually chose an

49   incorrect response – likely through some process of reflection and deliberation – despite very

50   initially displaying accurate looking, which may be accounted for by quick responses without

51   conscious awareness.

52   Currently, there are at least three divergent views on the relationship between these two

53   manifestations of knowledge. Firstly, explicit understanding is perceived to be a partial

54   version of tacit knowledge whereby the two exist within a single system (Kim, 2012; Kim &

55   Spelke, 1999; Spelke & Hespos, 2001). Specifically, in the process of elevating tacit

56   conceptions to the explicit level, elements are omitted, causing differences in outcomes

57   between tasks relying on different knowledge. According to the second view, on the other

58   hand, explicit and tacit knowledge are two mutually exclusive coexisting systems, seemingly

59   unaffected by each other (Hogarth, 2001; Plessner & Czenna, 2008). Depending on task

60   requirements only one of the systems is accessed. The more recent third view rejects

61   omission and separation, and proposes a hybrid model in which there are two, partially

62   associated knowledge systems wherein explicit knowledge is, in part, an embellishment of

63   knowledge held at the tacit level (Carey, 2009; Howe, 2014; Howe et al., 2012, 2014). There

64   is to date no clear evidence favouring just one of these views – a shortcoming addressed by

65   the present research.

66   Object mass, being one of the most fundamental concepts of the physical world (Galili,

67   2001), may help shed light on this matter. It is a concept that appears to be in place early in

68   development; the general ability to distinguish between heavy and light emerges within the

69   first year of life (Hauf & Paulus, 2011; Hauf, Paulus, & Baillargeon, 2012; Molina, Guimpel,

70   & Jouen, 2006; Molina & Jouen, 2003; Paulus & Hauf, 2011). Furthermore, this particular

71   concept plays a key role in the development of commonsense theories of motion, as children

72   rely upon mass to explain their predictions of fall – many children hold the persistent belief

73   that one object will fall faster than another because the first is heavier than the second (Baker,

74   Murray, & Hood, 2009; Chinn & Malhotra, 2002; Hast & Howe, 2012, 2013a; Nachtigall,

75   1982; Sequeira & Leite, 1991; van Hise, 1988). Given the ubiquity of dynamic events, as

76   well as the early developing understanding of the concept of mass, that inform everyday

77   experiences, these limitations in understanding of object motion might seem surprising.

78   The importance of object mass in the current context therefore lies with the fact that it has,

79   in actuality, little effect on motion patterns – two balls of same size but different mass will

80   move at almost identical speeds – thereby becoming irrelevant to recognition tasks. An ability

81   to recognise events as correct where objects move at the same speeds would suggest that

82   recognition is not susceptible to interference from object mass concepts. This in turn would

83   imply that predictive beliefs are a result of independently existing structures or of

84   embellishment of underlying conceptions rather than omission. Research with adults suggests

85   that expectations specifically relate to mass – a heavy ball is expected to fall faster than a

86   light ball – but acceptance of such motion patterns as correct is much lower, with a tendency

87   towards a more accurate representation of object motion (Naimi, 2011). Children also expect

88   items to fall faster than others because they are heavier – but can similar mass-based

89   differences between prediction and recognition be observed during childhood?

90   Three hypotheses can be stated to address each of the three divergent views outlined

91   above. In all three cases, based on the literature, the anticipated outcome is that children will

92   *predict* (P) the heavy ball (H) to be faster, with next to no light-faster (L) or same-speed (S)

93   predictions (P = H>L=S). The omission view would envisage a *recognition* (R) task outcome

94   where factors in addition to mass are being taken into account. If other object variables such

95   as size and shape are controlled for this should lead to a similar outcome as in predictions

96   since mass would continue to be a part of the process (R = H>L=S). On the other hand, under

97   the proviso that underlying knowledge is highly accurate, the separate systems view would

98   dictate a distinct set of recognition task findings. Same-speed trials would be uniquely

99   recognised as being correct; heavy-faster and light-faster trials would be rejected in equal

100   manner (R = S>H=L). Finally, if knowledge representations exist within a hybrid model high

101   success rates on same-speed trial recognition should be anticipated but, in line with

102   predictions, also some heavy-faster trial recognition that significantly exceeds that of light-

103   faster trials (R = S>H>L). The study described below was an attempt to assess children's

104   recognition of dynamic events, with motion either adhering to physical laws or contravening

105   them, by placing particular emphasis on the role that object mass plays in such events.

