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ORIGINAL ARTICLE

Eye movements during language-mediated visual search reveal a strong link between overt visual attention and lexical processing in 36-month-olds

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Abstract The nature of children's early lexical processing was investigated by asking what information 36-month-olds access and use when instructed to find a known but absent referent. Children readily retrieved stored knowledge about characteristic color, i.e., when asked to find an object with a typical color (e.g., strawberry), children tended to fixate more upon an object that had the same (e.g., red plane) as opposed to a different (e.g., yellow plane) color. They did so regardless of the fact that they had plenty of time to recognize the pictures for what they are, i.e., planes and not strawberries. These data represent the first demonstration that language-mediated shifts of overt attention in young children can be driven by individual stored visual attributes of known words that mismatch on most other dimensions. The finding suggests that lexical processing and overt attention are strongly linked from an early age.

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Introduction

Word recognition in children is fast and efficient. When a familiar word is named, young children rapidly shift their gaze toward a picture of the recognized word (e.g., Hollich, Hirsh-Pasek, & Golinkoff, 2000). If a word is uttered when the named referent is not visually present, children's looking behavior is far less determinate (e.g., Naigles & Gelman, 1995). In general, it appears that on hearing a word, children activate conceptual information related to that word and then search for the referent in the visual array. Off-line studies involving overt responses report convergent findings. When given both spatial and color cues for recently labeled objects, even 16-month-olds show evidence of comprehending references to absent objects (Saylor 2004). Moreover, given the right circumstances, toddlers have been shown to update mental representations of unseen objects based on what other people tell them (e.g., Ganea, Shutts, Spelke, & DeLoache, 2007).

However, the fact that a child looks to or verbally identifies a target when they hear it labeled does not indicate the type of stored conceptual knowledge that the child has accessed upon hearing the label. Clearly they have accessed a representation upon hearing an object labeled. How else could comprehension be possible? But what type of information is stored in the representation? How is the information organized? And how do such early representations mediate overt visual attention? Nearly all missing referent studies to date have presented children with objects that either fully match or fully mismatch named targets,[1] leaving much to be learned from studies manipulating the attributes that missing referents share with objects in the visual scene. We know, for example, that when adults hear *frog* they will tend to rapidly look at a green sweater more than an unrelated distractor that does not share the same typical color as the named target (Huettig & Altmann, 2004, 2010). Similarly, if they are asked to look at a *snake* they will look longer at a rope than an unrelated distractor that does not have the same approximate shape as a snake (e.g., Huettig & Altmann, 2004, 2007; Dahan & Tanenhaus, 2005). No one has yet shown whether young children's lexicons are structured in such a way that leads them to behave in a similar manner during online word recognition. Perhaps this rapid online activation of *specific* attributes of heard words is not part of the original design of early lexicons, but only emerges with accrued experience. Alternatively, the adult-like organization and accessibility of semantic and conceptual information may be foundational to human cognition and thus be evident very early in development.

How likely is it that on hearing spoken words young children might access and process semantic or conceptual representation differently from adults? On one hand, young language learners' early semantic knowledge appears to be fairly advanced. They understand that some words in their lexicon are related. For example, toddlers know that words such as *shoe* and *boot* or *cake* and *biscuit* are related in a way that *shoe* and *bread* or *cake* and *trousers* are not (Styles & Plunkett, 2009; see also von Koss Torkildsen, Syversen, Simonsen, Moen, & Lindren, 2007). Young children also recognize taxonomic relationships between words (e.g., Bauer & Mandler, 1989; Markman & Hutchinson, 1984). They even have some ability to recognize more typical over atypical examples of familiar objects, i.e., they perform above chance when given a forced choice test in which they must indicate the typical color of well-known foods (Macario, 1991; see also Meints, Plunkett, & Harris, 1999). On the other hand, none of these abilities indicate whether individual properties of known references are stored in such a fashion that they are readily accessed as the speech signal unfolds and drive language-mediated shifts in visual attention as in adults. Children may know that a green frog looks more like a frog than a blue frog, but cannot extract the greenness away from their notion of frogs on hearing the word frog and register online as the speech signal unfolds the similarity between frogs and other green (but otherwise unrelated) objects such as lettuce. It could also be the case that children attend to the world differently than adults. Certain attributes such as color tend not to be the most reliable indicator of object identity and classification. Perhaps, adults only readily access typical color of objects during word recognition after years of experience talking about and interacting with those objects. Children, in contrast, may have a more economical approach, focusing more heavily on other attributes such as shape that are presumably more reliable predictors of object identity or type (Graham & Diesendruck, 2010). Fitting with this view, numerous studies have shown that young children do not treat color as a defining characteristic of newly learned words (e.g., Graham & Poulin-Dubois, 1999; Landau, Smith, & Jones, 1988).

