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Children's thoughts on unborn babies
Representational redescription in preconceptions of children on fetal development

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Abstract

This study aims to examine if children have a coherent, naïve theory or, alternatively, only fragmented knowledge of prenatal development. Following Karmiloff-Smith's theory of representational redescription, it examines whether these theories are influenced by age related constraints in representational flexibility. Children aged 6-13 (N=317) filled out a forced-choice questionnaire and completed two drawing tasks. Examination by latent class analysis indicates that children do have coherent theories on prenatal development for the changing morphology, but not for the changing bodily functions and that coherence of their mental model is increased by a preceding generative task. The observed mental models are characterized by different levels of representational flexibility.

Keywords: fetal development, naïve theory, mental models, representational redescription, conceptual flexibility.

Introduction

Most children are familiar with newborn babies, which they have observed. But what ideas do children have of prenatal development, which they cannot observe?

The literature on children's preconceptions on fetal development is scarce. Most studies focus on either conception (e.g. Bernstein and Cowan, 1975) or birth models (e.g. Nagy, 1951, Kreitler and Kreitler, 1966). Discussing the creation of babies, Kreitler and Kreitler argue that children's views are based on three theories: (1) the baby is created in the mother's belly from the food she eats (2) the baby has always existed in the mother's belly (3) or the baby should be swallowed by the mother.

The more specific topic of fetal development is hardly focused on, however. The study with the largest emphasis on prenatal development is done by Zoldosova (2007). It is a qualitative analysis of drawings and structured interviews. Even though some misconceptions were found in this study, the small sample size and the absence of a focus on age related differences make it difficult to draw firm conclusions. The purpose of the current study is to gain a better insight in the preconceptions children have on fetal development.

Coherent versus fragmentated knowledge. In developmental psychology, there exists a general debate about whether children's knowledge is coherent or fragmented. Theorists on the coherence side of this debate maintain that children's naïve knowledge is organized into coherent and consistent theories, which structure everyday thinking, and are more or less resistant to change (Wellman & Gelman, 1998). Hatano and Inagaki (1994) describe young children's naïve theory of biology. They suggest that children have a coherently organized body of knowledge applicable to living things. In contrast, theorists on the fragmentation side claim that children's naïve knowledge is fragmented (DiSessa, 1988). For example, Straatemeier et al. (in press.) show evidence for children's fragmented knowledge about the earth. The current study examines the question whether children have a coherent theory of fetal development.

A more specific issue within the coherence site of the debate is whether children form mental models 'on the spot'. A mental model is defined as a mental representation that is analogous to the state of affairs the model represents (Johnson-Laird, 1983). Vosniadou et al. (2004) state that the formation of a mental model is based on observations and everyday experiences, which are in turn subject to the constraints of the underlying conceptual structures. Children form dynamic situation-specific representations, formed on-the-spot for the purpose of answering questions. It is argued that generative tasks like drawing or making clay models encourage children to make generative use of the scientific information that they have at their disposal, and encourage the on-the-spot formation of mental models, increasing the coherence of these models. Whether the use of a generative task indeed increases the coherence of children's use of a mental model is another point of focus in this study.

Representational Redescription. If children have a coherent theory of prenatal development, how do these preconceptions develop? In order to answer this question we focus on a theory-like perspective on knowledge acquisition proposed by Karmiloff-Smith (1990). She describes how knowledge develops through representational redescription. This model has already found support in several areas of cognitive development, like language, mathematics, and physics (Karmiloff-Smith, 1992, Critten et al, 2007, Hollis and Low, 2005, Pine and Steffler, 2007). It describes the acquisition of knowledge through sequential phases, starting with a representation of knowledge in a procedural way, followed by a re-representation at different levels of abstraction. This re-representation is the phase of representational redescription (RR), which means that the knowledge embedded in the previously efficiently functioning procedures becomes available as a data structure to other parts of the cognitive system. According to Karmiloff-Smith; '*Development appears to involve reiterated cycles of representational change, from the simple running of automatized procedures, to redescriptions of internal representations specified as a sequentially fixed list, and then to internal representations specified as a structured yet flexibly ordered set of features, that is, a* *manipulable concept*' (Karmiloff-Smith, 1990, p.80, lines 25-29).

