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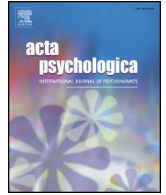
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Near or far: The effect of spatial distance and vocabulary knowledge on word learning



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ABSTRACT

The current study investigated the role of spatial distance in word learning. Two-year-old children saw three novel objects named while the objects were either in close proximity to each other or spatially separated. Children were then tested on their retention for the name-object associations. Keeping the objects spatially separated from each other during naming was associated with increased retention for children with larger vocabularies. Children with a lower vocabulary size demonstrated better retention if they saw objects in close proximity to each other during naming. This demonstrates that keeping a clear view of objects during naming improves word learning for children who have already learned many words, but keeping objects within close proximal range is better for children at earlier stages of vocabulary acquisition. The effect of distance is therefore not equal across varying vocabulary sizes. The influences of visual crowding, cognitive load, and vocabulary size on word learning are discussed.

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1. Introduction

During the first three years of life, children learn hundreds of words (Fenson et al., 1994), particularly names for objects (Samuelson & Smith, 1999). In real life, many of these object names are learned in cluttered environments—in stark contrast to immaculate laboratory environments, where only a handful of objects are present at any one time. Recent research demonstrates that children retain new words (Horst, Scott, & Pollard, 2010) and learn new concepts (Fisher, Godwin, & Seltman, 2014) better when their learning environments are less cluttered. However, even in relatively uncluttered environments, children still encounter many ambiguous naming situations where a target object is seen among several other objects when it is named. As the number of objects presented increases, the space between the objects decreases, especially in laboratory-based tasks where space is typically restricted. In the current study, we control for the number of objects present and demonstrate that the spatial distance between objects may influence early word learning, but that the effect is mediated by pre-existing vocabulary knowledge.

Numerous studies have demonstrated the importance of space in attentional learning. Both infants and adults form associations between the spatial locations of visual and auditory information presented

simultaneously (Richardson & Kirkham, 2004; Richardson & Spivey, 2000). That is, they “spatially index” the location where visual information is presented and look to the same location when the same auditory information is presented again even in the absence of the visual stimuli. However, memory for object locations is affected by the space between the objects. Observers demonstrate better memory for object locations when the objects are spatially separated compared to when the objects are in close proximity to each other—even when the number of objects is controlled for (Franconeri, Alvarez, & Enns, 2007).

Object locations also influence word learning in children. Specifically, children use spatial locations to bind a name to an object—even when the name and object do not occur together. Samuelson, Smith, Perry, and Spencer (2011) presented 18-month-old children with two novel objects consistently to either side of a table. After removing the objects, the experimenter stated a name three times (e.g., “modi”) while pointing to the space previously occupied by one of the objects. Later when asked to select the “modi,” children systematically chose the object corresponding to that location. In follow-up experiments, inconsistent object locations interfered with children's ability to form name-object associations. Benitez and Smith (2012) also found that children were better at retaining novel words if they were consistently presented with objects in the same locations rather than in varied locations.

Empirical evidence suggests that keeping target objects at a distance from competitors during naming could facilitate word learning as it could help children disambiguate a speaker's referent from other objects that may be present. For example, in a series of experiments,

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Horst and Samuelson (2008) presented 24-month-old children with disambiguation/referent selection trials with novel and familiar objects and tested children's retention of the novel objects' names after a 5-minute delay. In the final experiment, children were given feedback after each referent selection trial. For children in the follow-in labeling condition, the experimenter followed the child's gaze and named the target object when the child looked at it, thus the objects remained in close proximity to each other during the feedback phase. However, for children in the ostensive naming condition the distance between the objects increased as the target was held up and away from the competitors before the experimenter pointed to it. Only children in the ostensive naming condition retained the novel names. In a follow-up study, objects remained in close proximity to each other during the feedback phase and children who received ostensive naming with pointing, but without moving the objects, demonstrated poor retention (Axelsson et al., 2012). Similarly, using a head-mounted camera to examine children's visual perspectives during interactions with parents, Pereira, Smith, and Yu (2014) also found that clear, uncluttered views of objects during naming events led to better retention of object names. This was particularly the case if the same clear object view was held before, during, and after the naming event.