In the current study, we examined whether children rapidly access and use stored individual conceptual attributes of heard words, e.g., on hearing *strawberry*, do children tend to look longer at a red plane than a yellow plane? Using an online eye tracking procedure is necessary to ask this question, since we expect that if children do indeed readily activate stored color knowledge during word recognition, then they will be like adults in that they will display a brief shift of visual attention toward objects that are of the same color as the named target. Note that adults who show this behavior pattern tend not to be aware that they are shifting their eyes toward color-matched competitors. It is clear that simply asking children to name another object with the same color as a strawberry would not allow us to address our question of interest, since we would then be asking children to perform a complex meta-linguistic task rather than studying processes that naturally occur during online auditory word recognition. Meta-linguistic tasks may not provide accurate information regarding young children's knowledge and processing of the typical color of objects. For example, children may tell you that bananas are typically blue, simply because blue is their favorite color (Gleason et al. 2004).

In the current study, children were presented with three types of trials (see Fig. 1). During target trials, children were asked to find one of two familiar objects presented on the screen. During unrelated distractor trials, children saw two objects that were identical (except for their color) and were asked to find an object not pictured on the screen (e.g., children viewing a red and a green book were asked to find a table). These trials served as a control condition. We predicted that in unrelated distractor trials, children's fixations would be random because the spoken target (e.g., table) gave them no reason to attend to one colored object over the other. Finally, during color-matched distractor trials,

[1] We are aware of two exceptions. Saylor (2004) used off-line tasks to ask toddlers about recently labeled missing referents when both spatial and color cues to the missing referent were present. Saylor's study was designed to test whether toddlers exhibited comprehension of missing referents when multiple visual cues to that referent were available. It was not designed to explore the content or attention driving properties of early lexical representations. Naigles and Gelman (1995) presented children with two animals (e.g., cow and cat) and asked children to find a third (e.g., dog). Their study was designed to study the relationships between overextensions in production and comprehension.

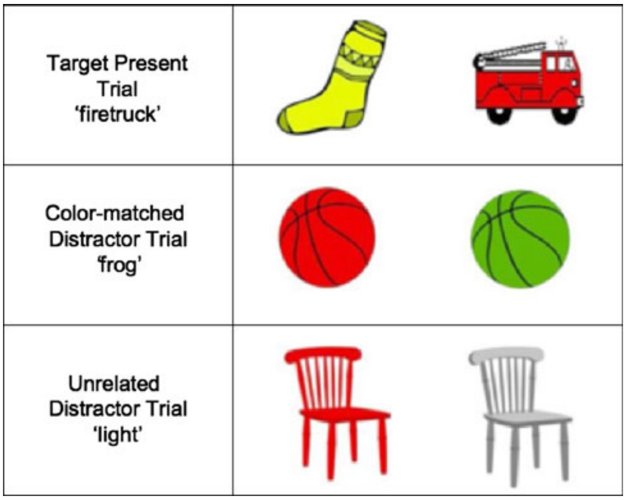

Fig. 1 Examples of the visual stimuli for the three types of trials

children once again saw two objects that were identical (except for their color). As in the unrelated distractor trials neither object matched the requested target. However, unlike the unrelated distractor trials, the spoken target in the color-matched distractor trials always had a characteristic color associated with it (e.g., strawberries are red). This last type of trial was critical because we predicted that if children store color attributes in their lexicon and use them in the cognitive processing of their visual surroundings, then they should look longer at color-matched than color-mismatched distractors (e.g., on hearing strawberry, children should tend to fixate on the red as opposed to the yellow plane). We also predicted that children's inattention to the screen (i.e., the proportion of time spent looking away from the screen or shifting between pictures on the screen rather than inspecting the two pictured objects) would vary systematically: Target trials have the lowest look away time; unrelated distractor trials have the most look away time; and color-matched distractor trials have an intermediary time spent looking away. The logic behind this prediction is that when children find a partial visual match for a named referent, they would look away from the screen less than when they found no match, but more than when they found a complete match. Importantly, during each trial, children viewed the objects for 4 s prior to target word onset, ensuring that they had time to recognize the objects for what they were (e.g., planes and not strawberries).