In the first level of RR a sequential constraint exists. This means that children are, for instance, able to draw a human being, but that this procedure has a fixed sequence. When asked to draw a human being that does not exist, children have to operate in some way on their internal representation of a normal human being. Young children are not able to be flexible in their representation and stick to their fixed sequential procedure. Firstly, this results in a restriction in intra-representational flexibility, limiting the child in respect to the changes it can introduce into the representation. This means that only changes within the concept are allowed, such as adding an extra head to the human being. Secondly, the sequential constraint results in a restriction in inter-representational flexibility. This means that the child cannot link the new representation to other representations outside the domain. Children cannot for instance add an animals head to their drawing of a human being. This sequential constraint becomes more relaxed later in development, leading to an increase in intra- and inter-representational flexibility with age. This allows children to access elements from other conceptual categories and establish inter-representational connections.

Karmiloff-Smith (1990) used children's drawings to explore representational flexibility. She focused on the constraints children have in their representational flexibility by looking at what changes children make in their representation of a concept (e.g. a house), when asked to draw a non-existing concept (e.g. a fake house). Changes introduced by the younger children (aged 4-6) involved deletions and changes in size and shape, whereas older children (aged 8-10) changed position and orientation of elements and added elements from other conceptual categories. This finding supports that representational flexibility increases with age. In this study we examine if preconceptions children have on fetal development are related to the increase of conceptual flexibility with age as proposed by Karmiloff-Smith.

Representational Redescription in preconceptions on fetal development. What ideas do children have of prenatal development? When asked what a fetus looks like, children are stimulated to operate in some way on their internal representation of a born baby. Young children have difficulty with conceptual change. This results in conceptual change first consisting of a concept lacking an element. Only at a later stage, children will allow conceptual change, which is considered more complex. More specifically, a child in the earliest stage of RR does not allow for conceptual change. When a child in the earliest stage of RR is asked what a fetus looks like, it will answer that it looks exactly the same as a born baby. A child which allows a slight bit of representational change could have the understanding of growth, thinking a fetus looks exactly the same as a born baby but smaller. A child in a later stage of RR would allow for a deletion in it's concept of a born baby, indicating that the fetus is 'incomplete'; for instance the hand of a fetus having not five but three fingers in an early stage. A child in an even later phase of RR would allow for changes of shape to it's concept of a born baby. It would think the hand of a fetus could look entirely different.

This results in four theories we expect children have on prenatal development, representing the different sequential stages proposed in the RR theory. First a theory allowing no change to the concept of a born baby, leading to what we will call the 'equal response' when asked what a fetus looks like compared to a born baby. Secondly, a theory that shows only growth, leading to the 'growth response'. Thirdly, a theory that only shows deletions, leading to the 'incomplete response'. And, fourth, a theory that shows conceptual changes, leading to the 'conceptually different response'.

Methodological issues. Studies on prenatal development have thus far used different methodologies; anecdotal reports (Freud, 1908), (semi)structured interviews with and without the use of dolls (Conn, 1947 in Bernstein and Cowan, 1975), questionnaires and drawing tasks (Nagy, 1951, Kreitler and Kreitler, 1966, Bernstein and Cowan, 1975, Zoldosova, 2007). After a broad exploration of these methodologies and the methodologies used in other area's concerning mental models (Straatemeijer et al., in press), it can be concluded that the most favorable methodology for the study of children's knowledge on prenatal development is the creation of a forced-choice questionnaire in which all mental models are represented. This method has several advantages; it is a critical test for the existence of coherent theories; social interaction is minimal reducing a bias; training of experimenters is not required; the procedure is standardized; and data can be scored objectively. In the questionnaire we will use pictures rather than written responses in order to circumvent problems related to verbal methodologies. Drawing tasks are also used, allowing the examination of the effect of a generative method on the coherence of a mental model.

Statistical analysis. In previous studies on mental models, methodologies used are comparable to Siegler's rule assessment methodology (or shortly RAM, 1981); patterns of responses to different problem types are compared with theoretically expected score patterns. These expected response patterns are based on previous research. Subjects are attributed to a rule according to the best matching rule pattern. A high number of successful classifications of subjects is taken as an index of the fit of the rule system.