However, there may be cases when presenting objects in close proximity to each other *does* facilitate learning. Oakes and Ribar (2005) argue that when short-term memory capacity is limited (i.e., during early childhood), the ability to quickly shift attention between images or objects in space could be critical to encoding. Thus, large distances between objects may make it difficult for children to see both the targets and competitors simultaneously. Indeed, encountering category exemplars simultaneously in close proximity promotes adult category generalization as it aids in comparing and contrasting exemplars (Spencer, Perone, Smith, & Samuelson, 2011). Thus, encountering objects in close proximity may help young children learn object names.

In addition, there is some evidence that a larger vocabulary is associated with better word learning. For example, Bion, Borovsky, and Fernald (2013) found that children with larger productive vocabularies looked longer at a novel target during disambiguation and retention trials (but see Mather & Plunkett, 2009). According to the critical mass effect (e.g., Bates & Goodman, 1997), children who have acquired more words have stronger phonological representations, and this allows them to more readily build on their knowledge. Torkildsen et al. (2009) found that children with larger vocabularies demonstrated word learning in fewer trials than children with smaller vocabularies. Similarly, the speed of response when comprehending words correlates with lexical and grammatical development in 12- to 24-month-old children (Fernald, Perfors, & Marchman, 2006). Larger vocabulary size is also positively associated with novel noun generalization, and this is argued to be due to an increased ability to focus on the relevant, defining features of categories as vocabulary increases (see Smith, Colunga, & Yoshida, 2010 for a review). However, whether spatial distances between objects has differential effects on children's ability learn novel object names as a function of overall vocabulary size has yet to be investigated.

In the current study, we explored the effect of spatial distance between objects on children's ability to learn names for objects. Children were taught names for three novel objects. For half of the children, names were introduced when targets and competitors were within a close proximal range to each other and for the other children, names were introduced when objects were spatially distant to each other. All children received the same word learning test trials. If the spatial distances between the objects during naming influence children's ability to learn the objects' names, then we should find differences in children's word learning depending on whether the objects had been in close proximity to each other or spatially separated.

2. Method

2.1. Participants

Forty monolingual, British-English-speaking, typically developing children between 21 and 28 months ($M = 24$ m, 13 days, $SD = 1$ m, 28 days) participated. Four additional children were tested but their data not analyzed due to fussiness (2) and experimenter error (2). Twenty children were randomly assigned to each of the two conditions: near (11 boys) and distant (9 boys). There were no differences between conditions in age ($t(38) = 1.95, p = .92$, two-tailed, (near: $M = 24.14$ months, $SD = 52$ days; distant: $M = 24.12$ months, $SD = 67$ days) or total productive vocabulary ($t(38) = 0.07, p = .94$, two-tailed, (near: $M = 314$ words, $SD = 171$ words; distant: $M = 319$ words, $SD = 198$ words). There was no difference between conditions in maternal education levels, Fisher's Exact Test = 0.318, $p = 0.99$. Three mothers in the near condition and four mothers in the distant condition had completed high school (GCSEs and/or A-levels) and/or completed a vocational diploma. Ten mothers in each condition had completed an undergraduate degree and/or an undergraduate degree with a postgraduate certificate (e.g., Postgraduate Certificate in Education (PGCE), an additional teaching qualification). Five mothers in each condition completed a Master's degree and two mothers in the near condition and one in the distant condition completed a doctoral degree. Parents were reimbursed for travel and children received a small gift (e.g., a coloring book) for participating.

2.2. Stimuli

Three novel objects served as stimuli: a blue massager (*pabe*), a red gardening funnel (*yok*), and a yellow cup-and-ball toy with the ball glued to the side of the handle for better spatial placement control (*dite*) (see Fig. 1). Novel objects were on average 6.2 cm × 9.3 cm × 13.7 cm. Novel words were chosen to be short, easy to pronounce and distinctive (Deák & Toney, 2013). We introduced children to three novel names to enhance the likelihood that children would disambiguate objects at test on the basis of each name rather than on the basis of selecting the only novel object presented with a novel name (see Axelsson & Horst, 2013 for a discussion). Each object was assigned the same name for all children to reduce experimenter errors (Capone & McGregor, 2005). Six familiar toy-like objects served as stimuli for the warm-up trials: a bus, an airplane, a penguin, a tiger, a pair of children's sunglasses and a baby shoe.