106

107   **2. Method**

108

109   *2.1 Participants*

110

111   Participants were recruited from a state primary school located in a suburban area of

112   Cambridge, UK. The sample was drawn from those children whose parents did not object to

113   their participation, and who, when they were non-native speakers of English, were identified

114   by class teachers as capable of understanding the research instructions. This amounted to 121

115   children (66 girls), including 23 Year 1 children (12 girls; age *M* = 6.15 years, *SD* = 0.40), 31

116   Year 2 children (18 girls; age *M* = 7.12 years, *SD* = 0.34), 33 Year 4 children (19 girls; age *M*

117   = 9.12 years, *SD* = 0.37) and 34 Year 6 children (17 girls; age *M* = 11.17 years, *SD* = 0.44).

118   An additional nine children participated but were not considered for data analysis due to

119   insufficient completion of practice trials, not completing both tasks, or due to technical errors.

120

121   *2.2 Design and Materials*

122

123   Both tasks were computer-presented scenarios involving two balls, a dark green marble

124   and a bright pink table tennis ball (green = 'heavy', 75 g, 4 cm diameter; pink = 'light', 3 g, 4

125   cm diameter). Real equivalents of the two balls were made available to the children during

126   the tasks to support full understanding of scenarios, as simulations are more effective in

127   meaning when accompanied by relevant tactile experiences (cf. Lazonder & Ehrenhard,

128   2014). Scenarios for both tasks were presented using DMDX, which also records response

129   times (Forster & Forster, 2003). The order of scenarios within individual test stages was

130   randomly varied via the computer program.

131

132   *2.2.1 Prediction task*

133

134   Scenarios were developed in PowerPoint. Each scenario showed the two balls at their

135   initial point of anticipated motion and being held by a hand. Next to the scenarios were three

136   brief possible motion outcomes written in large font against coloured backgrounds. The

137   options read 'A is faster', 'B is faster' and 'Same speed' (see Figure 1, left). Each of the three

138   response options had a different background colour; the top response had a red background,

139   the response in the middle had a yellow background, and the bottom response had a blue

140   background. Background colours always remained in the same order but response options

141   were rotated across locations. Thus, a total of six scenarios were prepared for this task,

142   amounting to all possible combinations of ball location and response location. In addition,

143   practice scenarios were developed in PowerPoint, with each scenario showing two squares of

144   same or differing sizes with three options to choose from ('A is bigger', 'B is bigger', 'Same

145   size').

146

147   *2.2.2 Recognition task*

148

149   Scenarios were recorded with a Sony DCR-HC35E digital video camera recorder. Clips

150   were initially filmed individually with one ball only, using the same set-up of transparent

151   tube placed in a vertical position as in the prediction task. A hand would hold one of the two

152   balls into the tube and release it. Clips were filmed to account for the two ball types and hand

153   location (left versus right). Using Windows Movie Maker each of the clips was slowed down

154   to half the speed. These clips were then compiled to show two tubes within one scenario,

155   ensuring the two balls were always contrasting in colour but accounting for location (left

156   versus right). Both balls were shown being held into the tubes and then released

157   simultaneously (see Figure 1, right). By compiling these clips three different scenarios were

158   created: either showing motion as it occurs naturally ('same-speed'), or showing modified

159   motion where, non-naturally, one ball was twice as fast as the other – either the heavy ball

160   ('heavy-faster') or the light ball ('light-faster'). Thus, a total of six scenarios were prepared

161   for this study, amounting to all possible combinations of ball speed and ball location. Quality

162   of scenarios was not compromised between compilations, including where slowed-down clips

163   had been used. All compiled video clips were 10 s long, with motion occurring at 5 s into the

164   clip, to give enough opportunity to note ball locations. In addition, practice scenarios were

165   developed in PowerPoint, with each scenario either showing a blue circle or a red triangle.