In the process of designing the questionnaire RAM is used. Rules were formulated based on the mental models we expected to find. Next, items were constructed such that maximum differentiation was possible between these expected rules.

In analysis, assignment to mental models depends on the percentage of correspondence between the expected and the observed responses. Yet, the use of RAM in analysis of mental models has several shortcomings. A considerable problem of RAM is that the assignment of subjects to rules takes place by an arbitrary criterion of correspondence between observed and expected responses. Also the amount of rules chosen is arbitrary. Moreover, only models that are formulated beforehand can be detected, meaning that the detection of alternative, unexpected, models is not feasible. Additionally, RAM does not provide statistical information on the goodness of fit of the models to empirical data.

Several researchers (Straatemeier et al., in press; Jansen and van der Maas, 1997) state that the use of latent class analysis (LCA) can provide additional information filling the gaps of RAM. LCA is a standard statistical technique for models with a categorical latent variable. Many good introductions are available (McCutcheon, 1987). Parameters that need to be estimated in LCA are firstly the unconditional probabilities, which are the a priori probabilities of being in a latent class (i.e. the proportion of subjects belonging to class). Secondly, the conditional probabilities have to be estimated, which are the probabilities of making a particular response to an item, given membership of a certain latent class (the probability of a response in accordance with a mental model, given that the child adheres to this model). If children have a mental model on prenatal development, we should find a limited number of latent classes with conditional probabilities consistent with the expected mental models.

LCA provides a statistical measure of fit of the models to empirical data. In LCA there is no statistical test for the best fitting model, yet model selection is based on a statistical approach; the model with the lowest BIC (Bayesian information criterion) and AIC (Akaike's information criterion) is the best, most parsimonious model. This determines how many latent classes (mental models) are needed to fit the data. Models do not have to be formulated beforehand, so detection of alternative mental models is possible. A restriction exists to the models we find, which is inherent to the methodology used in designing the questionnaire, but the classes we find can also exist out of children using different combinations of rules not formulated beforehand.

Method

Participants. We tested 317 children (age: $M = 9.35$, $SD = 1.84$) from three different primary schools from different parts of the Netherlands all providing regular education.

Materials

Questionnaire 'Children's preconceptions on prenatal development'. The questionnaire was designed for children aged six and older. The question topics are drawn from results from the LOOL-project[1], a project in which children were asked to draw the developmental stages from an egg cell to the actual baby. Interesting differences appeared between the drawings, which were used for the response categories in our questionnaire. The questionnaire is based on expected rules resulting from the earlier described theories. Response options were designed maximizing the possibility to discriminate between the theories. Four types of responses directly related to the expected theories were used: 1) the equal response, 2) the growth response, 3) the incomplete response, and 4) the conceptually different response. The questionnaire starts with an example item, followed by fifteen questions on prenatal development, which can be divided into two parts; an early and a late stage of fetal development. In turn, the items within these parts concern either morphology or the bodily functions of a fetus. Topics used in the shape related items were the hand, the leg, the ear, the foot, the arm, and the eye. Topics used in the function related items were breathing, drinking and maintaining body temperature. In the booklet the response options of the shape related items are depicted in adapted photographs. The response options of the function related items are given in a few short, easy to read, words. The order of the response options is randomized.

An example of an early stage, shape related item is:

This is what the hand of a baby looks like, when it has just been born. What picture resembles the hand of a baby most, when the baby still has to stay in the belly of the mother for a long, long time? [See figure 1]

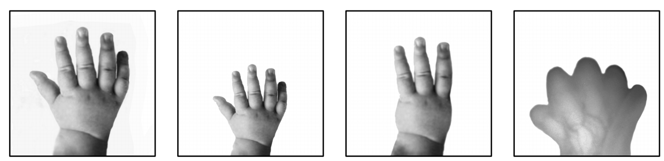
a) A hand looking exactly the same (equal response)

b) A hand looking exactly the same, but a bit smaller (equal response, allowing for growth)

c) A hand looking like the hand of a born baby, but it does not have all the fingers yet (incomplete response)

d) A hand that looks different from the hand of a born baby, it has a different shape (conceptually different response.

