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REPORT

Object identification in preschool children and adults

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Abstract

We introduce computer-based methodologies for investigating object identification in 3 to 5 year old children. In two experiments, preschool children and adults indicated when they could identify degraded pictures of common objects as those pictures either gradually improved *or* degraded *in clarity. Clarity transformations were implemented in four ways: blurring, decreasing the picture's physical size, decreasing the pixel signal-to-noise ratio, and cropping. In Experiment 1, all age groups correctly identified objects at a more degraded state when those objects began moderately, as opposed to very, degraded and then clarified. This finding supports the notion that previous perceptual hypotheses interfere with object identification (i.e.* the perceptual interference effect*). In Experiment 2, children, but not adults, overestimated their ability to recognize objects in a degraded state when the object's identity was given to them beforehand. This suggests that for young children knowledge of the object's true identity cannot be ignored when evaluating their current perceptions. This is the first demonstration of the perceptual interference effect in children. We discuss both methodological and theoretical implications of the findings for research on object perception and theory of mind.*

A person traveling down a road spots an object in the distance. Although at first the object is unidentifiable, eventually it is identified. How is identification ability related to the person's age as well as the object's distance when it was first spotted? The former question has received surprisingly little attention from developmental psychologists (e.g. Anooshian, 1997; Guttentag & Dunn, 2003; Rose, Jankowski & Senior, 1997; Wiegel-Crump & Dennis, 1986). The second question has received attention from cognitive psychologists and has a counterintuitive answer. The more degraded the object initially, the clearer it must become before being identified. Thus, an object initially seen 60 meters away needs to be closer to be identified than the same object initially seen 30 meters away, a phenomenon known as *perceptual interference* (e.g. Bruner & Potter, 1964; Galloway, 1946; Schulkind, 2002; Snodgrass & Hirshman, 1991; Wang & Reinitz, 2001).

In a classic experiment, Bruner and Potter (1964) asked adults to identify pictures of common objects that clarified gradually from one of three initial blur levels. The more blurred the starting point, the worse the identification performance. In another experiment, observers identified pictures that either *clarified* from extreme to moderate blur or *degraded* from moderate to extreme blur. Observers who watched pictures clarify performed far worse than observers who watched the pictures degrade. The authors accounted for these findings by suggesting that exposure to degraded variations of a visual stimulus interferes with its subsequent identification. In such cases, observers generate incorrect hypotheses about what they are seeing, and these hypotheses interfere with the ability to correctly identify the stimulus.

Thus far, investigators of perceptual interference have focused their attention on adults. In the present work, we modified Bruner and Potter's (1964) procedures to directly compare perceptual interference in preschoolers and adults. The question of whether perceptual interference changes or remains constant from childhood to adulthood has a bearing on a larger developmental issue: cognitive flexibility may be defined as the ability to simultaneously conceptualize an object in multiple ways (Frederiksen, 1967), and is thought to increase in the 3- to 4-year-old age range (e.g. Deloache, 1987). This suggests that 3-year-old children will demonstrate greater perceptual interference than older children, inasmuch as they will have more difficulty letting go of, or switching from, their initial construal of the object. Indeed, there is ample evidence that young children focus on irrelevant perceptual information (Piaget & Inhelder, 1973; Springer, 2001) and tend to perseverate on incorrect hypotheses about the world (e.g. Luria, 1973), perhaps due to poor inhibitory control (Carlson, Moses & Breton, 2002).

The chief rationale for using 3- to 5-year-olds to trace development of object identification is that it is a time of

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rapid change in children's perceptual and conceptual perspective taking, as shown in 'theory of mind' research. In particular, there is a sharp developmental change in: (a) the realization that something can 'look like' one thing but 'really be' something else (Flavell, Green & Flavell, 1986; Flavell, 1999); (b) children's understanding that picture fragments are difficult for other people to identify, even if the underlying picture is known to the self (Chandler & Helm, 1984; Taylor, 1988); (c) children's accuracy at reporting their own past perceptions/beliefs (e.g. Gopnik & Astington, 1988; Wellman, Cross, & Watson, 2001); and (d) children's susceptibility to visual illusions requiring perceptual flexibility, such as the 'duck–rabbit' illusion (Gopnik & Rosati, 2001). These factors all suggest that younger children will exhibit greater perceptual interference than older children and adults.

The three specific goals of this paper are to introduce and describe a new computer methodology for efficiently collecting large amounts of perceptual data from young children, investigate perceptual interference in young children and adults, and quantify and examine the way in which identification of visually degraded objects improves with age.

Experiment 1

In Experiment 1, observers identified degraded common objects as they gradually clarified. In half the trials the image began clarifying from a highly degraded state, while in the remaining trials the image began clarifying from a less degraded, but still unidentifiable, state.