2.3. Procedure and design

2.3.1. Naming phase

The child sat in a booster seat at a small table with a 67.7 cm × 120 cm white surface. The experimenter sat across from the child and the parent sat next to the child and completed the MacArthur Communicative Development Inventory (MCDI, (Klee, Marr, Robertson & Harrison, 1999). The experimenter set the three novel objects on the table and named each object in a random order. Each object was only named when the child was looking at the object and it was the focus of the child's attention. Each time an object was named, the experimenter repeated the name three times in close succession. For example, the experimenter might name an object by saying, "Look at this *pabe*. It's a *pabe*. Have a look at the *pabe*." Each object was named three separate times yielding a total of 9 repetitions for each word. Previous studies suggest that 5–10 repetitions of ostensive naming support word learning when one word is introduced to 12- to 24-month-old infants (Hollich, Hirsh-Pasek, & Golinkoff, 2000; Woodward, Markman, & Fitzsimmons, 1994) or even four times when two names are introduced to 18-month-old infants (Bion et al., 2013; Gurteen, Horne, & Erjavec, 2011). To ensure each object was named exactly nine times, before each session the experimenter placed nine sticky bookmark tabs

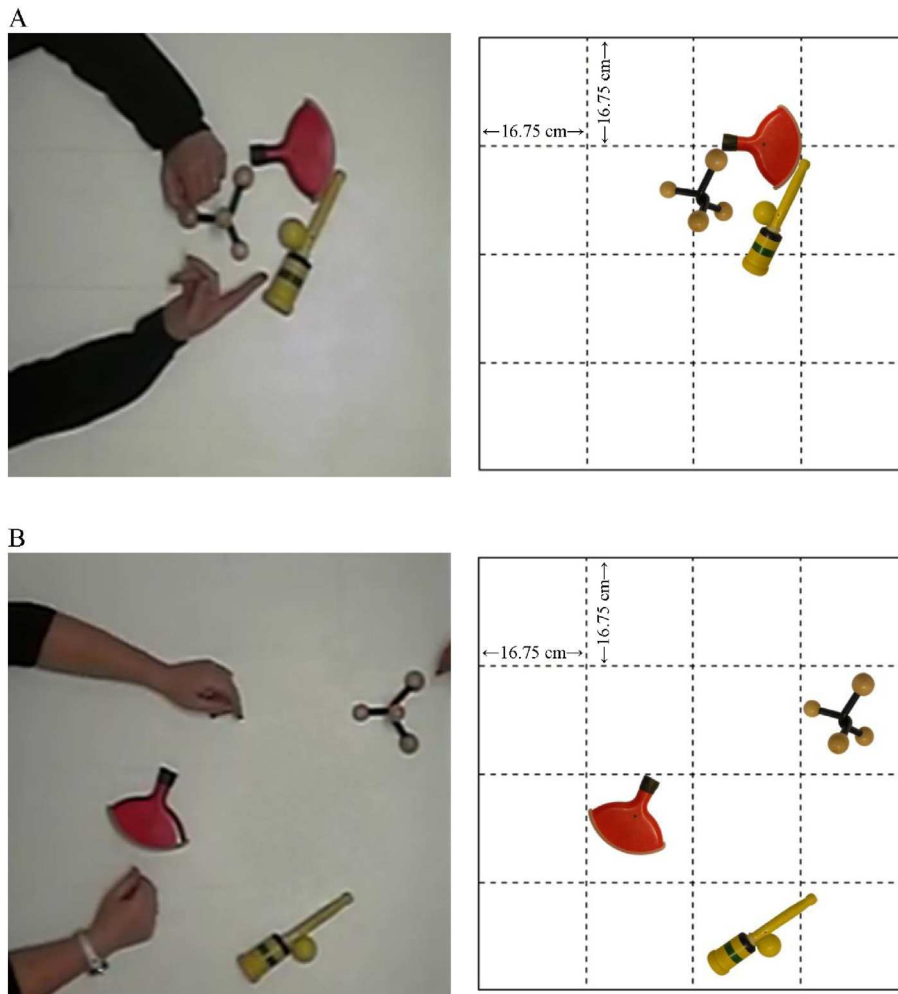


Fig. 1. Aerial view of photographic and schematic depiction of object positions in the near condition (Panel A) and distant condition (Panel B).

(three in each of three colors, corresponding to the three novel objects) on the rim of experimenter's side of the table, outside of the child's view. During the session, the experimenter discreetly removed a corresponding tab each time an object was named (recall, objects were always named three times in close succession for a total of nine naming tokens). This allowed the experimenter to inconspicuously keep track of which objects still needed to be named and how many times without placing additional items (e.g., paper and pencil) on the table.