Method

Participants

A total of 42 Dutch-learning 36-month-olds (mean: 36 months 3 days, range: 35 months 7 days to 36 months 15 days, 23 females) were tested. Six additional participants were excluded due to color blindness in the family (3), fever (1) or parental interference (2).

Stimuli

Sixteen words commonly known by 36-month-olds were chosen for use as targets. Twelve of these words were characterized by a typical color (*aardbei* 'strawberry', *sinaasappel* 'orange', *kikker* 'frog', *wortel* 'carrot', *banaan* 'banana', *brandweerauto* 'fire truck', *peer* 'pear', *olifant* 'elephant', *varken* 'pig', *tomaat* 'tomato', *komkommer* 'cucumber', *zon* 'sun') and four were not (*lamp* 'lamp', *huis* 'house', *tafel* 'table', *bed* 'bed'). An additional eight animate objects were chosen for use in filler trials (e.g., *schaap* 'sheep'). All test trial target words were recorded in the sentence frame *Kun je de/het* ____ *vinden* 'Can you find the ____'. Filler trial targets were recorded in a variety of frames (e.g., *Vind je de/het* ___ *leuk* 'Do you like the ____'). The fillers were included to reduce the proportion of trials that asked for a missing referent. All audio materials were digitally recorded by a female speaker in a child-directed manner. Cartoon drawings of the above-mentioned typically colored objects along with 12 additional objects lacking a typical color (plane, t-shirt, ball, couch, chair, car, hat, bottle, pants, cup, book and sock) were combined with the audio files in iMovie to create six 3-min videos (3 lists, 2 pseudo-randomized orders of each list) containing 20 trials each (12 test trials plus 8 fillers; see Appendix for more details). The test videos were exported to digital tape for playback on a digital video recorder during the experiment. Each participant viewed one of the six videos. During each trial, two pictures were presented side by side against a white background for 8 s. The onset of the target word occurred exactly 4 s after the pictures appeared (average target word duration = 526 ms). To encourage children to attend to the screen, an attention-getting statement (e.g., *ah, wat leuk*) always preceded the target-labeling sentence. A 2-s zooming star against a black background separated successive trials.

Design

Participants were randomly assigned to one of three test lists. All lists included four occurrences of each trial type: target, unrelated distractor and color-matched distractor. The lists were counterbalanced in such a way that no participant was asked to find the same target more than once.

Procedure

A variant of the preferential looking paradigm was used in this study (for discussion, see Johnson & Zamuner, 2010).

Participants sat facing forward on a caregiver's lap in a dimly lit testing booth. The test video was presented on a large TV about 1 m from the chair where the caregiver and participant were seated. Targets occurred equally often on the left and right. Trials were presented in a pseudo-randomized order. Pictures were approximately 15 cm apart and approximately 1/4 of the height and width of the monitor. Each 8-s trial presented two side-by-side pictures. Test sessions were recorded on digital video. Caregivers listened to masking music over headphones.

After the video ended, the experimenter used a flip book to test the participant's color term knowledge. Over a course of seven trials, children were asked to point to one of four objects on a page (*Waar is de blauwe* 'Where is the blue one?'). The colors yellow, blue, orange, pink, green, gray and red were tested. The experimenter avoided looking at the pictures until the child made his choice. Performance was beyond chance, though not good. Children pointed to the correct object 74% (SD = 27) of the time, t (37) = 5.5, $p < 0.001$ (data from 4 children were excluded due to experimenter error).