Method

Participants

Three groups of 16 children, aged 36 to 71 months, participated: 3-year-olds (M = 42.6 months, range = 37–46; seven female); 4-year-olds (M = 55.9 months, range = 48–59; six female); and 5-year-olds (M = 68.6 months, range = 60–72; seven female). One group of adults (n = 16; nine female) participated for course credit. Children were drawn from the greater Seattle area, and represented families of varying socioeconomic and ethnic backgrounds.

Design

There were three independent variables: Age (3/4/5/Adults) × Degradation Type (Blur/Pixel/Size/Crop) × Initial Degree of Degradation (Hard/Easy). The initial degree-of-degradation levels at which the object was initially shown we designated as 'Hard' and 'Easy' according to whether they were very, or moderately, degraded, respectively. Degradation type and initial degree of degradation were within-subject factors, and age was a between-subject factor.

Stimuli

Stimuli were 48 line drawings of common objects (Snodgrass & Vanderwart, 1980), chosen, based on pilot work, as identifiable to young children. There were six object categories: animals (16 pictures), food (nine pictures), furniture/indoor objects (eight pictures), vehicles (five pictures), clothing (four pictures), and body parts (six pictures). Images of each original object were scaled to fit within a 245 × 245 pixel square on a laptop screen with a 1024 × 786 resolution. Images subtended 6.6 degrees of visual angle with observers seated approximately 63 cm from the screen. Observers could move their heads closer if they wished. Each object was degraded in four ways (Blur, Pixel, Size and Crop, as described below). For each object in each degradation type, we created 30 separate images of the object, entailing 30 levels of increasing degradation.

Four different degradation transformations (Blur, Pixel, Size and Crop) were chosen for their ecological validity, and were obtained using specific criteria. First, for each degradation condition, we designed the set of 30 increasingly degraded versions of each object's image such that the degradational differences between successive versions were roughly equal perceptually. Second, we avoided large floor and ceiling effects. That is, imagine an object starting at its most degraded level and gradually clarifying, across the 30 images, to its least degraded level. At any degradation level i, there is some overall probability, p_i, (across objects and observers) of identifying the object. Through pilot work, we constructed the range of degradations such that p_i would (a) begin at zero at the most degraded level, (b) not rise above zero until at least half (15) of the clarifying steps had occurred in order to give the observer the opportunity to make many guesses, and (c) rise to 1.0 shortly before the clarifying process ended (see Sadr & Sinha, in press, for similar techniques). Third, for reasons described later, we defined a ratio scale metric for each degradation type. Two requirements for the metric were that it should have a natural zero point, and that it should be unbounded. For three of the degradation conditions – Blur, Size and Crop – this metric was *distance* (e.g. in feet) while for the fourth, – Pixel – the metric was a *noise-to-signal ratio*. The four degradation conditions are shown in Figure 1, and mathematically defined in Appendix 1.

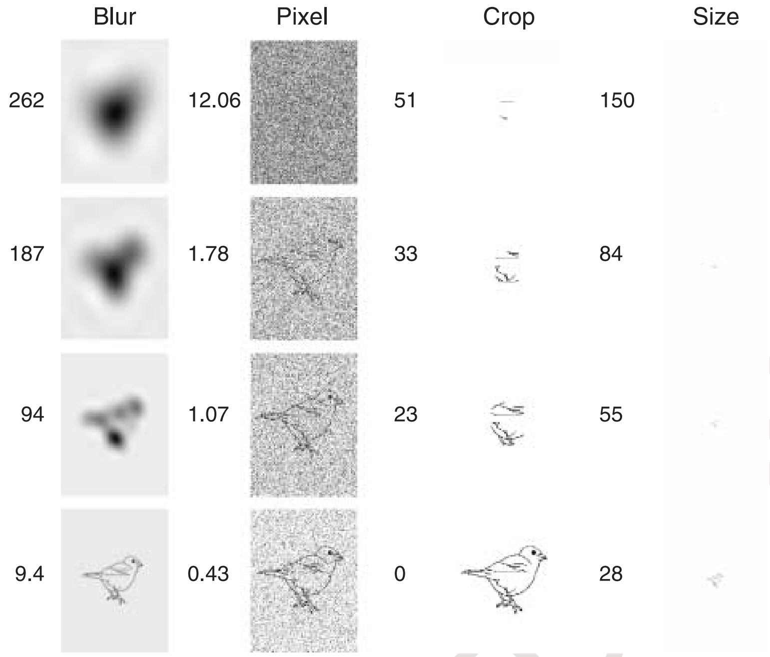

Figure 1 *Examples of degraded stimuli. Numbers indicate the degree of degradation in the scale devised for the particular degradation condition. For Blur, Crop and Size, the scale is 'distance' in arbitrary units. For Pixel, the scale is 'noise-to-signal', which is a pure number.*

Object clarification

In each of the four degradation conditions, objects began degraded and progressively clarified. In the Hard conditions, the object's initial image was the most degraded of the 30 versions of that object, and object clarification consisted of presenting, in increasing order of clarity, the images corresponding to the remaining 29 degradation levels. In the Easy conditions, the initial image was the 15th most degraded of the 30 versions, and object clarification occurred by presenting the remaining 14 degradation levels.