The experimenter kept the objects within a 67×67 cm area of the table, which had a faintly visible grid drawn in pencil on the surface. The grid was made up of 4×4 squares, each 16.75×16.75 cm (see Fig. 1). The grid served as a guide for the experimenter to maintain consistent distances between the objects in each condition. For children in the near condition, the experimenter kept all three objects within or on the borders of the same grid square when naming one of the objects (see Fig. 1a). Based on the measurements of the stimuli and the grid squares, the center points of the objects were on average 5.3 cm apart and the distances between the edges of the objects were on average 0.5–3.0 cm apart. For children in the distant condition, the three objects were always separated by a minimum of one grid square when one of the objects was named (see Fig. 1b). Objects could not be in adjacent squares, but could be in an adjacent diagonally positioned square. The center points of the objects were on average 34–50 cm apart and the distance between the edges were on average 34–40 cm. The experimenter moved the objects to new positions on the table before each naming event. Children were free to hold and explore the objects between naming events, but the experimenter moved the objects and

ensured they were touching the table and, depending on distance condition, were either located spatially near or distant from each other before each naming event.

2.3.2. Test phase

Then, the experimenter tested children's word retention. The experimenter began with three warm-up trials with known objects to familiarize the child to the test procedure and ensure children were compliant and attentive (Deák & Toney, 2013; Hollich et al., 2000). On each trial, three objects were placed on a clear, plexiglass tray divided into three sections (one animal, one vehicle, and one wardrobe item). Holding the tray close to herself, with the three objects in view but unreachable by the child, the experimenter asked the child to get one object by name (e.g., "Where is the *shoe*? Can you get the *shoe*?"). The tray was pushed forward for the child to choose an object. During this period, the experimenter maintained her gaze directly at the child's eyes. Correct choices were praised and incorrect choices were corrected (children were highly accurate in both the near, $M = 98\%$, $SD = 7\%$ and distant conditions, $M = 95\%$, $SD = 16\%$). For each child, the same objects were used on all three trials, but the locations were changed. Object locations were pseudorandomized so that the child was asked to choose an object from each location (left, middle, right) once. Each of the three objects was requested once and served as a foil on the other two trials. The test trials followed immediately and were identical to the warm-up trials except no feedback was provided. Again, each object was requested once and served as a foil on the other two trials.

2.4. Coding

Children's responses were coded by the experimenter. A second coder watched video footage of 20% of the sessions and scored children's responses as correct or incorrect. Cohen's Kappa for agreement between coders was .92. Disagreements were resolved through discussion.

3. Results

3.1. Word retention

Our main question was whether the distances between the objects during naming in the learning phase affected retention of the novel names. Overall, the proportion of novel words learned was significantly better than expected by chance (0.33) in both the near, ($M = 0.53$, $SD = 0.29$, $t(19) = 3.04$, $p = .007$, $d = 0.69$), and the distant conditions ($M = 0.50$, $SD = 0.30$, $t(19) = 2.52$, $p = .021$, $d = 0.57$). However, there was no significant difference in word learning between conditions, $t(38) = 0.35$, $p = .726$, $d = 0.10$.

3.2. Vocabulary and distance

Although children learned equally well in both conditions, we explored the possibility that children's existing noun vocabulary knowledge might have influenced their ability to learn the names of objects if naming occurred when the objects were positioned closer together or farther apart. We focused on noun vocabulary, rather than total vocabulary, because previous studies have found a link specifically between the nouns children know and their word learning biases (Gershkoff-Stowe & Smith, 2004; Perry & Samuelson, 2011; Samuelson & Smith, 1999; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002). Preliminary analyses confirmed there was no significant difference in noun vocabulary size between the near ($M = 158.25$, $SD = 88.44$) and distant ($M = 150.80$, $SD = 83.58$) conditions, $t(38) = 0.27$, $p = .79$, $d = 0.09$.

We used logistic mixed regression to examine the interaction between children's noun vocabulary size and distance condition on retention accuracy (for similar analyses see Perry & Samuelson, 2011; Perry, Samuelson, Malloy, & Schiffer, 2010). Each mixed regression model includes random subject and item effects. Age was significantly correlated with noun vocabulary size, $r = .56$, $p < .001$, so we included a main effect of age in each model to examine what effects vocabulary had on retention above and beyond age. Significance levels were calculated using chi-square tests that compared the fit of mixed-effects models with and without the factor of interest on improvement in the model fit. We report the details of all models and comparisons in the appendix.