Coding

Coding of the perception study was done off-line with the volume muted. Coders were unaware of which test order participants were assigned to. Lighting changes on the video indicated the onset of trials. Each 40-ms frame was coded as a look at the left picture, right picture or neither one (http://hincapie.psych.purdue.edu/Splitscreen/index.html). Five children were chosen at random for recoding, and correlations were high (Mean = 96.6%; SD = 1.5).

Results

We first examined the proportion of fixations to the target broken down by trial type, as this was our primary measure. Figure 2 shows a time-course graph that illustrates the fixation proportions to the target picture at 40 ms intervals. Zero represents the acoustic onset of the spoken target word. In target trials, the target picture fully matched the specification of the spoken target word. In color-matched distractor trials, the target was defined as the item matching in color the spoken target. In unrelated distractor trials, the target was defined as the item that served as the color-matched distractor for children assigned to another list. Note that before target word onset, children looked equally at target and control pictures.

We analyzed eye gaze within conditions over three 500 ms time periods starting from 300 ms after target onset (fixations prior to this point were unlikely to reflect a response to the spoken target; Canfield & Haith, 1991). We

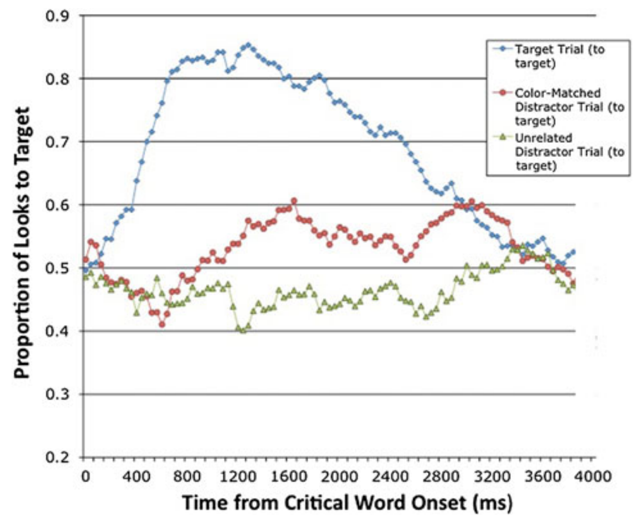

Fig. 2 Mean proportion of looks to target object as a function of time (ms) after target onset. For color-matched distractor trials, the target was defined as the item matching in color with the named object (e.g., the red plane as opposed to the yellow plane when children were asked to find the strawberry). For unrelated distractor trials, the target was defined as the item that served as the color-matched distractor for children in another condition (e.g., the red plane as opposed to the yellow plane for children who were asked to find the table; tables are not stereotypically red). Note that since the picture pairs presented on color-matched and unrelated distractor trials were identical, any differences in fixations between the two conditions had to be driven by the named target rather than inherent differences in how attractive or interesting the children found the pictures

calculated the ratio between the proportion of fixations to the target and the sum of the target and control picture fixation proportions for each of the three conditions. We then compared the mean ratio by participants to 0.5 (see Huettig & McQueen, 2007; Huettig & Hartsuiker, 2008). Note that chance performance would predict that children would spend an equal proportion of time fixating each of the two pictures. A ratio greater than 0.5, however, would show that of all the fixations directed toward the target and control pictures, the targets attracted more than half of those fixations.

One-sample t tests showed that during the first time region (300–799 ms after target onset), the targets were fixated significantly more than the controls in the target trials (mean ratio of 0.73, t (41) = 7.58, $p < 0.001$), but not in the color-matched distractor trials (mean ratio of 0.45, t (41) = −1.54, $p > 0.1$) and the unrelated distractor trials (mean ratio of 0.45, t (41) = −1.37, $p > 0.1$). Similarly, during the second time region (800–1,299 ms after target onset) the targets were fixated significantly more than the controls in the target trials (mean ratio of 0.83, t (41) = 11.89, $p < 0.001$), but not in the color-matched distractor trials (mean ratio of 0.52, t (41) = 0.55, $p > 0.1$) and the unrelated distractor trials (mean ratio of 0.45, $t\ (41) = -1.78$, $p > 0.05$). Importantly, during the third time region (1,300–1,799 ms after target onset), the targets were fixated significantly more than the controls in the target trials (mean ratio of 0.80, $t\ (41) = 8.29$, $p < 0.001$) and in the color-matched distractor trials (mean ratio of 0.57, $t\ (41) = 2.09$, $p < 0.05$), but not in the unrelated distractor trials (mean ratio of 0.44, $t\ (41) = -1.30$, $p > 0.1$).