166

167   [Insert figure 1 about here]

168

169   *2.3 Procedure*

170

171   Each child was assessed on an individual basis. To begin, the child was introduced to

172   the two balls. Both balls could be handled at any time, but the child was prevented from

173   carrying out relevant actions during the task, that is, deliberately letting them fall was not

174   permitted. The trials were presented on a Sony VAIO VGN-NR21J laptop and displayed on

175   an external 15" LCD colour monitor connected to the laptop. An external KeySonic™ Nano

176   Keyboard ACK-3400U, also connected to the laptop, was used for responding to the trials.

177   The keyboard was masked to reduce distractions from unnecessary keys. Three keys were

178   indicated by colour on the masking. Keys not used were disabled. One key was in the centre

179   of the keyboard (yellow key); the other two were at the left end (red key) and at the right end

180   (blue key) in the same row as the centre key. Each child completed both tasks and the tasks

181   were carried out approximately six weeks apart from one another.

182

183   *2.3.1 Prediction task*

184

185   With the monitor screen blank, the researcher familiarised the child with the monitor and

186   the keyboard. He asked the child to point out each key according to its colour. The child was

187   then asked to press the yellow key. This elicited an on-screen introduction to the materials.

188   The child saw a series of diagrams of the monitor and keyboard, which the researcher used to

189   explain the procedure by showing the link between response choices and keys to press. At the

190   end of the introduction the child was told that there would be some easy trials to practice

191   with. If children were unable to read the response options the researcher followed the trials

192   and gave the child instructions, which always corresponded to the particular trial on the

193   screen. Responses were always read out from top to bottom. The researcher pointed to the

194   picture in question and the corresponding response option each time. In the practice trials the

195   researcher would say to the child: "If you think the square on the top [*researcher points at*

196   *picture A*] is bigger, press the red key. If you think the square on the bottom [*researcher*

197   *points at picture B*] is bigger, press the yellow key. If you think they are both the same size,

198   press the blue key". For the test trials the child was given the following instruction: "If you

199   think the ball on the left [*researcher points at picture A*] will fall faster, press the red key. If

200   you think the ball on the right [*researcher points at picture B*] will fall faster, press the

201   yellow key. If you think they will both fall as fast as each other, press the blue key". No

202   motion occurred and children were not provided with feedback whether their response was

203   correct or not. Each child was expected to respond to all trials, and the task took around 15

204   minutes per child.

205

206   *2.3.2 Recognition task*

207

208   For half of the children the 'yes' response was the left key and the 'no' response the right

209   key, and vice versa for the other half. For the practice trials, the child was given the following

210   instruction: "Watch carefully, and decide as quickly as you can. I want you to look for a blue

211   circle. Every time you see a blue circle, press 'yes' [*researcher points to 'yes' key*]. Every

212   time you see a red triangle, press 'no' [*researcher points to 'no' key*]". The child was then

213   asked to press the yellow key, which started the trials. For the test trials the child was given

214   the following instruction: "You are going to see two hands holding these two balls

215   [*researcher points to both balls*] inside the tube and letting them go. Watch carefully, and

216   decide, as quickly as you can, whether it looks right or not. If it looks right, press 'yes'

217   [*researcher points to 'yes' key*] and if it does not look right, press 'no' [*researcher points to

218   'no' key*]". To support the explanation children were shown two sheets of paper next to the

219   two keys, showing the word 'yes' accompanied by a green tick and the word 'no'

220   accompanied by a red cross. Children were not provided with feedback whether their

221   response was correct or not. Each child was expected to respond to all trials, and the task took

222   around 15 minutes per child.