A comparison of mixed-effects models with and without the interaction between vocabulary size and distance condition revealed a significant interaction, $b = .85$, 95% CI (0.07, 1.63); $X^2(1) = 4.74$, $p = .03$. However, additional model comparisons revealed that there were no main effects of distance, $X^2(1) = 0.10$, $p = .76$, vocabulary size, $X^2(1) = 2.15$, $p = .14$, or age, $X^2(1) = 0.22$, $p = .64$. Planned follow-up comparisons revealed that the interaction was driven by those in the distant condition, as those in the distant condition showed a significant effect of vocabulary size on retention accuracy, $b = .68$, 95% CI (0.12, 1.25); $X^2(1) = 6.20$, $p = .01$; while those in the near condition did not, $X^2(1) = 0.10$, $p = .75$ (see Fig. 2a).

Next, to further understand how vocabulary size influenced children's ability to learn words in the near and distant conditions, we conducted a median split on children's noun vocabulary (median = 154, see Table 1). Model comparison revealed that there was no significant effect of distance condition on the performance of either those in the low vocabulary group or those in the high vocabulary group. Thus, we also compared the performance of children in each distance condition at each vocabulary level to chance. As can be seen in Fig. 2b, in

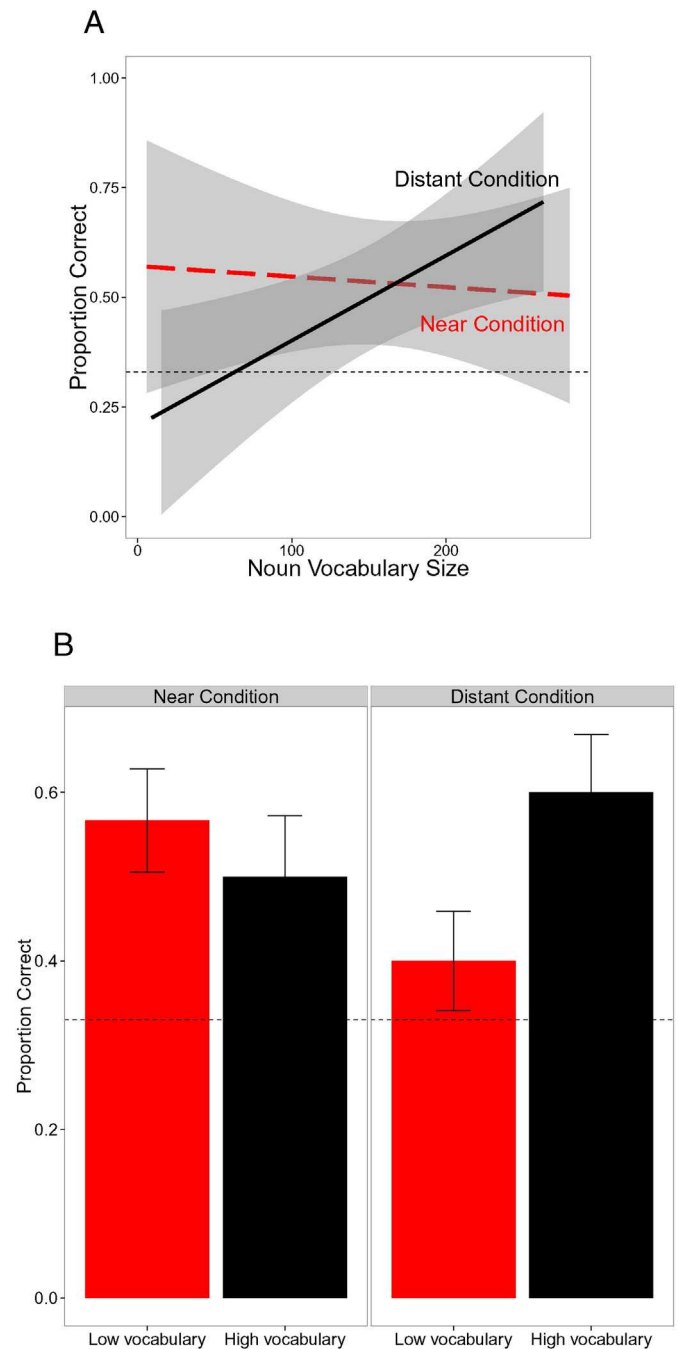


Fig. 2. Relationship between word learning accuracy and noun vocabulary size measured continuously (A) and based on a median split (B) for children in the near and distant conditions. Dotted lines represent chance performance (0.33). Error bands/bars represent standard error.

