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Developmental changes in the effect of inversion: Using a picture book to investigate face recognition

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Abstract. A novel child-oriented procedure was used to examine the face-recognition abilities of children as young as 2 years. A recognition task was embedded in a picture book containing a story about two boys and a witch. The story and the task were designed to be entertaining for children of a wide age range. In eight trials, the children were asked to pick out one of the boys from amongst eight distractors as quickly as possible. Response-time data to both upright and inverted conditions were analysed. The results revealed that children aged 6 years onwards showed the classic inversion effect. By contrast, the youngest children, aged 2 to 4 years, were faster at recognising the target face in the inverted condition than in the upright condition. Several possible explanations for this 'inverted inversion effect' are discussed.

1 Introduction

Children's face-recognition abilities have been found to improve with age until around the mid-teens. This development has been attributed to older children and adults relying more on the configural properties of faces, which appear to be abstracted more efficiently with increasing age and expertise (Diamond and Carey 1986). The notion of a qualitative change, involving a switch from encoding piecemeal characteristics to encoding the face in a more configural manner, was supported by experiments which tested recognition of disguised (Diamond and Carey 1977) or inverted faces (Carey and Diamond 1977; Carey et al 1980). These studies found that children under the age of 10 years made more errors of recognition than older children when the unfamiliar facial images were disguised with misleading paraphernalia cues such as wigs, hats, and glasses. This was used to support the idea that, when recognising an unfamiliar face, the younger children relied more on these paraphernalia (piecemeal) cues than their older peers. Children under the age of 10 years were found to recognise unfamiliar inverted faces as accurately as unfamiliar upright faces, whereas children older than 10 years showed an inversion effect similar to that seen in adults (eg Yin 1969), with accuracy to upright faces exceeding that to inverted faces. As inversion disrupts the encoding of configurational features, older children and adults have to rely on the piecemeal encoding strategy. Inversion would not affect the performance of younger children as they rely on this strategy for both upright and inverted faces.

Further research by Flin (1985) showed that such findings were sensitive to task difficulty; young children are not always fooled by paraphernalia cues and inversion can disrupt their ability to recognise faces. Similarly, Carey (1981) has argued that the recognition performance of children younger than 10 years might be affected by orientation, but that such an effect has been masked by floor effects. Indeed, an inversion effect in children as young as 3 years has been observed when an attempt was made to control for task difficulty. The size of the set of faces was reduced according to age (eg a single face for 3-year olds and a set size of 6 for 5-year olds) so that performance for upright faces was held constant across age groups (Carey, Diamond, Ginsburg, and Jaaskela—cited in Carey 1981).

Whilst it is necessary to avoid floor effects, it is equally important to consider ceiling effects in order to determine whether young children are prone to the inversion effect. Ellis (1990) has noted that the use of response time, rather than recognition accuracy, as the major dependent variable, has proved very useful in studies of face recognition by adults. It is possible that, by using response time as the dependent variable in developmental studies, the problems of ceiling and floor effects may be limited. Carey and Diamond (1994) used both response times and error rates to investigate the performance of children on a task involving the use of chimeric faces (as devised by Young et al 1987). The results of this study suggested that already at 6 years of age children are encoding faces holistically, and that an encoding switch from complete reliance on piecemeal features of faces to greater reliance on configurational features can be ruled out.

Most of the research on these age-related changes has been conducted on school-aged children and relatively little is known about the face-recognition abilities of children aged 2 to 4 years. It is likely that it is during this period that children start to develop the skills necessary to discriminate among individuals as many start attending playgroups and nursery schools. They are required to learn to recognise a reasonably large number of previously unfamiliar individuals. The aim of the study presented in this paper was twofold. First, to devise a task that was suitable for children of a wide range of ages. Second, to use response-time data as a means of investigating the effects of inversion on children's performance in a face-recognition task.

For the purposes of designing an appropriate task to suit all age groups, the following constraints were considered. First, the procedure must be child-centred and be enjoyable for children of a wide range of ages. Second, the procedure must ensure that the child understands the task requirements, and is motivated to comply with them. Third, the equipment must be portable enough to be taken to the child's normal environment. Fourth, the procedure must be simple enough to allow the child's normal carer to be involved in conducting the experiment. Finally, the procedure must be interesting enough to engage the child's interest and maintain a high level of motivation throughout the experimental session.

