Journal of Experimental Child Psychology 183 (2019) 134–145

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Taking their eye off the ball: How shyness affects children's attention during word learning

Matt Hilton [a,*], Katherine E. Twomey [b], Gert Westermann [c]

[a] *Developmental Psychology, Department of Psychology, University of Potsdam, 14476 Potsdam, Germany*
[b] *Division of Human Communication, Development and Hearing, University of Manchester, Manchester M13 9PL, UK*
[c] *Department of Psychology, Lancaster University, Lancaster LA1 4YF, UK*

A R T I C L E   I N F O

Article history:
Received 5 June 2018
Revised 29 January 2019

Keywords:
Word learning
Shyness
Language development
Temperament
Individual differences
Referent Selection

A B S T R A C T

The current study tests the hypothesis that shy children's reduced word learning is partly due to an effect of shyness on attention during object labeling. A sample of 20- and 26-month-old children ($N = 32$) took part in a looking-while-listening task in which they saw sets of familiar and novel objects while hearing familiar or novel labels. Overall, children increased attention to familiar objects when hearing their labels, and they divided their attention equally between the target and competitors when hearing novel labels. Critically, shyness reduced attention to the target object regardless of whether the heard label was novel or familiar. When children's retention of the novel word–object mappings was tested after a delay, it was found that children who showed increased attention to novel objects during labeling showed better retention. Taken together, these findings suggest that shyer children perform less well than their less shy peers on measures of word learning because their attention to the target object is dampened. Thus, this work presents evidence that shyness modulates the low-level processes of visual attention that unfold during word learning.

© 2019 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

* Corresponding author.
E-mail address: matt.hilton@uni-potsdam.de (M. Hilton).

https://doi.org/10.1016/j.jecp.2019.01.023
0022-0965/© 2019 The Authors. Published by Elsevier Inc.
This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Introduction

Reports on the development of language usually begin by celebrating children's remarkable ability to learn words. For example, it is often stated that by the time of their second birthday, children have typically acquired a vocabulary of more than 300 words (Fenson et al., 1994). Although these summaries are an impressive illustration of the speed of language acquisition, they often ignore an equally fascinating aspect of early language acquisition—its variability. For example, on closer examination, the data also show that 10% of 2-year-old children are able to produce more than 528 different words, whereas the 10% at the opposite end of the scale produce fewer than 66 different words. Interestingly, the majority of children in the bottom 10% will show no later difficulties with language development (Kelly, 1998).

Research into variability in early language acquisition typically focuses on the role of environmental factors. We know that wide-ranging extrinsic factors such as socioeconomic status (SES), birth order, and differences in daycare quality exert an effect on children's language development. For example, it has been consistently shown that children from more affluent backgrounds acquire language more quickly than their less well-off peers (Hoff-Ginsberg, 1991). Similarly, children with older siblings show an earlier grasp of pronoun use than first-born children (Oshima-Takane, Goodz, & Derevensky, 1996) and, unsurprisingly, children in higher-quality daycare show advanced language and communication skills (Burchinal, Roberts, Nabors, & Bryant, 1996).

The mechanisms underlying extrinsic effects on language development are often also explained in terms of the environment. Taking SES as an example, many argue that children raised in better-off families acquire language more quickly because their language input is easier to learn from (Hirsh-Pasek et al., 2015), contains more words overall (Hart & Risley, 2003), contains a greater variety of word types (Hoff, 2003), and is more likely to be in a child-directed register (Rowe, 2008). Thus, these accounts argue that the effect of SES on language development can be attributed to the effect of SES on children's language input.

Yet, variability during development is not only present in the environment but also exists within children. Even from birth, children show marked differences in their reaction to the environment. Some babies are consistently quick to settle after stressful events (e.g., sudden loud noises or inoculations), whereas others are highly reactive to such events, as demonstrated by a display of intense motor reaction and distress (e.g., Kagan & Snidman, 1991; Worobey & Lewis, 1989). Throughout development, further individual differences in response to the environment emerge. Some infants become easily distracted, whereas others show no difficulty in focusing attention on toys or events for long periods of time (Rothbart, 1981). Thus, such myriad individual differences suggest that, even given identical input, two children taken at random could process this input very differently.

We know that individual differences in children's behavioral style, better known as temperament (Rothbart, 1981), can explain some variability in early language development. Differences in children's inhibition and discomfort in novel social situations (i.e., shyness; Putnam, Gartstein, & Rothbart, 2006), have been consistently shown to affect children's language development. Shyness is negatively correlated with vocabulary size when measured via parent-report checklists of children's vocabulary (Paul & Kellogg, 1997; Slomkowski, Nelson, Dunn, & Plomin, 1992), and these differences in productive vocabulary have also been confirmed experimentally, with shyer children being found to speak less than their less shy peers in both familiar and unfamiliar settings (Asendorpf & Meier, 1993; Crozier & Badawood, 2009; Evans, 1987).

Various explanations have been put forward to explain the relation between shyness and measures of language development. Some have argued that shyness affects the propensity to respond (e.g., Smith Watts et al., 2014). According to this account, shyness does not affect language development per se; instead, shy children are less likely to demonstrate their language skills, leading to their reduced scores on language measures. Others argue that shyness exerts an effect on language development indirectly by modulating the environment; shyer children are likely to reduce their interactions in novel social settings and, in this way, restrict their exposure to language in comparison with less shy peers (e.g., Evans, 1993). This suggestion has some support, for example from Evans

(1996), who found that children who are consistently reticent to talk in social settings, rather than those who are just slow to warm up, show reduced scores on tests of language ability.