223

224   **3. Results**

225

226   Mean scores for both tasks were converted to percentages and analysed according to

227   which types of trials – heavy-faster, light-faster or same-speed – were more likely to be

228   predicted and more likely to be recognised as being correct, regardless of whether they were

229   actually correct. One-sample t-tests were used to compare trial type percentages with chance

230   levels (33.3% for each prediction trial and 50% for each recognition trial). One-way

231   ANOVAs and post hoc t-tests with Bonferroni corrections were then used to examine

232   differences between the three types of trials in each task type as well as to examine

233   differences between age groups on each trial type. The results are summarised in Figure 2. To

234   examine any further details in the reasoning process of the recognition task one-way

235   ANOVAs and t-tests were used to evaluate response times. In addition, between-samples t-

236   tests were carried out to evaluate any gender differences. No significant gender differences

237   were noted so these are not considered further. All data were analysed using SPSS 21.

238

239   [Insert figure 2 about here]

240

241   *3.1 Prediction task*

242

243   Heavy-faster predictions (M = 88.29%, SD = 30.78) occurred significantly more

244   frequently than if performing at chance level, $t(120) = 19.64$, $p < .001$, $r = .87$, with the same

245   effect noted for each age group. There was significant variation in predictions among the four

246   age groups, $F(3, 117) = 3.28$, $p < .05$, but there was only a significant difference between

247   Year 2 and Year 6 children, $p < .017$. Light-faster predictions (M = 6.34%, SD = 23.60)

248   occurred significantly less frequently than if performing at chance level, $t(120) = -12.59$, $p <$

249   .001, $r = .75$, with the same effect noted for each age group. There was no significant

250   variation among the four age groups. Same-speed predictions (M = 5.37%, SD = 20.89) also

251   occurred significantly less frequently than if performing at chance level, $t(120) = -14.73$, $p <$

252   .001, $r = .80$, with the same effect noted for each age group. Again there was no significant

253   age-related variation. Overall, the heavy ball was predicted to be faster more frequently than

254   the light ball, $t(120) = 17.78$, $p < .001$, $r = .85$, but there was no significant difference

255   between light-faster and same-speed predictions.

256

257   *3.2 Recognition task*

258

259   Recognition of heavy-faster trajectories as being correct ($M = 44.63\%$, $SD = 39.69$) did not

260   deviate significantly from performance at chance level. Recognition of light-faster

261   trajectories as being correct ($M = 4.96\%$, $SD = 16.34$) was significantly below chance level,

262    $t(120) = -30.33$, $p < .001$, $r = .94$. Recognition of same-speed trajectories as being correct (M

263    $= 79.75\%$, SD $= 35.70$) was significantly above chance level, $t(120) = 9.17$, $p < .001$, $r = .64$.

264   The same trajectory-related effects were noted within each age group, but there were no

265   significant age-related variations. Overall, same-speed trials were recognised as being correct

266   more frequently than the incorrect heavy-faster trajectories, $t(120) = -5.59$, $p < .001$, $r = .45$.

267   The incorrect heavy-faster trajectories in turn were recognised as being correct more

268   frequently than the equally incorrect light-faster trajectories, $t(120) = 10.09$, $p < .001$, $r = .68$.

269   Although recognition scores did not vary with age with increasing age children made

270   faster responses. This was the case for heavy-faster trials, $F(3, 117) = 13.37$, $p < .001$, light-

271   faster trials, $F(3, 117) = 11.28$, $p < .001$, and same-speed trials, $F(3, 117) = 11.68$, $p < .001$.

272   Mean heavy-faster trial response times ($M = 3765$ ms, $SD = 1332$) were significantly higher

273   than for light-faster trials ($M = 2243$ ms, $SD = 1114$), $t(120) = 29.52$, $p < .001$, $r = .94$, but

274   mean response times for light-faster and same-speed trials ($M = 2303$ ms, $SD = 1134$) did not

275   differ significantly. The heavy-faster trials were then examined in more detail by comparing

276   response times when both trials were rejected, one was accepted as correct or both were

277   accepted as correct. Mean two-trial rejection times (M = 2996 ms, SD = 1337) were

278   significantly lower than mean one-trial acceptance times (M = 3956 ms, SD = 1233), $t(87)$ = -

279   3.52, p < .05, r = .35, which in turn were significantly lower than mean two-trial acceptance

280   times (M = 4584 ms, SD = 788), $t(74)$ = -2.53, p < .05, r = .28.