2 Method

2.1 *Design*

A face-recognition task was presented to participants as a game within a picture book. A $2 \times 2 \times 5$ mixed factorial design was employed. The first factor was the within-subjects factor of orientation of the image (either upright or inverted). The second factor was the between-subjects factor of target face (either target face 1 or 2). The third factor was the between-subjects factor of age of participant (with a total of five age groups). The dependent variable was the time taken by the participant to correctly identify a target face. The experiment was conducted in two phases, a learning phase and a test phase, separated by a time delay of approximately 3 min. In the learning phase, participants were introduced to three different photographs of the target face (one full-face and two three-quarter views). The test phase commenced with two practice trials to introduce participants to the two orientations and the procedure, and these were followed by six experimental trials, three upright and three inverted, presented in a random order.

2.2 *Participants*

A total of one hundred and fifty-three children participated in the study. Table 1 shows the distribution of children across age group and target face.

Table 1. The number of participants in each age range for each target face.

	Age range/years				
	2–4	5–6	7–8	9–10	11+
Target face 1	21	13	12	14	11
Target face 2	19	16	17	15	15

The children in the youngest age group were recruited from a variety of playgroups and nurseries. The children in the other age groups were recruited from different classes in mixed primary schools in the south of England. The children were unfamiliar with all of the faces that served as stimuli. More 2–4-year-old children were recruited, as it became apparent that some were unable to complete the task successfully (see results for further information).

2.3 *Materials and apparatus*

2.3.1 *The book.* A special colour picture book of A3 pages was constructed. Each page consisted of a hand-painted scene partially overlaid with text. The first pages of the book contained paintings of the bodies of two boys: Tom and Jamie. The heads of these children were created by photographing in colour, from a number of angles, the faces of two 8-year-old boys and positioning them above the bodies painted in the book. This process was used to form one page that presented a full-face picture of both boys and two pages that presented two different three-quarter views of both boys' faces. The first page showed the boys wearing T-shirts printed with their names, and the text on the first three pages introduced the participants to the characters. The following five pages did not include any photographs. The inclusion of these pages ensured that recognition of the target face was not attempted immediately. The delay ranged from 2½ to 3½ min and was dependent on the speed with which the participants wanted to proceed with the story. The text on these pages revealed that one of the boys had been kidnapped by a witch and taken to her castle, Glubedeglub Castle, and how he could be rescued. The witch explained that the kidnapped boy had been turned into a variety of objects and hidden amongst other children who had been similarly transformed, and sometimes turned upside down. (For example, they were transformed into saucepans, so that the faces of the children were positioned on the bottoms of saucepans hanging from a rack, or alternatively into robots, so that the faces of the children were positioned in the helmets of the robots.) Two versions of the book were produced with different target faces. In the first version, the face used to depict 'Jamie' was the target face (target face 1), whereas in the second version the face previously used for 'Tom' was now used to depict 'Jamie' (target face 2) and a new face was used for the character of 'Tom'. The target faces were matched for age, sex, and race.

2.3.2 *The arrays.* For the recognition task, eight colour A3 pages were created that again featured painted background scenes (depicting saucepans, robots, balloons, books, lions, mirrors, bells, and washing on a clothes line) with colour photographs of real boys' faces positioned over the top (see figure 1). All photographs were full-face views. Two of these arrays, one depicting all faces upright and one depicting all faces inverted, were used in the practice trials; and six arrays, three depicting all faces upright and three depicting all faces inverted, were used in the experimental trials. Each page consisted of an array of eight distractor faces and the target face (either target face 1 or target face 2), all of similar age, race, and sex. This layout and number of faces were chosen so that the task would not be too difficult for the younger children, whilst avoiding a ceiling effect in the response times of the older children. A different photograph (containing minor differences in perspective view and lighting) of the target face

Figure 1. An example of an array used in the test phase.

was used each time so that the participant never saw a duplicate photograph in any stage of the experiment. Also, a different set of distractor faces was used for each page, so that no distractor face was used more than once. To form the inverted arrays, only the faces were turned upside down, leaving the painted background upright. The position of the target face within the array was pseudorandomised.