Next, we examined our secondary measure: proportion of time spent looking away from the screen, broken down by trial type (see Fig. 3). Recall from the "Method" section that each frame of the test phase was coded as a look at the target, a look at the distractor or a look away. Look away frames included those during which children were either shifting between pictures or looking away from the screen altogether, i.e., the time during which they were not fixating on either the target or the distractor. Note that since our fixation ratios were calculated as proportion of fixations to target divided by the sum of the target and control picture fixation proportions, our analysis of look away time provided a completely independent secondary measure of children's differential attention during trials involving matching, partial matching or absent spoken referents. We predicted that the proportion of time spent by children looking away from the screen would be inversely related to the degree of match they found between the spoken targets and picture objects, i.e., the greater the match between the spoken target and pictured object, the less time children would spend looking away. In accordance with our predictions, Fig. 2 shows that initially (on hearing the critical word) the likelihood that children would look away from the screen was very similar in color-related distractor trials and target trials. Paired t tests showed that during the time region (1,000–2,500 ms after target onset) participants looked away more from the screen during unrelated distractor trials (proportion of trials participants looked away: 0.13) than during color-matched distractor trials (proportion of trials participants looked away: 0.07; $t\ (40) = -2.69$, $p = 0.01$). There was no reliable difference between color-matched distractor trials (proportion of trials participants looked away: 0.07) and target trials (proportion of trials participants looked away: 0.05; $t\ (40) = 1.09$, $p > 0.1$). Later on, however, this pattern reversed. Children's look away behavior during color-related distractor trials began to look much more like their look away behavior during no target distractor trials. Paired t tests showed that during the time region (2,500–4,000 ms after target onset), there was no reliable difference between color-matched distractor trials (proportion of trials participants looked away, 0.16) and unrelated distractor trials (proportion of trials participants looked away, 0.16; $t\ (40) = -0.10$, $p > 0.1$). There was, however, a difference between color-matched distractor trials (proportion of trials participants looked away, 0.10) and

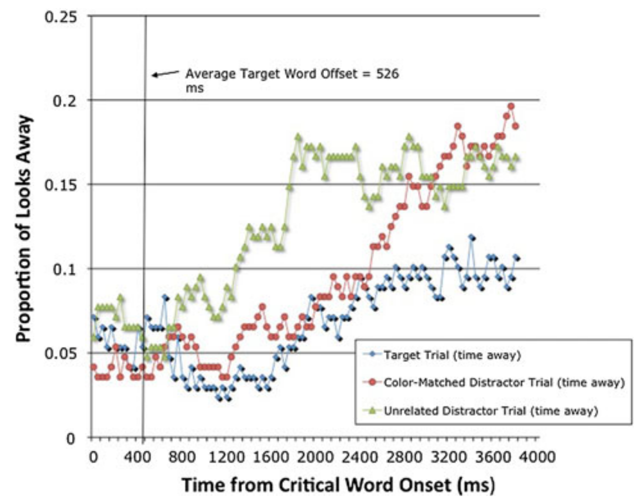

Fig. 3 Mean proportion of looks away from the screen as a function of time (ms) after target onset. This measure included time spent shifting between the two pictures as well as time spent looking away from the screen altogether

target trials (proportion of trials participants looked away, 0.16; $t\ (40) = 1.98$, $p = 0.055$).[2]

Discussion

In this study, 36-month-olds listened to spoken sentences while looking at a visual display with two objects. The crucial difference between this and past missing referent studies was that we presented children with carefully constructed stimuli sharing only *one* attribute (i.e., color) with the missing referent. We systematically controlled whether the color of the displayed objects matched the color associated with the concept activated by the spoken target words. In the critical trials, children were asked to look for a familiar object while viewing two copies of another familiar object. On recognizing the spoken word (e.g., strawberry), children fixated the object that matched the typical color of the spoken word (e.g., the red plane) significantly more than the object that did not (e.g., the yellow plane). The language-mediated eye movements tracked in this study indicate that 36-month-olds are sensitive to the overlap between *specific* conceptual attributes accessed on hearing spoken words and the properties of objects concurrently present in the visual array. In other words, children represent and access specific properties of spoken words in a similar fashion to adults (cf. Huettig & Altmann, 2005). These data demonstrate that in this paradigm, 3-year-olds readily extract the green from