Table 1

Means and ranges of noun vocabularies for children in both distance conditions who fell into each half of the median split in noun vocabulary size. Standard deviations in parentheses. There were no significant differences between the two low vocabulary groups ($t(18) = 0.05$, $p = .96$) or between the two high vocabulary groups ($t(18) = 0.82$, $p = .42$).

	Near condition	Distant condition
Low vocabulary	83.90 (52.12) Range = 6–140	82.70 (52.35) Range = 9–146
High vocabulary	232.60 (34.91) Range = 189–280	218.90 (37.36) Range = 162–263

the near condition children with smaller vocabularies ($M = 0.57$, $SD = 0.27$) were significantly more accurate than expected by chance (0.33 ; $t(9) = 2.73$, $p = .023$, $d = 0.89$), but those with larger vocabularies ($M = 0.50$, $SD = 0.32$) were no different than chance ($t(9) = 1.66$, $p = .13$, $d = 0.69$). In the distant condition, however this pattern was reversed: children with smaller vocabularies ($M = 0.40$, $SD = 0.26$) were no different than expected by chance ($t(9) = 0.84$, $p = .422$, $d = 0.27$), but those with larger vocabularies ($M = 0.60$, $SD = 0.31$) were significantly more accurate than chance ($t(9) = 2.79$, $p = .021$, $d = 0.87$). In sum, the findings from both the logistic mixed regression and the comparison to chance following the median split on vocabulary size suggest that children with larger vocabularies learned more words if objects had been named when they were spatially distant to each other (i.e., children in the distant condition). The comparison to chance following the median split also indicates that children with smaller vocabularies learned more words if objects had been named when they were in close proximity to each other (i.e., children in the near condition).

4. Discussion

The current study explored the role of spatial distance between objects in word learning. Twenty-four-month-old children encountered three novel objects (named nine times each) that were either in close proximity or spatially distant to each other during naming. Children learned the object names significantly better than expected by chance in both conditions. However, additional analyses revealed a significant interaction between noun vocabulary size and distance between objects during naming: those with larger vocabularies benefitted from larger distances between objects and those with smaller vocabularies demonstrated better learning when the objects were in closer proximity to each other during naming.

These findings extend previous research demonstrating that the distances between objects influence word learning. For example, [Pereira et al. \(2014\)](#) found that children retained more words when they focused largely on a single object than if they had other objects in view when parents named objects. Similarly, in a fast mapping study, [Horst et al. \(2010\)](#) found that as the number of competitors increased during referent selection, later retention accuracy decreased. In that study, all of the objects were presented on the same tray in each condition. Therefore, as more objects were present, the distances between objects was smaller. Together, these studies provide converging evidence that it may be easier for children to learn words when their view is less cluttered with fewer objects taking up visual space. However, the results in the current study suggest this is only the case for children with larger vocabularies. Surprisingly, for children with smaller vocabularies it was easier to learn words when their view included more objects in closer proximity to each other. Thus, these findings suggest that the effect of distance between objects changes with vocabulary size.

Object locations, however, are often unstable as objects move in space and time and learners also frequently change their own locations ([Pereira et al., 2014](#)). Consequently, the distances between objects change, which can also affect attention and learning. When observers attend to an object, the object is at a higher resolution than the surrounding area. Consequently, when other objects are in close proximity to the target object visual crowding can occur, which visually suppresses neighboring objects ([Anstis, 1974](#); [Bahcall & Kowler, 1999](#); [Bouma, 1970](#); [Caputo & Guerra, 1998](#); [Cutzu & Tsotsos, 2003](#); [Fehd & Seiffert, 2010](#); [Franconeri, Jonathan, & Scimeca, 2010](#)). For example, because the visual resolution of objects is reduced at shorter distances, adults remember ([Franconeri et al., 2007](#)) and track ([Shim, Alvarez, & Jiang, 2008](#)) the locations of target objects with displays with more distance between objects better than displays with less distance between objects—even when the number of objects is controlled for (see also [Bouma, 1970](#); [Franconeri et al., 2010](#); [Intriligator & Cavanagh, 2001](#); [Pelli & Tillman, 2008](#)). Further, if a task irrelevant stimulus is presented

within close proximity to a target, there is a smaller neural response than if it is presented farther away ([Hopf et al., 2006](#)), again providing evidence for visual suppression surrounding a focal point.