2.3.3 *The machine.* To enable response time to be accurately measured, a machine was constructed that allowed the arrays to be placed beneath a touch screen, which was connected to and controlled by a portable computer. A blind that was opened by depressing a switch button covered the touch screen. As the blind rolled back (taking about 0.1 s to reveal the picture underneath), the touch screen was triggered and the computer started timing. The participants indicated which of the faces in the array they thought was that of the target by touching the face. When the screen registered this touch the computer stopped the timer and recorded response time to an accuracy of 0.01 s.

2.4 *Procedure*

Children participated in the experiment individually, either in their nursery, their home, or their schoolroom. Depending on their age, they were asked either if they would like to read a story, or whether they would like the experimenter to read them a story, which entailed playing a special game. Those who agreed to participate sat next to the experimenter, who placed the picture book on a table in front of the child. On the first page of the story, the name of each boy was printed on his T-shirt. The participant was told which of the two boys was Jamie and which was Tom, and was asked to point to each in turn. If the child got this wrong, she or he was again told which boy was Jamie and which was Tom. This procedure was repeated on the next two pages, where the T-shirts did not display the names. This ensured that, regardless of whether the participant could read, she or he had become familiar with and could correctly name the two key characters of the story. Therefore, all children included in later analyses were able to identify both boys at this stage in the experiment. The participant was then read the pages of the book that contained no photographs, or, if old enough, the participant would read these pages to the experimenter.

On completing the part of the story where the Wicked Witch explains that the kidnapped boy can be rescued, the participant was asked whether she or he would like to play a game of finding the target face (either Tom or Jamie). Each participant was warned that there would be lots of faces and sometimes these would be upside down. If they agreed, the machine containing the arrays was placed in front of them at a height that allowed them to see and touch the whole of the array. They were told that, when they said the magic word 'Glubedeglub', the blind would open, and they were to touch the target face with their finger as quickly as possible. When the participant was ready and had said the magic word, the experimenter pressed the switch that released the blind. After the participant had indicated her or his choice, the experimenter closed the blind and removed the array so that the next one would be revealed in the following trial. Each participant was first shown two practice trials, one upright and one inverted. Once these had been completed, the children were shown the six experimental trials. Each participant saw the trials in a different random order. The story was then continued to achieve a happy ending, and any queries that arose were answered.

3 Results

Only participants who identified the correct target face on at least one upright trial and one inverted trial were considered to have responded above chance level, and only their data were included in the statistical analysis. The number of participants who were included from each age group is shown in table 2.

Table 2. Mean response times (in seconds) and standard deviations (SD) for each target face by age and orientation. N = number of participants included from each age group.

Age range/years	Target face 1			Target face 2			Overall	
	N	mean	SD	N	mean	SD	mean	SD
2–4								
upright	12	6.5	1.9	14	5.0	2.2	5.7	2.1
inverted	12	5.0	1.4	14	4.0	1.7	4.4	1.6
5–6								
upright	12	4.4	1.8	9	6.0	2.2	5.1	2.1
inverted	12	5.3	1.5	9	7.0	1.7	6.0	1.8
7–8								
upright	12	4.0	1.3	15	3.9	1.2	3.9	1.2
inverted	12	4.9	1.8	15	4.5	1.9	4.7	1.8
9–10								
upright	14	2.7	1.4	14	3.2	1.0	2.9	1.2
inverted	14	3.1	1.5	14	3.5	1.0	3.3	1.2
11+								
upright	10	3.2	1.4	15	3.6	1.6	3.4	1.5
inverted	10	3.6	1.2	15	4.0	1.8	3.8	1.6
Overall								
upright	60	4.1	2.0	67	4.2	1.9	4.2	1.9
inverted	60	4.3	1.7	67	4.4	1.9	4.4	1.8

3.1 *Response-time data*

Response times were measured by recording the time (in seconds) taken for participants to recognise the target face (ie by touching the appropriate image) once the array was uncovered. Only the times for correct responses were analysed and response times in excess of 10 s were excluded. (There were occasions when a child was distracted whilst making a response or when the computer did not register a touch because it was too light and the child had to be urged to press harder.)