[2] The difference between color-matched distractor trials and target trials was more statistically reliable during the time window ranging from 3,000 to 4,000 ms after target onset ($t\ (40) = 2.06$, $p = 0.046$).

their mental representation of a frog and can recognize this same trait in other objects in the world. Importantly, this process takes place naturally during online word recognition and does not require overt instruction. Moreover, this effect holds for attributes that are not necessarily the most reliable indicators of object type or identity, i.e., color.

Our secondary measure, look away time, provided convergent evidence for children's recognition of attributes shared by spoken words and objects in the visual array. Figure 3 illustrates that from about 1,000 ms after spoken target word onset, the likelihood that children would look away from the screen began to diverge as a function of trial types. At first, the likelihood that children would look away from the screen looked very similar in color-related distractor trials and target trials. Presumably, in both cases, there was something interesting on the screen to keep the children's attention on the task. However, about 2,500 ms after word onset, children's look away behavior during color-related distractor trials began to look much more like their look away behavior during no target distractor trials. Thus, color-elated distractor trials could not hold children's attention the way target trials could. In other words, the look away behavior we report provides additional evidence that color-matched distractor trials were distinct from both target trials and no target distractor trials.

It is important to note that factors such as visual complexity, familiarity, salience or other possible artifacts cannot account for our results. In the critical trials, the objects were identical in all aspects besides color. Thus, when the 36-month-olds heard *strawberry*, they saw two (except for color) identical planes in front of them. Importantly, they looked significantly more at the red plane than the yellow plane. The shifts in eye gaze driven by *partly* matching conceptual information (i.e., color) were slower and more transient than the shifts in eye gaze driven by *fully* matching conceptual and phonological information (hearing *strawberry* and seeing a strawberry), nonetheless these looks to color-matched competitors were fast and reliable.

How strongly do children attend to color information in an online word recognition task? The results of the current study clearly show that color attributes of spoken words are activated strongly enough to drive fixations in the visual field. This result is particularly interesting given that toddlers and young children do not appear to consider color to be a defining property of objects (e.g., Graham & Diesendruck, 2010; Landau et al., 1988). One is led to suspect that other attributes that children appear to weigh more heavily (e.g., shape) might result in even stronger effects in terms of looks to color-matched competitors. One could even argue that since the color-matched distractor trials used in this study presented two objects that only differed in color, we forced children to artificially attend to color in a way that they would not had the objects differed along additional perceptual dimensions. Thus, children may not attend to a less important object property such as color in a more naturalistic setting. However, in ongoing work, we have addressed this issue by testing even younger children with color distractor trials that present photographs of real-life objects that differ along many dimensions (e.g., a red cup and blue chair). In this case, we still observe the same effect of looks to color-matched competitor items when absent objects are named (Johnson, Huettig, & McQueen, 2008). In future work, given that studies showing that the saliency of different perceptual domains change with experience and maturation (e.g., Odom & Guzman, 1972), it might be interesting to see whether toddlers attend to attributes such as shape and color differently from older children in this type of paradigm.

Past studies have suggested that 3- and 4-year-olds are extremely poor at identifying the typical color of known objects possibly because they perform this task through 'verbal association' rather than consulting 'colored mental templates' (Davidoff & Mitchell, 1993). Evidence for this view comes from studies showing that knowledge of color terms correlates with the ability to identify the typical color of known objects (Gleason, Fiske, & Chan, 2004). In addition, 3- to 4-year-olds find it easier to say that a frog is 'green' than to identify whether a frog picture is of the right color (Davidoff & Mitchell, 1993). According to parental report, all of the participants in our study produced at least some color terms. Moreover, our participants performed above chance levels on our color comprehension task. Thus, it is not clear to what extent the effect we observed was mediated by stored verbal and/or visual knowledge. Investigating this issue with younger children who are yet to learn any color terms, or comparing access to stored color knowledge in different language populations who lexically encode colors in different ways (e.g., Russian versus English blue; Davies & Corbett, 1997), might help to clarify this issue.