It was not possible to control simultaneously for total viewing time per trial and the time to view each degradation level across Hard and Easy. We chose to equate total viewing time, thus varying the time to view each degradation level in the Hard and Easy conditions (see Bruner & Potter, 1964; Loftus & Harley, in press; and Luo & Snodgrass, 1994). In the Hard condition, each of the 30 images remained onscreen for 600 ms before being replaced by the next, less degraded level; correspondingly, for the Easy condition, each of the 15 images remained onscreen for 1,200 ms. In future work, it would be useful to replicate our procedure, equating for viewing time within each degradation level.

Counterbalancing

A *trial* consisted of a single clarifying object along with an associated response. An experimental session contained eight blocks of six trials per block. The 48 objects were shown in a fixed order across the resulting 48 trials. Each block of trials used one degradation type. The four degradation types occurred in one order across the first four blocks and then in the opposite order across the second four blocks. Counterbalancing was such that each object appeared once in each of the eight conditions (four degradation levels × Easy/Hard) across eight observers within a given age group. The randomization and counterbalancing were identical for each of the four age groups. The order of the 48 objects and the order of initial degree of degradation within each block were freshly randomized for each of the two eight-observer counterbalancing modules within each age group that constituted the experiment.

Procedure

Observers were tested individually in their homes or in the laboratory on a Macintosh G4 laptop computer. MATLAB Psychophysics toolbox routines (Brainard, 1997; Pelli, 1997) controlled all aspects of the experiment, including stimulus degradation, stimulus presentation and data analysis.

Children were first familiarized with the computer. Children and adults were told that they would see pictures of everyday objects on the computer screen. They were also told that the pictures would be hard to see at first, but would get clearer. Observers were encouraged to guess the identity of the picture as it clarified: 'What do you think it is?' Before the experimental trials began, observers received eight practice trials: two pictures in each of the four degradation types. The first practice trial was always in the Hard condition. None of the pictures from the practice trials appeared in the experimental trials.

Before each block of trials, the experimenter read a printed message on the screen describing the degradation type for the next block of trials (e.g. 'Next will be blurry trials'). On each trial, the observer watched the object clarify and made identification responses at will. When a child offered an identification, the experimenter pressed the space bar and typed the child's response. Adults typed their own responses after pressing the space bar. The space bar halted the clarification of the object, during which time the object remained on screen. After typing the response, the experimenter (or adult observer) pressed the return key, which resumed the clarification process. Observers could offer a different response if they decided that a previous response was in error, though this rarely occurred. At the end of each object clarification trial, observers were prompted to identify the object by, 'OK. What is it?' On all trials, regardless of degradation type, the object clarified to a level that made identification easy. Observers received no direct feedback about the correctness of their final responses. Instead, child observers were encouraged with phrases like, 'good job'. When children guessed before the object had fully resolved, they were encouraged with phrases like, 'ok, let's see if you're right' prior to resumption of the clarification process.

Children were permitted to take a break at any time: the experimenter halted the procedure, and then resumed when the child was ready. Testing time was approximately 45 minutes for children and 35 minutes for adults. Except for one 5-year-old child who refused to play at all, every observer completed the study.

Results and discussion

Of 48 possible objects, the average per cent identified was: 3-year-olds: 82.9 (SD = 8.9); 4-year-olds: 91.5 (SD = 4.1); 5-year-olds: 95.6 (SD = 2.7); adults: 98.6 (SD = 1.8). The average number of incorrect guesses was: 3-year-olds: 5.6 (SD = 5.6); 4-year-olds: 8.9 (SD = 6.9); 5-year-olds: 11.6 (SD = 8.7); Adults: 6.1 (SD = 6.5). There was no effect of gender in either experiment. For all subsequent results, we pool across gender and omit responses in which observers failed to ever identify the object.

How does the perceptual-interference effect change with age?

The perceptual-interference effect is measured as a function of the degree to which objects are identified earlier (i.e. at a greater level of degradation) in the Easy compared to the Hard condition. To quantitatively assess the nature of the perceptual-interference effect across degradation level and age, we defined perceptual interference as the ratio of Easy-Condition performance to Hard-Condition performance (see Figure 2), where performance is the first trial in which the object was correctly identified. This allows us to directly compare results from the four different degradation conditions.

As Figure 2 demonstrates, a ratio of 1.0 indicates no perceptual-interference effect. All 16 means exceed 1.0 implying a perceptual-interference effect for all age groups in all degradation conditions. Although the effect's magnitude varies over degradation condition (being larger for Blur, Pixel and Crop than it is for Size), it declines over age for the Crop and Blur conditions while remaining constant for Pixel and Size.