The mean response times for each target face by age group and orientation are displayed in table 2. Mean response times were analysed with a $2 \times 2 \times 5$ mixed analysis of variance (ANOVA). There was a significant main effect of age ($F_{4,117} = 12.7$, $p < 0.0005$). Mean response times for each age group were as follows: 2–4-year olds—5.1 s; 5–6-year olds—5.7 s; 7–8-year olds—4.3 s; 9–10-year olds—3.1 s; and those aged 11 years or more—3.6 s. There was no main effect of target face ($F_{1,117} = 0.77$, $p = 0.382$). A main effect of orientation approached significance ($F_{1,117} = 3.87$, $p = 0.052$), reflecting that overall response times to upright trials were faster than those to inverted trials (means = 4.2 s and 4.5 s, respectively). Whilst orientation did not interact with target face ($F_{1,117} = 0.10$, $p = 0.753$), importantly it did interact with age ($F_{4,117} = 10.96$, $p < 0.0005$)—see figure 2. The three-way interaction was not significant ($F_{4,117} = 0.36$, $p = 0.836$), but there was an interaction between age and target face ($F_{4,117} = 3.05$, $p < 0.05$), as the 5–6-year olds responding to target face 2 took appreciably longer than the 5–6-year olds responding to target face 1.[(1)]

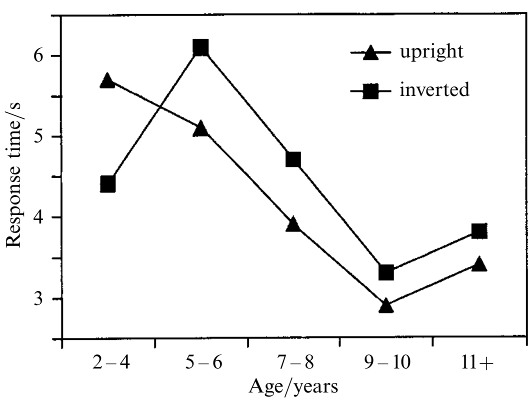

Figure 2. Interaction between age and orientation in response times.

The interaction between age and orientation was analysed further by combining the mean response times for the upright and inverted trials into a percentage decrement score. This was calculated by applying the formula

$$\frac{\text{upright} - \text{inverted}}{\text{upright}} \times 100\%$$

to the response-time data. (The formula has previously been used by Rhodes et al 1993.) The mean decrement scores for each target face by age group are presented in table 3.

A positive value in table 3 reflects a faster response in the upright than inverted trials. All but the youngest age group produced a positive mean decrement score. The youngest group produced a negative mean decrement score. For both target faces, children aged 2–4 years were faster at recognising the target face in the inverted than upright trials. Thus, rather than displaying an inversion effect like the other age groups, the 2–4-year-olds showed the opposite pattern (this will be referred to here as an *inverted inversion effect*).

[(1)] The above analysis was repeated on the data from children who made one or no mistakes and revealed a similar pattern of results. The only difference to emerge was the interaction between age and target face was now nonsignificant, but critically the interaction between age and orientation remained significant.

Table 3. Mean percentage decrement in response times and standard deviations (SD) by age.

Age range/years	Target face 1		Target face 2		Overall	
	mean	SD	mean	SD	mean	SD
2–4	−19.7	25.9	−14.8	35.6	−17.1	31.0
5–6	32.2	55.8	26.5	30.2	29.7	45.7
7–8	29.1	45.7	17.4	29.6	22.6	37.3
9–10	19.5	27.7	13.3	28.8	16.4	27.9
11+	18.0	26.4	13.3	29.2	15.2	27.6
Overall	15.9	41.5	10.1	32.8	12.8	37.1

A one-way between-subjects ANOVA was performed on the decrement scores calculated for each target face. A significant main effect of age group emerged for target face 1 ($F_{4,55} = 3.51$, $p < 0.02$) and for target face 2 ($F_{4,62} = 3.22$, $p < 0.02$). A posteriori multiple-range tests employing the least-significant-difference procedure revealed that, in both cases, the only significant differences to emerge were between the decrement scores of the youngest group and those of all of the other age groups. All other comparisons were nonsignificant.

To examine whether this inverted inversion effect was a significant effect, the response times for upright and inverted trials for the youngest age group were compared. Three t-tests were computed. Comparing upright and inverted response times across both target faces yielded a significant difference ($t_{25} = 3.35$; $p < 0.005$, two-tailed test). Comparing upright and inverted response times for target face 1 yielded a significant difference ($t_{11} = 2.72$; $p < 0.02$, two-tailed test). Comparing upright and inverted response times for target face 2 yielded a difference that approached significance ($t_{13} = 1.99$; $p = 0.069$, two-tailed test).