281

282   **4. Discussion**

283

284   This study was an attempt to evaluate children's predictions and recognition of dynamic

285   events, with particular reference to the role played by object mass. The study sought to

286   answer several questions related to this issue. Firstly, are the widely held limitations observed

287   in children's explicitly stated predictions an accurate expression of their overall

288   understanding about motion? Leading on from this, can children appropriately recognise

289   physically correct and physically incorrect dynamic events on the basis of object mass? If so,

290   how does their recognition of such events compare with their predictive beliefs? And finally,

291   what is the relational manifestation of the different knowledge levels?

292   As far as the prediction task is concerned, children consistently believed that the heavy

293   ball would be faster than the light ball. These predictions show no significant variation across

294   the age groups and reflect the literature addressing children's beliefs about object fall (Baker

295   et al., 2009; Chinn & Malhotra, 2002; Hast & Howe, 2012, 2013a; Nachtigall, 1982; Sequeira

296   & Leite, 1991; van Hise, 1988). At the same time, despite holding predictive conceptions

297   incommensurate with real events it is clear from the present results that the same children are

298   able to correctly recognise object motion. Accuracy is revealed in their ability to accept

299   physically natural events as correct and to reject non-natural events. This general finding is in

300   line with prior literature on underlying recognition (Friedman, 2002; Howe et al., 2012, 2014;

301   Kaiser & Proffitt, 1984; Kaiser et al., 1992; Kannass et al., 1999; Kim & Spelke, 1992, 1999;

302   Naimi, 2011; Shanon, 1976), particularly with those of the studies that are concerned with

303   children. More specifically, however, the findings suggest that children can correctly

304   recognise dynamic events despite the central role object mass plays in the development of

305   predictive beliefs about motion. Their predictions are considered to be explicit conceptual

306   knowledge since identical responses were obtained in tasks requiring children to give verbal

307   justifications for their predictions using the same apparatus (Hast & Howe, 2013a) and

308   showing high similarity between real-life object tasks and computer-presented versions (see

309   Hast & Howe, 2013b).

310   Nonetheless, the role of object mass does not appear to be entirely irrelevant in recognition

311   of events. Children consistently acknowledged the correctness of trials where the balls

312   travelled at same speeds. At the same time, they almost always rejected light-faster trials –

313   trials that are neither physically correct nor reflected in their predictions. No significant

314   changes with age were noted, suggesting some stability in recognition of motion across

315   childhood. Trials corresponding to explicit predictions, on the other hand, were recognised as

316   correct rather frequently: Children fairly often recognised incorrect trials to be correct where

317   the heavy ball was faster. This may be linked to deliberation. Underlying knowledge is

318   typically associated with fast evaluation whereas explicit knowledge is accessed through

319   prolonged evaluation (Collins, 2010). More careful reflection on scenarios may have

320   provided access to explicit knowledge structures. Research with young children may provide

321   similar supportive insight. Upon following falling events 2-year-olds initially looked at the

322   correct location but then largely pointed at an incorrect location (Lee & Kuhlmeier, 2013).

323   Here, too, children may initially have held underlying expectations that were correct but

324   prolonged deliberation resulted in misconception. This also seems to be exemplified by the

325   response time data, although more careful examination in task variations would help shed

326   more light on this matter, such as through time constraints and the impact on recognition

327   accuracy. Despite this issue, as a whole the children were still much better at recognising true

328   dynamic events but simply refined their ability to do so with increasing age.