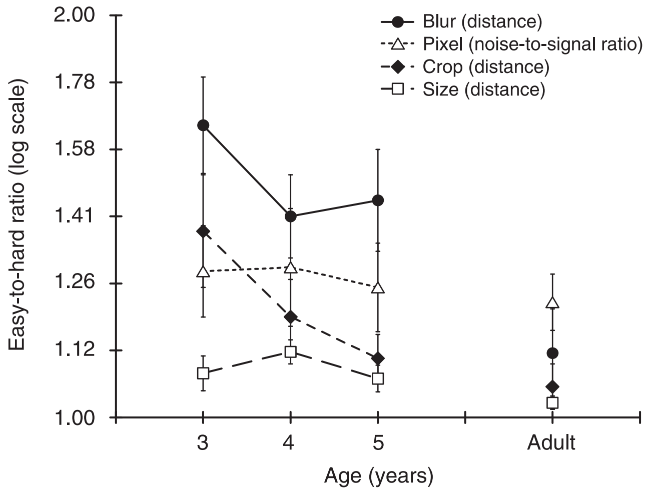

Figure 2 *The perceptual-interference effect in Experiment 1: log Easy/Hard ratio for four degradation conditions and four age groups. In the Easy condition, objects began moderately degraded and then clarified. In the Hard condition, objects began highly degraded and then clarified. Note that a ratio of 1.0 indicates no perceptual interference effect. Errors bars are standard errors.*

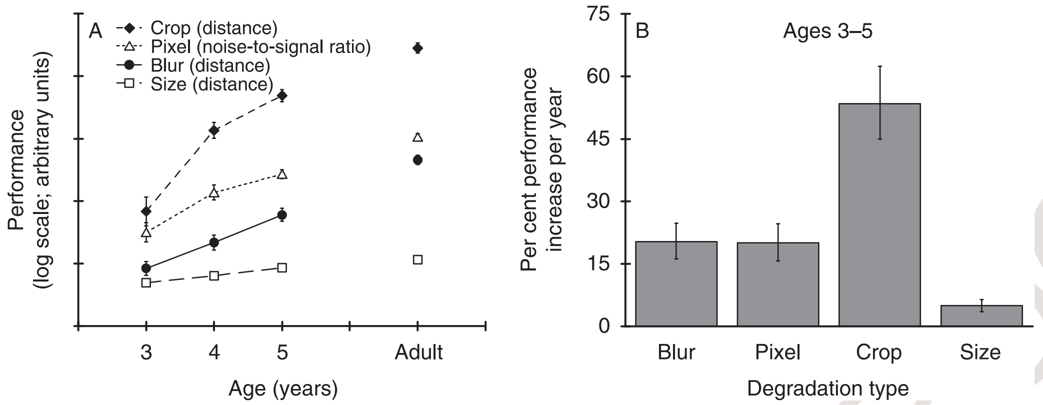

Figure 3 *Panel A depicts log performance of the Hard condition for the four age groups in Experiment 1. 'Performance' is defined as the degradation level at which correct recognition is achieved on the scale appropriate to the particular degradation condition. Because degradation-condition differences are scale-dependent, their main effect is meaningless; thus, for ease of viewing, the four curves have been vertically offset from one another. Panel B depicts the slope (increase in per cent performance per year) for each of the four degradation types in Experiment 1. Data are for children, Hard condition only for comparison with comparable Experiment 2 data. Error bars are standard errors.*

To assess the statistical reliability of this pattern, we computed contrasts corresponding to monotonic decreases over age (weights = 6, 1, −1, −6 across the four ages) for each of the four degradation types. The magnitude of these contrasts (i.e. the sum of the weight × mean cross-products, which reflect the magnitude of the perceptual-interference effect decrease across age) was significantly greater than zero for Blur and Crop (1.001 ± 0.479 and 0.731 ± 0.479, respectively), but not for Pixel and Size (0.153 ± 0.479 for both). The small age effect for the Size condition may be a floor effect; however, the same argument cannot be made for the Pixel condition. Overall, these data demonstrate that perceptual interference occurs as early as 3 years of age. Moreover, the magnitude of the effect as children age depends on the way in which the stimulus is degraded, declining as a function of age for two of the degradation types but not for the other two.

How does the overall ability to identify degraded objects change with age?

To determine how age affects the overall ability to identify degraded objects, and to facilitate an eventual direct comparison to the corresponding Experiment 2 data, we conducted the following analysis. For each of the 16 observers in each of the four age conditions, we computed the mean initial correct identification in the Hard condition for each of the four degradation conditions. The logarithms of these four scores constituted the dependent variable over which we computed means and standard errors over observers for each of the 16 (4 ages × 4 degradations) conditions. These data are shown in Figure 3, panel A. Because across-degradation type comparisons are meaningless due to the different scales, we have offset the four curves from one another for visual clarity.