To examine whether the traditional inversion effect was present in the older age groups, the response-time data for both target faces were subjected to t tests. These revealed a significant difference or close to significant difference in every age group: for 5–6-year olds ($t_{20} = -3.37$; $p < 0.005$, two-tailed test); for 7–8-year olds ($t_{26} = -2.99$; $p < 0.01$, two-tailed test); for 9–10-year olds ($t_{27} = -1.96$; $p = 0.06$, two-tailed test); for 11+-year olds ($t_{24} = -2.32$; $p < 0.05$, two-tailed test).

3.2 *Accuracy data*

For each participant included in the analysis of response-time data, the number of correct responses (from maximum of 3) to the upright and inverted trials was recorded (see table 4).

Table 4 reveals that, for all but the 2–4-year olds and those 5–6-year olds responding to target face 2, recognition accuracy was close to ceiling or at ceiling. Furthermore, there is virtually no difference in accuracy scores for the youngest children. Although the accuracy scores do not repeat the effect observed in response times, lower accuracy scores do not accompany the faster response times in the inverted condition. Inspection of the accuracy data also suggests that the children were remembering the face from the story and not simply choosing the face that appeared in every trial. For example, 90% of the children correctly selected the target face in the first trial whereas 85% did so in the last trial (the range across all trials was 85%–91.3%).

Table 4. Mean correct recognition scores and standard deviations (SD) for each target face. N = number of participants included from each age group.

Age range/years	Target face 1			Target face 2			Overall	
	N	mean	SD	N	mean	SD	mean	SD
2–4								
upright	12	2.2	0.8	14	2.3	0.9	2.2	0.9
inverted	12	2.1	0.8	14	2.3	0.8	2.2	0.8
5–6								
upright	12	2.9	0.3	9	2.6	0.7	2.8	2.5
inverted	12	2.7	0.8	9	2.2	0.7	0.5	0.7
7–8								
upright	12	2.8	0.5	15	3.0	0.0	2.9	0.3
inverted	12	2.7	0.7	15	2.7	0.5	2.7	0.6
9–10								
upright	14	3.0	0.0	14	2.9	0.3	3.0	0.2
inverted	14	2.8	0.6	14	2.7	0.6	2.8	0.6
11+								
upright	10	3.0	0.0	15	2.7	0.7	2.8	0.6
inverted	10	2.9	0.3	15	2.6	0.7	2.7	0.6
Overall								
upright	60	2.8	0.5	67	2.7	2.5	2.7	0.6
inverted	60	2.6	0.7	67	0.6	0.7	2.6	0.7

4 Discussion

The aim of this study was to develop a technique suitable for use with children of a wide range of ages that would allow an investigation of the developmental changes in the recognition of upright and inverted faces. The picture book and game devised for this purpose were successful in that all the children enjoyed participating in the study, and many of those in the youngest age group could correctly recognise previously unfamiliar faces. Results indicated that many children were able to perform the task at above chance level, with fourteen of the forty children aged 2–4 years and eight of the twenty-nine children aged 5–6 years excluded from statistical analysis. It is important to note that it was not the youngest children that were excluded: the mean age of those included in the analysis was 41.83 months compared with 43.22 months of those excluded. The fact that some of the younger children could not complete the identification task successfully should, however, be considered against the difficulty of the task, namely to identify the target face from amongst eight distractor faces. In previous research considerably fewer distractors have been used; Carey et al (1981) showed a single face to 3-year olds after displaying the target face.

Response-time data showed that children took less time to identify the target face as they got older, and that the differences across the five age groups were significant. The orientation of the face significantly interacted with age, with the youngest group showing, on average, faster response times in the inverted trials, whereas all the other age groups performed faster in the upright trials. Percentage decrement scores were calculated to examine the effect of inversion more closely by taking into account the decrease in response times generally observed with an increase in age. These scores revealed that all children from the age group of 5–6 years showed evidence of the classic inversion effect as observed by Yin (1969). This result does not support Carey and Diamond's earlier (1977) encoding-switch hypothesis and instead is consistent with the notion of children aged 6 years having 'face expertise'. Several recent studies have found that the abilities of children aged 6 years are comparable with those of adults, and that a switch in encoding strategies does not take place at the age of 10 years, as had been earlier suggested. Carey and Diamond (1994) concluded that their results did not reveal any developmental change in configural or holistic encoding of faces and their youngest participants were 6 years of age. Stevenage (1995) used the caricature advantage as an indicator of expertise and also found that children as young as 6 years showed a level of performance equivalent to adults.