329   Failure in various search tasks is denoted by toddlers reaching for incorrect locations,

330   especially when multiple incorrect locations are provided – but looking behaviour data in

331   these same studies indicate that they are aware of the correct location (e.g. Baker, Gjersoe,

332   Sibielska-Woch, Leslie, & Hood, 2011; Haddad, Kloos, & Keen, 2008; Hood, Cole-Davies,

333   & Dias, 2003). Indeed, recent work addressing conceptual knowledge in a range of domains

334   has identified that although scientific knowledge can be learnt it does not appear to replace

335   earlier understanding about those concepts (Shtulman & Valcarcel, 2012). It is plausible that

336   additional task requirements, in this case processing of language when choosing response

337   options, interfere with retrieval of underlying information (cf. Low, 2010). Parallels can thus

338   be drawn to Karmiloff-Smith's (1992) discussion that mastery of a particular executive skill

339   level is required before a new skill level can be engaged with. This would also explain why

340   children did not differ across age groups in their actual recognition scores but did improve by

341   becoming faster at reaching the same level of decisions. As this study only focused on middle

342   childhood it is possible that further refinement either in terms of accuracy or in terms of

343   response speed would be noted towards adulthood (cf. Naimi, 2011) that could help explore a

344   more complete developmental trajectory. However, because different task types require skills

345   of different difficulty level (e.g. looking, reaching or verbal responses) each mode is

346   represented at the same time but only the most relevant information is actively retrieved. The

347   work by Shtulman and Valcarcel, and other work showing, for instance, Alzheimer's patients

348   reverting to childhood conceptions (Lombrozo, Kelemen, & Zaitchik, 2007), would appear to

349   support this notion.

350   But are these layers a single representation of knowledge, independent from one another,

351   or overlapping? Out of the three potential views offered in the literature, omission (Kim,

352   2012; Kim & Spelke, 1999; Spelke & Hespos, 2001) would appear to be the least likely

353   candidate. For if the disparity observed in the present study were due to omission, then

354   deliberation should call upon underlying knowledge and leave out conceptual elements. But

355   since object mass actually plays a very minor role in natural object motion events, same-

356   speed recognition would not necessarily depend on any understanding of mass in order to

357   correctly identify trials, and children are evidently satisfactorily adept in their recognition of

358   events. Yet they specifically call upon mass in order to support their – mostly erroneous –

359   predictions. It therefore seems more likely that predictive beliefs during childhood are either

360   the result of an independently developed knowledge system or that they are an embellished

361   form of tacit understanding, whereby additional information about object mass is added to the

362   underlying knowledge structures. This means the hypothesis $R = H > L = S$ cannot be accepted

363   here.

364   Distinguishing further between separate systems (Hogarth, 2001; Plessner & Czenna,

365   2008) and the hybrid model (Carey, 2009; Howe, 2014; Howe et al., 2012, 2014), on the

366   other hand, is a more formidable task. Nonetheless, the results from the present study seem to

367   favour the hybrid model, since here too the substantial instances of recognition that mirror

368   predictive knowledge suggest overlap between the two knowledge systems in a way that was

369   anticipated by the hypothesis $R = S > H > L$. Instead it is suggested that access to relevant

370   conceptual structures is affected by various factors such as language and executive control

371   and is therefore dependent on task requirements – looking, manual or verbal – that determine

372   the depth of conceptual layers that needs to be overcome. In a simple recognition task

373   children may merely need to map dynamic events onto relevant pre-existing models and

374   rejection or acceptance is based on the goodness of fit with these models. Explicit predictions

375 require input from some form of symbolic representation such as language or symbols which

376 may add onto the underlying knowledge, such as through discourse (an explanatory dual-

377 pathway model of reasoning is presented in Hast, 2014). This is equally compatible with the

378 dual processing pathways used to explain differences between infants and toddlers (e.g.

379 Gjersoe & Hood, 2009) but favours the view that they are not separable from one another.

380

381 **5. Conclusion**

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383   Children's knowledge about the physical world is extensive but often expressed in a

384 manner incommensurate with scientific views. At the same time a popular viewpoint is that

385 we hold underlying knowledge about physical events that, at its core, remains unaltered

386 throughout development, but with further knowledge added to it. The present study shows

387 that while children's predictions are inaccurate their recognition of related dynamic events is

388 largely correct. However, instead of omitting information at the predictive level it appears

389 children are adding mass as a key variable. Such additional conceptual layers may hinder

390 access to underlying knowledge, depending on task requirements, but underlying knowledge

391 may nonetheless still be tapped through recognition tasks and access may become easier with

392 increasing age.

393

394 **Acknowledgements**

395

400

401   **References**

402

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