We draw two conclusions. First, identification ability clearly increases with age: for each of the four degradation conditions, the average level of difficulty at which identification occurs increases monotonically from the age of 3 through to adulthood. Second, the rate of change across age (indicated by the slopes of the curves) is approximately equal for Blur and Pixel, large for Crop and small for Size.

To quantify the apparent rate-increase differences over degradation type, we computed the *slope* – log performance increase per year – for each of the four degradation conditions, along with the slope standard errors, computed (as described by Loftus, 2002, pp. 370–372) for the children's data. These slopes, converted to per cent increase per year, are shown in Figure 3, panel B. It is apparent that the ability to identify pictures degraded by cropping increases very quickly – over 50% per year. The increase is 20% per year for the Blur and Pixel conditions, but only 5% per year for Size.

Experiment 2

In Experiment 2 we replicated and extended Experiment 1, using another computer-based task to compare perceptual performance in young children and adults. Observers either identified a degraded object as it clarified (the 'Degraded–>Clear' or 'D–>C' condition; note that this condition is identical to the Experiment 1 Hard condition) or they indicated when they could no longer identify an object that started off clear and began to degrade ('Clear–>Degraded' or 'C–>D' condition). This procedure permitted us to explore how knowing an object's identity affects our estimate of its perceptibility. Such top-down information processing has been demonstrated in comprehension and memory for prose and ambiguous figures (Bower, Karlin & Dueck, 1975; Bransford & Johnson, 1972; Carmichael, Hogan & Walter, 1932), and perception of complex visual scenes (Sanocki, 2003). This work suggests that it should be easier to identify a known degrading picture than an unknown clarifying picture, given the same level of degradation in each case. A compelling demonstration of this effect is the well-known picture of a Dalmatian embedded within a visually noisy scene (Sekuler & Blake, 1990). Naïve viewers initially cannot locate the dog. Once identified, the dog seems to 'jump out' on subsequent viewings and it is difficult *not* to see it, even if the scene is viewed under imperfect conditions.

Experiment 2 allowed us to determine the precise point at which young children and adults cease to recognize an object as that object degrades. As in Experiment 1, we expected that younger children would exhibit greater perceptual interference than older children and adults – in this case it would be due to the inability to 'let go' of clear information or knowledge about what the object really is. Our main interest here was whether observers would say that they could identify objects in the C–>D condition at a more degraded state than they could identify objects in the D–>C condition. Such a finding would constitute evidence that the identical physical stimulus is interpreted differently if it is encountered in a series of pictures that were progressively degrading or clarifying.

Method

Participants

Three groups of 12 children participated: 3-year-olds (M = 40.8 months, range = 37–44; seven female); 4-year-olds (M = 56.3 months, range = 52–59; four female); and 5-year-olds (M = 66.9 months, range = 61–70; six female). One group of adults (n = 12; eight female) participated for course credit. Children were drawn from the same population as in Experiment 1.

Design

The design resembled that of Experiment 1. There were three independent variables: Age (3/4/5/Adults) × Degradation Type (Blur/Pixel) × Degradation Order (D–>C/C–>D). Degradation type and degradation order were within-subject factors while age was a between-subject factor. Counterbalancing was identical to Experiment 1, except that the experimental session contained four blocks of eight trials per block. The order of the 32 objects and degradation order were freshly randomized for each set of four observers within each age group.

Stimuli and object clarification

Stimuli were a subset of 32 of the objects used in Experiment 1, chosen to be identifiable by most observers. Each object was degraded in two ways (Blur and Pixel, chosen because they yielded similar performance increases with age in Experiment 1). Instead of the continuous clarification procedure used in Experiment 1, objects clarified or degraded with distinct stopping points. Each version of the object remained onscreen for 600 ms, and was replaced by the next version – next clearer or next more degraded, depending on the degradation order condition. After three versions had been shown, the image remained onscreen until the observer responded. Over the 30 versions of each object, comprising a single trial, there were therefore 10 stopping points. These stopping points permitted us to control for the particular points at which observers could respond.

Procedure

The procedure resembled that of Experiment 1, except for the following. Observers received four practice trials, consisting of two pictures of each degradation type (Blur, Pixel) in each of the two degradation orders (D–>C and C–>D). The D–>C condition resembled the Hard condition in Experiment 1, but instead of continuous clarification, the image stopped at 10 distinct points, where observers were asked, 'What do you see in the picture right now?' At the beginning of the C–>D condition, observers were told that they would see pictures that were clear and that the pictures would get harder and harder to see. They were told to indicate, when asked, what they saw in the picture ('What do you see in the picture right now?'). They were told that at some point they would no longer be able to see the object, and to indicate this point. At the beginning of each trial, observers saw a clear picture that they were asked to identify. After identification, the picture degraded in steps of three before stopping and prompting a response. Examples of responses that children gave to indicate that they no longer saw the object included: 'not anymore', 'nothing', 'it's gone'. The experimenter recorded children's responses. The experiment took approximately 35 minutes.