However, [Holcombe, Chen, and Howe \(2014\)](#) found that the advantage distance confers only occurs within a particular range: the ‘crowding zone’ and beyond the crowding zone, distance does not provide additional benefit. The notion of a crowding zone sheds light on the current findings. In the near condition, children likely experienced visual crowding. Specifically, given an average viewing distance of 33.5 cm (the distance from the child to the target), the visual angles between the objects were between 0.8–5°, so the neighboring objects were likely at a lower resolution than the target object. Importantly, the competitors were also in close proximity to each other. This may have had a facilitative effect on the children with smaller vocabularies as they likely received visual input from the target object and less from the competitors, which could have reduced cognitive load during naming. In contrast, in the distant condition, it is unlikely that children experienced visual crowding. The distance between the objects in the distant condition were at approximate viewing angles of 53–61°. These distances are outside reported zones of visual suppression (e.g., [Bouma, 1970](#); [Falkner et al., 2010](#); [Holcombe et al., 2014](#); [Hopf et al., 2006](#); [Mounts, 2000](#)). Children with larger vocabularies are faster at comprehending words ([Fernald et al., 2006](#)) and have stronger phonological representations that help them further acquire new words more easily (e.g., [Bates & Goodman, 1997](#); [Torkildsen et al., 2009](#)). Thus, children with larger vocabularies in the current study could likely handle and even capitalize on simultaneously perceiving the target object and competitor objects while forming an association between the target object and its name (see also [Zosh, Brinster, & Halberda, 2013](#)). Children with a low vocabulary size might not have performed well in the distant condition as perceiving all three objects simultaneously might have increased cognitive load. In the near condition, where visual crowding could have suppressed visual input from the competitors, children with smaller vocabularies performed better.

This explanation is purely speculative and the effects of visual suppression and visual crowding depend on stimuli size, task complexity (e.g., number of stimuli), distances from the central fixation point (eccentricities) and distances between competitors (see [Bouma, 1970](#); [Cutzu & Tsotsos, 2003](#); [Holcombe et al., 2014](#); [Hopf et al., 2006](#); [Intriligator & Cavanagh, 2001](#); [Mounts, 2000](#); [Pelli et al., 2007](#); [Pelli & Tillman, 2008](#)). Thus, future research is needed to explore this explanation in more detail with more controlled distances between the objects.

In addition, these findings may have implications for children with language delays. Compared to typically developing (TD) children, children with Specific Language Impairment (SLI) have difficulties processing verbal and spatial information and in coordinating these two sources of information ([Hoffman & Gillam, 2004](#)). They also experience difficulties with sustained attention ([Marton, 2008](#)) and forming associations between objects and locations ([Bavin, Wilson, Maruff, & Sleeman, 2005](#)). Further, compared to TD children, children with autism spectrum disorder (ASD) are less likely to follow a speaker's gaze ([Carpenter, Pennington, & Rogers, 2002](#); [Leekam & Ramsden, 2006](#)) and their ability to learn words from social cues is limited ([Baron-Cohen, Baldwin, & Crowson, 1997](#)). Children at-risk for ASD are receptive to a speaker's referent, but show impaired long-term retention ([Gliga et al., 2012](#)) and benefit less from ostensive naming ([Bedford et al., 2013](#)). Therefore, future investigations should explore the effects of spatial distance between objects when teaching object names to children with both typical and atypical language development.

Space is an essential component of communication along with social cues such as eye gaze and gestures used by speakers to direct listener's attention to particular spatial locations ([Samuelson et al., 2011](#)). The current study found that children with larger vocabularies learn names for novel objects better if objects are named when positioned at farther distances to each other so that they can clearly focus on the target object. In contrast, children with smaller vocabularies instead

performed better when objects were positioned closer together during naming, suggesting that keeping the competitors within closer view of the target appears to benefit these children. Together, these findings suggest that the distance between objects during naming can be one of many subtle, fleeting factors in a learning environment that can affect long-term learning in laboratory settings (Horst & Simmering, 2015), but also have broader implications on learning in the home (Petrill, Pike, Price, & Plomin, 2004) and in the classroom (Fisher et al., 2014). However, the effect of distance appears to vary at different stages of language development.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.actpsy.2015.11.006>.

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