Figure 1: Item used in the questionnaire



Drawing task on prenatal development. Participants were asked to make two drawings of a baby; one in an early stage of development and one in a late stage of development. The assignment for the first drawing was 'draw a baby in the belly of the mother, when the baby still has to stay in the belly of the mother for a long, long time'. The assignment for the second drawing was 'draw a baby in the belly of the mother, right before it is born'.

Drawing task of a human being. Following the procedure used by Karmiloff-Smith participants were asked to draw a fake human being with this instruction; 'draw a fake human being. So, not a human being like yourself, but a human being that does not exist. Maybe you even invented this human being'.

Design and Procedure. The experimental procedure existed out of three parts; making the questionnaire and the two drawing tasks. This sequence of tasks was administered group wise in a classroom setting. The children were tested under two conditions; either they first filled out the questionnaire followed by the drawing of the baby (151 participants), or they first made the drawing of the baby, followed by the questionnaire (166 participants). All children finished with the drawing task of a fake human being. The instructions of all tasks were read out loud by the test leader, as well as the questions of the questionnaire. Additionally, an enlarged version of all tasks was shown on a screen. All subtests took about twenty minutes.

Results

General. As a measure of test-retest reliability, three parallel questions were added to the questionnaire, reliability of the parallel items ranged from rS= .50 to rS= .70. The internal consistency, expressed by Cronbach's α, was .85 for all shape related items together and .49 for all function related items together. The low consistency of the function related items is partly due to the very little variation in the late stage function items. It can be concluded that the psychometric qualities of the questionnaire are acceptable. The purpose of the questionnaire is to compare groups, and not to make individual judgments.

The sequence of the tasks (drawing-questionnaire or questionnaire-drawing) had an effect on only three out of the fifteen items in the questionnaire when chi^2 analysis was performed. The differences found did not show a similar pattern within the direction of these effects, no conclusions can be drawn on it. For the remaining analysis the data of the two conditions are taken together. In the analysis the four response options of the questionnaire were reduced to three options, merging the 'equal response' and the 'growth response' to one group, still referred to as the 'equal response'. This was done since only little and inconsistent variation was seen between these two response options, and because this merge minimizes the amount of parameters allowing for more stringent conclusions.

Coherent model. In order to examine if children have a coherent model on prenatal development, a latent class analysis (LCA) was performed. If a coherent model exists, we should find a limited number of latent classes with conditional probabilities consistent with mental models, such as the models we described in the introduction. Using varying sets of items from the questionnaire in different models, LCA showed that based on the AIC and BIC values a four class model consistently shows the best fit (see table 1), and in one case a three class model.

Table 1: latent class models using different sets of items

Model N=317	**N of classes**	**L^2**	**Pb (L^2)**	**df**	**BIC**
Early stage 1[a]	3 class	30.79	.35	60	1588.76
	4 class*	20.65	.56	60	1578.62
Early stage 2[b]	3 class*	17.81	.68	62	1521.82
	4 class	13.35	.62	62	1534.63
Early stage 3[c]	3 class	47.74	.05	59	1862.24
	4 class*	29.41	.29	57	1855.43
Late stage[d]	3 class	11.85	.14	67	790.71
	4 class*	6.32	.43	69	773.65

*Note.**Indicates the most parsimonious, best fitting model; L^2, likelihood ratio statistic; pb(L^2), p value of L^2 obtained by Monte Carlo bootstrap; *df*, degrees of freedom; BIC, Bayesian Information Criterion; no restrictions were added. [a]Includes early stage items on hand, leg, drinking, breathing. [b]Includes early stage items on foot, arm, drinking, breathing. [c]Includes early stage items on ear, eye, drinking, breathing. [d]Includes late stage items on hand, leg, drinking, breathing.

<u>Interpretation of the early stage models.</u> The LCA of the models including early stage items shows a comparable pattern among the different models including varying sets of items; two large and two small classes exist. Interpretation of the different response patterns shows that the two large classes represent at first a group of children (initial probability in Model A is 40%) choosing equal responses options for shape related items and conceptually different responses for function related items, and a second group (initial probability in Model A is 55%) choosing conceptually different options on both shape and function related items. The third and fourth classes are broadly represented by children choosing incomplete options for shape related items. More specifically the two smaller classes represent firstly a group of children (initial probability in Model A is 2%) choosing incomplete options or equal options and secondly a group of children (initial probability in Model A is 3%) choosing incomplete or conceptually different options on shape related items. In the 'early stage model 2', a division into two subclasses is not made in the three class model which has the best fit, but the division does occur in the same way in the four class model. It is noticeable that the interpretation is mainly based on the shape related items, not on the function related items. All classes show a large probability of choosing the conceptually different response on function related items, except for one of the smaller classes represented by incomplete responses, here also incomplete responses have a high probability on the item on breathing. Because interpretation wise there is no large difference between the three and the four class model we chose to use the four class model for further analysis, in order to make an easier comparison with the other models.