Results and discussion

One 4-year-old and one 5-year-old failed to complete the study. They were not included in the analyses or in the observer count above. One 4-year-old adopted a unique strategy whereby, on most trials in the two C–>D conditions, she reported immediately that she could no longer see the object when it was still clearly visible. Her data were omitted. Observers identified nearly every object: 96.4% (SD = 3.5), 99.2% (SD = 1.4), 99.5% (SD = 1.2), and 100% (SD = 0) for 3-, 4-, and 5-year-olds and adults. The point at which observers correctly identified the object was calculated as follows: in the D–>C condition, it was the first stop point where observers indicated the correct name for the object. In the C–>D condition, it was the last stop point before observers indicated that they could no longer see the object.

How does the magnitude of perceptual interference change with age?

Perceptual interference magnitudes, defined in a given degradation × age condition as the ratio of mean C–>D condition identification value to mean D–>C condition identification value are shown in Figure 4. As in Experiment 1, a ratio value of 1.0 denotes no effect. Children, but not adults, showed the perceptual interference effect. The means for all three groups of children are above 1.0 for both Blur and Pixel, while the adult means are nearly 1.0. This suggests that children said that they could see objects at a more degraded state in the C–>D condition than the point at which they correctly identified similar objects in the D–>C condition. Adults showed no such effect. The effect's magnitude declines with age in the Blur condition, but not in the Pixel condition.

We constructed contrasts as in Experiment 1 for the Blur and Pixel conditions. As can be seen in Figure 4, the magnitude of these contrasts – reflecting the decline in the perceptual-interference effect across age – was significantly greater than zero for Blur (2.12 ± 1.19) but not for Pixel (.53 ± 1.51).

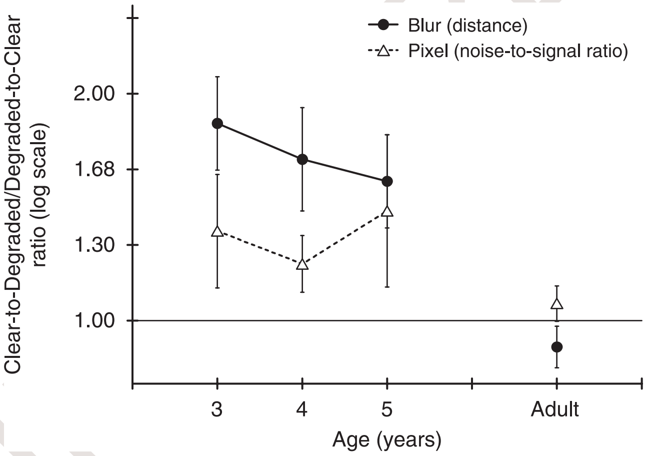

Figure 4 *The perceptual-interference effect in Experiment 2: log Clear-to-Degraded/Degraded-to-Clear ratio for two degradation conditions and four age groups. In the Clear-to-Degraded condition, objects began clear and then degraded. In the Degraded-to-Clear condition, objects began degraded and then clarified. Note that a ratio of 1.0 indicates no perceptual-interference effect. Error bars are standard errors.*

How does the overall ability to identify degraded objects change with age?

To determine how age affects the overall ability to identify degraded objects, we conducted the identical analyses as in Experiment 1. The normalized scores representing the mean identification point in the D–>C condition for Blur and Pixel appear in Figure 5.

Experiment 2 replicates the Blur findings of Experiment 1: identification ability increased monotonically with age. Identification ability also increased with age for the Pixel condition; however, the increase was non-monotonic. To quantify the rate-increase differences, we computed

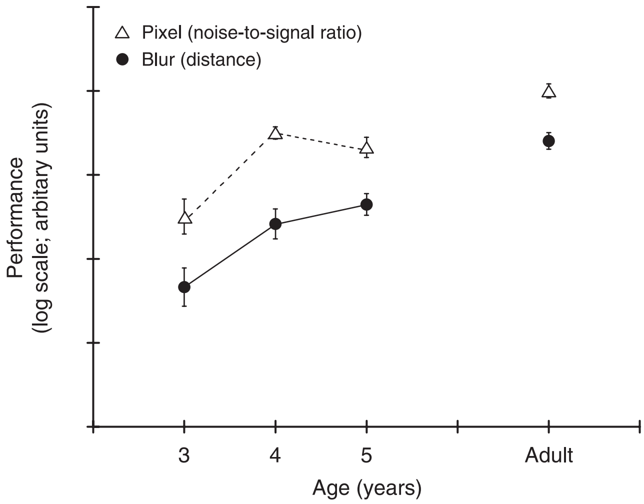

Figure 5 *Log performance of the Degraded-to-Clear condition for the four age groups in Experiment 2. 'Performance' is defined as the degradation level at which correct recognition is achieved on whatever scale is appropriate to the particular degradation level. Because degradation-condition differences are scale dependent, their main effect is of no interest. Accordingly, for ease of viewing, performance has been normalized such that each of the two degradation conditions has the same mean across ages. Error bars are standard errors.*

the *slope* log performance increase per year for Blur and Pixel, along with the slope standard errors for the children's data only as in Experiment 1. The results fully replicate Experiment 1 in which the ability to identify pictures degraded by blurring and removing pixels increased 20% per year from age 3 to 5. In Experiment 2, the increase was 21% for Blur and 17% for Pixel.