Regardless of whether the behavior observed in this study is verbally mediated or not, the point remains that this study represents the first demonstration of language-mediated shifts in visual attention driven by a single stored attribute, i.e., color. This is especially interesting given the secondary role that color attributes appear to play in object recognition and sorting. In spite of young children's difficulty in these tasks, there is nevertheless a strong link between overt visual attention and lexical processing from a very early age.

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Appendix

List	Trial condition	Pictured objects	Named target
1	Target	Strawberry and plane	Aardbei 'Strawberry'
1	Target	Couch and carrot	Wortel 'Carrot'
1	Target	Orange and t-shirt	Sinaasappel 'Orange'
1	Target	Ball and frog	Kikker 'Frog'
1	Color distractor	Green and yellow bottle	Zon 'Sun'
1	Color distractor	Green and yellow hat	Komkommer 'Cucumber'
1	Color distractor	Gray and red chair	Tomaat 'Tomato'
1	Color distractor	Pink and blue car	Varken 'Pig'
1	Unrelated distractor	Red and green pants	Lamp 'Lamp'
1	Unrelated distractor	Yellow and blue cup	Huis 'House'
1	Unrelated distractor	Gray and red book	Tafel 'Table'
1	Unrelated distractor	Yellow and red sock	Bed 'Bed'
2	Target	Banana and blue cup	Banaan 'Banana'
2	Target	Yellow sock and firetruck	Brandweerauto 'Firetruck'
2	Target	Red pants and pear	Peer 'Pear'
2	Target	Elephant and red book	Olifant 'Elephant'
2	Color distractor	Red and green ball	Kikker 'Frog'
2	Color distractor	Red and yellow plane	Aardbei 'Strawberry'
2	Color distractor	Orange and t-shirt	Sinaasappel 'Orange'
2	Color distractor	Green and orange couch	Wortel 'Carrot'
2	Unrelated distractor	Gray and red chair	Lamp 'Lamp'
2	Unrelated distractor	Pink car and blue car	Huis 'House'
2	Unrelated distractor	Green and yellow hat	Bed 'Bed'
2	Unrelated distractor	Green and yellow bottle	Tafel 'Table'
3	Target	Pig and blue car	Varken 'Pig'
3	Target	Gray chair and tomato	Tomaat 'Tomato'
3	Target	Cucumber and yellow hat	Komkommer 'Cucumber
3	Target	Green bottle and sun	Zon 'Sun'
3	Color distractor	Yellow and red sock	Brandweerauto 'Firetruck'
3	Color distractor	Yellow and blue cup	Banaan 'Banana'
3	Color distractor	Red and green pants	Peer 'Pear'
3	Color distractor	Gray and red book	Olifant 'Elephant'
3	Unrelated distractor	Red and yellow plane	Tafel 'Table'
3	Unrelated distractor	Orange and blue t-shirt	Bed 'Bed'
3	Unrelated distractor	Red and green ball	Lamp 'Lamp'
3	Unrelated distractor	Green and orange couch	Huis 'House'

References

Bauer, P. J., & Mandler, J. M. (1989). Taxonomies and triads: Conceptual organization in one- and two-year-olds. *Cognitive Psychology, 21*, 156–184.

Canfield, R. L., & Haith, M. M. (1991). Young infants' visual expectations for symmetric and asymmetric stimulus sequences. *Developmental Psychology, 27*, 198–208.

Dahan, D., & Tanenhaus, M. K. (2005). Looking at the rope when looking for the snake: Conceptually mediated eye movements during spoken-word recognition. *Psychonomic Bulletin & Review, 12*, 453–459.

Davidoff, J., & Mitchell, D. (1993). The color cognition of children. *Cognition, 48*, 121–137.

Davies, I. R., & Corbett, G. G. (1997). A cross-cultural study of colour grouping: Evidence for weak linguistic relativity. *British Journal of Psychology, 88*, 493–517.