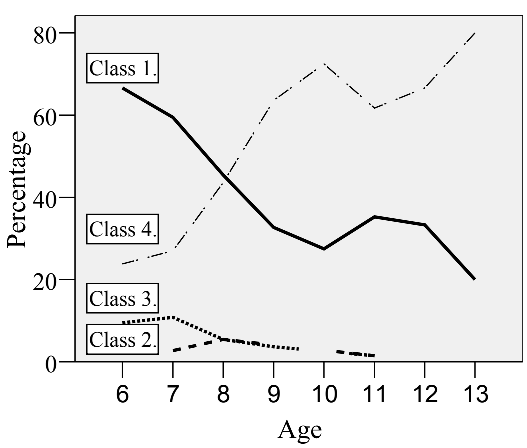
<u>Interpretation of the late stage model.</u> With this model four classes are found, but the majority of children (96,30 %) gives a correct answer to the questions, showing no conceptual differences on the shape related items and conceptual differences on the function related items. In the responses of the remaining 3,70 % no consistent pattern is found.

Validation of Model A. Classification based on RAM can function as a validation of the classification based on model A; a high correlation is found between the two ways of classification, rS=.81, p<.001. Classification by RAM means that children were assigned to the model for which they had the highest consistency score. The expected responses patterns we formulated were a group consistently choosing an equal response, a group consistently choosing an incomplete response and a group consistently choosing a conceptually different response. If the data are analyzed using RAM, only two of these expected response patterns are found. When using LCA these two main groups are found, but a third group and even a fourth group are added.

As an extra validation of the classes found in Model A, the other models (B & C) were fitted using different sets of items from the questionnaire. The correlation between the classification of class membership based on Model A and the classification based on Models B and C are moderate (*rS*= .65, *p* <.001, N=317, and *rS*= *.52*, *p* < .001). The correlation between the classification of class membership based on Model B and C is also moderate (*rS*= .54, *p* <.001). When using crosstabs to analyze the differences between the models it appears that the large groups (children choosing the equal option and children choosing the conceptually different option) are more or less consistent (e.g. 83% of children is classified in class according to model A and B).

Effect of age. To assess the influence of age on theory-use according to class membership as assessed by posterior probabilities of Model A, a χ^2 test was performed, showing a significant effect of age, χ^2 (21) = 45,678, p= .001. Interpretation of the direction of this effect is possible when looking at figure 2; the amount of children in class 1, represented equal responses, is largest in the youngest age group and the amount of children in class 4, represented by conceptually different responses, is largest in the oldest age group. So the older children are, the more flexible they are in their concepts. Class 2 and 3 are represented by children giving incomplete responses. A comparable pattern is found when classifications based on models using different sets of items are used (Model B and C).

Figure 2: age and class membership according to Model A



Mental models 'on the spot'. To examine whether a preceding generative task does indeed increase the coherence of a mental model, two conditions were formed in the design of the study. In one condition children first made the drawing task on prenatal development followed by the questionnaire and in the other condition this sequence was altered.

Consistency is defined as the percentage of equal responses in the whole questionnaire when a child belongs to equal response class according to classification based on highest consistency score, the same accounts for the incomplete response class and the conceptually different response class. An ANOVA showed a significant effect of sequence on consistency, F(1, 305) = 11.221, *p*= .001. Children have a significantly higher consistency score when a drawing is made before the questionnaire is filled out.