General discussion

In Experiment 1, 3- to -5-year-old children and adults identified objects at a more degraded state when those objects began moderately, as opposed to very degraded, and then clarified. This is the first demonstration of the perceptual interference effect in such young children. The effect's magnitude declined with age for the Blur and Crop degradations but not for the Size and Pixel degradations. In Experiment 2, children but not adults overestimated their ability to identify objects in a degraded state when the object's identity was given to them beforehand. As in Experiment 1, the magnitude of this perceptual interference declined with age for the Blur degradation but not for the Pixel degradation. The results provide a quantitative description of perceptual interference effects in preschool children.

We expected to see a decline in perceptual interference after the age of 3 regardless of the way in which objects were degraded. However, we observed a decline only in the Blur and Crop procedures. One possible reason involves the kind of information that is removed by the degrading procedure. The Blur and Crop procedures involved the removal of specific features (high spatial frequency features and peripheral features, respectively), while the Pixel and Size conditions involved a continuous degradation of all picture features. Perhaps older children and adults are better at restoring missing features using the remaining features as cues (as in the Blur and Crop), but no better than young children at recouping information from a picture that is uniformly degraded (see Biederman, 1987).

Children showed the perceptual interference effect in both experiments, but adults did so only in Experiment 1. One possible reason for this finding is that adults may have used metacognitive strategies while performing the Clear-to-Degraded condition in Experiment 2. During debriefing, several adult observers reported that they were trying to identify a *degrading* object 'as if' they did not know what the object was. In a sense, these observers were trying to 'correct' their perception and assess when they would have identified the object had they not already known what it was (Harley, Carlsen & Loftus, 2004). Young children, in contrast to adults, appear to perform this task without such strategies (see Guttentag & Dunn, 2003). They report how they currently perceive/interpret the object, and claim that they can see the object at a more degraded point than the point at which they are able to identify a similar object that is clarifying.

This finding is consistent with metacognitive deficits observed in preschoolers (Flavell, 1979). Moreover, inhibitory control and cognitive flexibility undergo rapid developmental change in the preschool years (Carlson, Moses & Breton, 2002; Deloache, 1987; Hughes, 1998), and it is conceivable that these contribute to the changes observed here. On a variety of tasks, younger children have relatively more difficulty overriding their own knowledge and reporting that what they currently perceive conflicts with what they know (see Bernstein, Atance, Loftus & Meltzoff, 2004; Birch & Bloom, 2003; Royzman, Cassidy & Baron, 2003). Gopnik, Slaughter and Meltzoff (1994) theorize that such *visual* perspective-taking tasks may provide a developmental foundation for children to later solve higher-order conceptual perspective-taking tasks, such as the classic false belief test.

In Experiment 2, we expected to find that the younger children, in particular, would maintain the object's identity long after it degraded past being identifiable. We found instead that even the 3-year-olds gave up identifying the object at some point before it was completely unidentifiable. This is theoretically important for at least two reasons: (a) Taylor (1988) and others (e.g. Pillow & Henrichon, 1996) have shown that 3-year-olds persist in claiming that another person knows that an ambiguous, nondescript portion of a picture conceals a shark (if the child him/herself knows this), and (b) 3-year-olds err on tasks that ask them to distinguish what they literally see from what they know to be the case (e.g. appearance–reality tasks, Flavell *et al.*, 1986; Wellman *et al.*, 2001). Why did our children relinquish their percept, when they do not do this on similar tasks designed within the theory of mind framework? Our Experiment 2 degradation procedure repeatedly prompted children to assess their own perception as the image degraded. This may have permitted us to find the point when the perceptual event is so obviously unidentifiable that even young children could (finally) differentiate appearance from reality. Another possibility is that the use of computer images (versus the use of real objects in the typical appearance–reality task) provided less intrusion from 'knowledge', because the pictures themselves may not be awarded the full weight of 'reality' by the children. We are currently testing this latter idea.

The present study permitted us to explore object identification in preschoolers. By presenting successive displays of a clarifying, degraded visual stimulus, we showed that correct identification improves from ages 3 to 5. This improvement occurred for all degradation types, although at different rates. The fact that object identification improved over age at different rates for different degradations suggests that there may be separate mechanisms in the visual system that permit us to identify different types of degraded visual stimuli.