Ganea, P. A., Shutts, K., Spelke, E. S., & DeLoache, J. S. (2007). Thinking of things unseen: Infants' use of language to update mental representations. *Psychological Science, 18*, 734–738.

Gleason, T. R., Fiske, K. E., & Chan, R. K. (2004). The verbal nature of representations of the canonical colors of objects. *Cognitive Development, 19*, 1–14.

Graham, S. A., & Diesendruck, G. (2010). Fifteen-month-olds attend to shape over other perceptual properties in an induction task. *Cognitive Development, 25*, 111–123.

Graham, S. A., & Poulin-Dubois, D. (1999). Infants' reliance on shape to generalize novel labels to animate and inanimate objects. *Journal of Child Language, 26*, 295–320.

Hollich, G., Hirsh-Pasek, K., & Golinkoff, R. (2000). Breaking the language barrier: An emergentist coalitietop model of word learning. Monographs for the Society for Research in Child Development, *65* (3, Serial No. 262).

Huettig, F., & Altmann, G. T. M. (2004). The online processing of ambiguous and unambiguous words in context: Evidence from head-mounted eye-tracking. In M. Carreiras & C. Clifton (Eds.), *The on-line study of sentence comprehension: Eyetracking, ERP and beyond* (pp. 187–207). New York: Psychology Press.

Huettig, F., & Altmann, G. T. M. (2005). Word meaning and the control of eye fixation: Semantic competitor effects and the visual world paradigm. *Cognition, 96*, B23–B32.

Huettig, F., & Altmann, G. T. M. (2007). Visual-shape competition during language-mediated attention is based on lexical input and not modulated by contextual appropriateness. *Visual Cognition, 15*(8), 985–1018.

Huettig, F., & Altmann, G. T. M. (2010). Looking at anything that is green when hearing 'frog'—How object surface color and stored object color knowledge influence language- mediated overt attention. *Quarterly Journal of Experimental Psychology* (in press).

Huettig, F., & Hartsuiker, R. J. (2008). When you name the pizza you look at the coin and the bread: Eye movements reveal semantic activation during word production. *Memory & Cognition, 36*, 341–360.

Huettig, F., & McQueen, J. M. (2007). The tug of war between phonological, semantic, and shape information in language-mediated visual search. *Journal of Memory and Language, 54*(4), 460–482.

Johnson, E., Huettig, F., & McQueen, J. M. (2008). Conceptual attributes of heard words modulate toddlers' attention to the visual scene. *Paper presented at the 11th International Congress for the Study of Child Language (IASCL)*, Edinburgh, Scotland, UK.

Johnson, E. K., & Zamuner, T.S. (2010). Using infant and toddler testing methods in language acquisition research. In E. Blom & S. Unsworth (Eds.), *Experimental Methods in Language Acquisition Research*. Amsterdam: John Benjamins (in press).

Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. *Cognitive Development, 3*, 299–321.

Macario, J. F. (1991). Young children's use of color in classification: foods and canonically colored objects. *Cognitive Development, 6*, 17–46.

Markman, E. M., & Hutchinson, J. E. (1984). Children's sensitivity to constraints on word meaning: Taxonomic versus thematic roles. *Cognitive Psychology, 16*, 1–27.

Meints, K., Plunkett, K., & Harris, P. (1999). When does an ostrich become a bird? The role of typicality in early word comprehension. *Developmental Psychology, 35*, 1072–1078.

Naigles, L. G., & Gelman, S. A. (1995). Overextensions in comprehension and production revisited: Preferential looking study of dog, cat, and cow. *Journal of Child Language, 22*, 19–46.

Odom, R. D., & Guzman, R. D. (1972). Development of hierarchies of dimensional salience. *Developmental Psychology, 6*, 271–297.

Saylor, M. (2004). Twelve- and 16-month-old infants recognize properties of mentioned absent things. *Developmental Science, 7*, 599–611.

Styles, S. J., & Plunkett, K. (2009). How do infants build a semantic system? *Language and Cognition, 1*, 1–24.

von Koss Torkildsen, J., Syversen, G., Simonsen, H. G., Moen, I., & Lindren, M. (2007). Electrophysiological correlates of auditory semantic priming in 24-month-olds. *Journal of Neurolinguistics, 20*, 332–351.