Of greatest interest, however, is the performance of the youngest participants in the present study, the group aged 2–4 years, as it is this age group that has received little attention to date. Although some were unable to complete the task successfully, those children that could did not show an inversion effect but an inverted inversion effect: response times for inverted trials were significantly faster than for upright trials overall. Analysis for each target face revealed a significant difference in response times for target face 1 and a difference that just failed to reach significance for target face 2. This inverted inversion effect is comparable to the finding of Carey and Diamond (1994), who reported that the youngest children in their study, aged 6 years, displayed an opposite pattern to that shown by older children and adults.

There are several possible explanations for this finding, which are not mutually exclusive. First, it could be there is an encoding switch from piecemeal to configural that takes place earlier than previously hypothesised, so that from the age of 5 years onwards children are able to use all available encoding cues. Flin (1985) pointed out that there was "no reason to designate age 10 as a transition point for an encoding switch" (page 132). The youngest group of children may not be processing the configural characteristics of the face very efficiently; hence response times to upright faces are delayed compared to those for inverted faces. Responses to inverted faces are faster as these faces are processed only according to their piecemeal features. This explanation, therefore, simply pinpoints a much earlier age for the acquisition of configurational processing abilities and suggests that performance is adversely affected whilst this processing strategy is being perfected.

A second explanation is that there is no encoding switch and that all age groups have available to them a range of strategies to encode the faces they encounter. Johnston and Ellis (1995) have suggested that developmental changes in face-recognition skills might reflect an increasing ability to discriminate among faces, which can be explained in terms of proficiency at the encoding stage, or in terms of the way in which the faces are stored as representations. Stevenage (1995) has pointed out that, even if configurational processing is available to a child, this does not necessarily mean that it is the preferred manner of processing. It is possible that when children start attending school they gain expertise at using a configural strategy, possibly because for the first time they are required to learn to recognise many unfamiliar faces and to start individuating large numbers of faces. Although individuation is also necessary at pre-school groups, the number of novel faces involved is still far smaller than at primary school. It may be that, when learning to recognise a large number of unfamiliar faces, with practice the encoding of configural characteristics becomes easier and speedier. Children younger than 5 years will not engage in configural processing when looking at inverted faces but this will result in faster response times.

Third, it is possible that the results of the present study mirror the strategy a child adopts to complete the task. Hole (1994) has highlighted the fact that participants in face-processing tasks will choose the strategy most appropriate to the task. Diamond and Carey (1977) found that children as young as 6 years were not fooled by the addition of paraphernalia, but only when the target face was highly familiar to them. Therefore, the strategy adopted may well depend upon the familiarity of the face. Whether or not the participants can engage in configurational or piecemeal encoding is not necessarily the most important question. In the present study, which employed unfamiliar faces, the longer response times of the younger children may reflect their general metacognitive skills rather than their specific face-processing skills. Thus, they may have employed an uneconomical strategy whereby they examined each face in turn. As they are processing all the available information, they may have spent longer looking at the upright faces, as it is only when the face is upright that it can be properly processed for attractiveness and emotional expression. Older children may be employing a more economical strategy, either by performing the task holistically and looking at several faces simultaneously to pick out the target, or by looking only for the defining features of the target face in each of the faces in front of them. In other words, the older children may be employing a strategy chosen in light of the task demands, reflecting their greater ability to discriminate among faces.

In conclusion, the findings of the present study demonstrate the usefulness of response-time data to investigate the development of face-recognition skills. Furthermore, it is possible to devise experimental tasks to investigate face processing that are suitable for a range of ages, including children as young as 2 years. Analysis of response-time data pinpoints 5 years as the approximate age at which the classic inversion effect first starts to appear, which is consistent with other evidence suggesting that children as young as 6 years have 'face expertise'. Finally, analysis of response-time data provides evidence for a novel effect—the 'inverted inversion effect' in children younger than 5 years.

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