In sum, our methodology and results offer a quantitative description of how object identification and perceptual interference develop in preschool children. Future work should aim to identify individual differences in perceptual-interference to see if such differences predict later outcomes (in school) and/or correlate concurrently with other tasks that could be hypothesized to tap related cognitive skills, such as measures of cognitive flexibility, inhibitory control, and classic theory of mind measures – particularly false belief, appearance–reality and the picture-fragment identification task.

Appendix 1

Blur

Blurring was accomplished by Fourier-transforming each object into spatial-frequency space, multiplying the resulting frequency amplitude spectrum by a low-pass filter and inverse-Fourier transforming the result back into pixel space. For blur level i ($1 = i = 30$) the filter passed frequencies perfectly, that is, had a value of 1.0 up to some value a_i cycles/image, and then fell parabolically, reaching zero at a value of b_i cycles/image where $a_i = 210/(30 - i + 1)$, and $b_i = 21/(30 - i + 1)$.

This blurring method allows us to define our degree-of-blurring metric in terms of *distance*. The rationale for this has been described elsewhere (Loftus & Harley, in press) and is as follows. Imagine a person viewing a picture from distance, *d*. The greater *d* is, the less the person will be able to perceive the high spatial frequencies in the picture. In our experiment, of course, the observer's distance from the picture displayed on the screen was constant; however, our blurring process simulated the loss of high-spatial frequency information that would occur were the observer viewing the picture from various distances. In short, the 30 blur levels were equivalent in terms of available spatial-frequency information to what would happen if the observer saw the object from 30 different distances. Accordingly, the deblurring of the object during the experiment corresponded to the information that would be available if the observer began looking at the object from a distance and gradually moved closer to it.

Within this scheme, the distance associated with a particular degree of blur is proportional to the blur level, *i*. For the purposes of this article, the units of distance are unimportant. For ease of exposition, we generated the distance scales for the Blur, Crop and Size degradation types so that the numbers would be roughly equal, and the constant of proportionality we chose for our blur-to-distance scale was 9.371; that is, the distance d_i was set equal to $9.371*i$.

Pixel

For the Pixel condition, some proportion, p, of image pixels were changed to random grayscale values. The 30 proportions of unchanged pixels were generated according to the equation,

$$p_i = \text{scale}(e^{i/12}) \times 0.7$$

where i ranges from 1 to 30, and scale (X), where X is a vector, scales the values of X to the range 0–1. Note that in the least degraded level, 70% of pixels are randomly changed. We defined our pixel measure in terms of *noise-to-signal ratio*: for condition *i*, the noise-to-signal ratio was defined to be, $(1 - p_i)/p_i$.

Crop

For the Crop condition, increasingly large 'windows' placed symmetrically around the center of the object's original image were presented until the entire object appeared onscreen. Crop values were calculated according to the equation:

$$p_i = \text{scale}(e^{i/12})$$

where, *p* is the proportion (height or width) of the original image revealed by the window, and again *i* ranges from 1 to 30. White space was added to each crop to fill the 245 × 245 pixel square.

We defined our crop measure in terms of *distance*, which we interpret as follows. Imagine that an observer views the picture through a small, stationary window of size w cm × w cm that is placed some distance from the picture. At some particular distance, which we define to be $d = 0$, from the window, the observer is able to see the picture exactly framed by the window. At this point, the picture's height subtends some visual angle, ?. Now imagine that the observer moves back from the window to a distance, $d > 0$, while at the same time the picture's size increases so the picture maintains the same visual angle, α. At this point, from the observer's vantage point, the picture is cropped; a less-than-complete portion of it can now be seen through the window.

Any degree of crop, p_i used in the experiment can be thus associated with a particular distance, d_i. The equation relating distance, d, to proportion of crop, p_i is,

$$d_i = \frac{\sqrt{\frac{25w^2}{p_i}} - w/2}{\tan(\alpha/2)}$$

where α is in radians (we thank Janice Chen for deriving this equation for us). Different values of w and α produce scales that are all proportional to one another, so choice of specific values for them is irrelevant. For purposes of describing our results, we used $w = 5$ and $\alpha = 0.349$ radians.

Size

For the Size condition, the object's original image was resized according to the equation:

$$p_i = 0.02 + \text{scale}(e^{i/150}) \times .18$$

where, again, i ranges from 1 to 30. After resizing, white space was added to the image to fill the 245 × 245 pixel square.

We defined our size measure in terms of *distance.* Here, distance d_i of a particular reduced-size picture is construed as the distance that an observer would have to be from the screen in order that the full-size picture of the object subtends the same visual angle as the reduced-size picture when the observer is a normal distance from the screen. This means that distance is inversely proportional to p_i above (e.g. reducing size by a factor of 2 is equivalent to increasing distance by a factor of 2). Again, because the units are irrelevant, we chose them so as to produce distance numbers roughly equal to those of the Blur and Crop scales: the distance, d_i, was set equal to $(1/p_i)$*5.62.

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