Conclusion and discussion

Coherent model and phases of conceptual flexibility. The current study supports the existence of mental models of prenatal development. These models are firstly a fixed concept; children that do not allow changes to their concept of a born baby when being asked what a fetus looks like, secondly an incomplete concept; children including deletions in their concept of a fetus, and thirdly a different concept; children including conceptual changes in their concept. Within these models, the phases of conceptual flexibility proposed by Karmiloff-Smith are supported. A specific correspondence between conceptual flexibility and the mental models will be analyzed in a comparison of the ‘strange person’ drawings with children’s mental models.

On the mental models we found, some of the results were unexpected. This is mainly the case for the second class of the LCA. These were children adhering to the 'incomplete' model, giving incomplete responses. This group chose the incomplete response more often than children from the other groups, but did not consistently choose this response. It can be suggested that this type of change, the incomplete response, functions as a transition phase to the more complex conceptual change and because of that shows a less consistent pattern.

Age related differences. When focusing on the age related increase in conceptual flexibility proposed by Karmiloff-Smith, the results indicate that older children more often have a more flexible response option, suggesting that that theories of fetal development are indeed importantly constrained by principles expressed in the representational redescription theory. The age related fixedness of this constraint is supported in our study.

Function versus shape. Unexpectedly, the models resulting from the interpretation of the conditional response probabilities is mainly based on the responses on shape related items. Responses to function related items showed a less consistent pattern. There is little variation among the function related items and the variation that does exist is not consistent. This suggests that children have a coherent theory on prenatal development of morphology, not on bodily functioning. In this difference, visual imagination could play a role. With shape related items a larger effort is needed within visual representation. Constraints in representational redescription could be more influential in information that could be represented as a picture.

Also, it can be suggested that within knowledge on prenatal development a division can be made in underlying structure, referring back to the coherence versus fragmentation debate. Knowledge on morphology seems to have a coherent structure and knowledge on bodily functioning seems to have a fragmentated structure. The difference in internal consistency on different parts of the questionnaire support this. A high agreement within function related items over different stages of prenatal development (breathing in the early stage and breathing in the late stage) exists as compared to the agreement between function related items within one stage (breathing and eating in the early stage). The response on a function related item seems to be dependent on the subject of the item, not on the stage. The shape related items however, show a large agreement among them within each stage. The response on a shape related is dependent not on subject, but on the naïve theory a child has on morphology.

Generative task and coherence of mental models. Vosniadou et al. (2004) stated that generative methods like making drawings encourage the formation of mental models. The hypothesis that the sequence in which children would make the test (drawing-questionnaire or questionnaire-drawing) influences the consistency within their responses on the questionnaire has been supported, a preceding generative task increases the coherence of a mental model. It can be opted that children give an ad hoc explanation at the time of the experiment. If this is the case, children do so at the beginning of the questionnaire and subsequently stick with their choice. This can be concluded from the consistency in the morphology items.

Methodological issues. A point of criticism could be that due to the limited response options in a forced choice questionnaire children are more likely to respond according to a specific model, increasing the chance on finding a coherent model. However, it appears that forced choice questionnaires do not necessarily lead to a coherent model (Straatemeier et al., in press). Our conclusion concerning the existence of a coherent model is not intrinsic to the methodology used. Moreover, the questionnaire consisted of adapted photographs. This could have resulted in a response bias; children might have just picked the weirdest picture. The lack of variation in the responses to the late stage items, children consistently choose the 'normal' equal response which looks exactly like the born baby provide evidence against the existence of such a bias. A bias towards the equal response could also be suggested, caused by the use of the word 'baby' in the questions. However, variation in the early stage items contradicts this bias. The data of this study underscore that more specific conclusions can be drawn using LCA as compared to RAM.

Previous literature and implications. Taking into account the scarcity on previous literature on naïve theories on prenatal development, in can be suggested that our study adds substantial insights to the subject. A general implication of this study is that it is essential to study conceptual flexibility and models that concern acquiring of knowledge in development. This development is an indication of how human cognition works. It gives insight into the initial architecture of the human mind, what influences it, and how knowledge can change over time (Karmiloff-Smith, 1992). This provides clues as to what the adult mind looks like after development. The findings of this study also has implications for the educational field. Teachers in primary schools will get a better understanding in what mental models children have on prenatal development and how these develop.

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[1] LOOL is a Dutch project on 'enquiry based learning and learning by design', lead by Marja van Graft and executed by Roos Franse in 2005 and 2006 in science center NEMO.