Generalization across previous reports of the relation between shyness and language is problematic due to differences in the precise operationalization and measurement of shyness. Whereas some have measured individual temperamental differences by examining children's responses in a face-to-face task (e.g., Slomkowski et al., 1992), the difficulty with such an approach is that it does not allow any certainty that the measure reflects stable individual differences. It is possible that "shy-type" behaviors are exhibited during a single session for more transient reasons (e.g., tiredness). Other studies have dealt with this issue by capitalizing on caregivers' experience of their children's enduring behavioral style, using parent-report measures of shyness (e.g., Asendorpf & Meier, 1993). The Early Childhood Behavior Questionnaire (ECBQ; Putnam et al., 2006) is one such parent-report standardized measure of children's temperament subdivided into different scales, one of which measures shyness by asking parents to indicate how often their child exhibits shy-type behaviors such as turning away from strangers and showing hesitation in approaching unfamiliar children. A recent account based on Putnam et al. (2006) approach argued that shyness can affect language development by modulating the low-level processes by which language is acquired (Hilton & Westermann, 2017). Shyer children demonstrate an avoidance of eye contact during social interaction (Putnam et al., 2006), indicating that shyness modulates attentional processing during these interactional episodes, and there is evidence that shyness may also modulate children's allocation of attentional resources in the absence of social interaction: Pérez-Edgar and Fox (2005) demonstrated in a screen-based cueing task that whereas less shy children attended preferentially to cued locations associated with a reward, shyer children preferentially attended to locations associated with a penalty. Given that the earliest stages of language learning are governed at least in part by the cognitive systems that underlie attentional focus abilities (e.g., Dixon & Hull Smith, 2008), it is likely that any effects of shyness on attentional processing could also affect language learning.

Much work on the critical role of attentional processes during language learning has examined how externally directing children's attention affects their formation and retention of novel word–object mappings. Typically, children are presented with *referent selection* trials on which one novel object is presented alongside familiar competitors and experimenters record whether children select the novel object when asked for a novel label (e.g., "Where's the blicket?"; Horst & Samuelson, 2008). Then, after a 5-min break, children's retention of this newly formed mapping is tested. Critically, by manipulating key elements of this task, such as the number and nature of the familiar competitors, researchers have uncovered evidence to suggest that children's attention during the presentation of objects and their corresponding labels affects their learning of these word–object mappings. For example, Axelsson, Churchley, and Horst (2012) drew children's attention to the novel object during labeling by flashing a light underneath it and partially covering competitors and demonstrated that children retained novel word–object mappings better under these conditions than when the novel object was only pointed to during labeling or when the light and covering were presented individually. Such work indicates that children who focus attention on targets during labeling are better able to learn the word–object mappings, and related work demonstrates that attention to the target can be modulated by extrinsic cues such as novelty (Horst, Scott, & Pollard, 2010; Kucker & Samuelson, 2012). Given the critical role of attention in successful word learning, it is possible that shyness affects language learning by modulating attentional processes during labeling episodes. However, there has been little examination of the intrinsic factors that may drive these differences in attention.

Hilton and Westermann (2017) were the first to test whether attentional processes during word learning are affected by shyness. In their study, 24-month-old children were presented with sets of three objects, one of which was novel and two of which were familiar. When asked for a novel object using a novel word, shyer children selected objects at chance levels, whereas less shy children reliably chose the novel object. Furthermore, after a 5-min break, shyer children did not retain any of the (few) novel word–object mappings that they had formed during referent selection, whereas less shy children showed evidence of retaining these mappings. The authors argued that these findings could be explained in terms of differences in attention during labeling. Specifically, shyer children's aversion to novelty (Kagan, Reznick, & Snidman, 1988) may have reduced their attention to the target (novel) object during labeling, disrupting encoding and, thus, formation of the word–object mapping.

Of course, given that Hilton and Westermann's (2017) study only measured children's manual object selection, it was impossible to directly demonstrate whether shyness affected children's word learning via attention during referent selection. Thus, the current study aimed to examine this possibility using a novel adaptation of the looking-while-listening paradigm (Fernald, Zangl, Portillo, & Marchman, 2008; Swingley, 2011). Children were presented with images of one novel object and two familiar objects on a screen, and their eye gaze across the objects was recorded while a familiar or novel label was heard. As well as providing a highly detailed picture of children's online processing, this approach has the advantage of measuring implicit behavior. An explicit response, such as pointing at an object as in Hilton and Westermann's (2017) study, has a social dimension, and it is possible that the random responses exhibited by shy children in that study related to social expectation. Recording eye movements in a task without an experimenter present addresses this possibility.

In this study, we explored whether shyness as measured by the ECBQ modulates children's attention to target objects during labeling. Based on the assumption that children's mapping of a novel label to a novel object involves ruling out potential competitors (Halberda, 2006; Horst et al., 2010), children's looking to competitor objects should be a critical step in the formation of a novel word–object mapping. However, in line with previous research (Axelsson et al., 2012; Horst et al., 2010), we expected that children who were better able to focus their attention on the novel object following this initial disambiguation would be better able to retain the mapping. Therefore, we also tested whether looking during labeling could predict retention of word–object mappings and whether this relation changes over development, as demonstrated in previous work (Bion, Borovsky, & Fernald, 2013).

Method

Participants

A total of 32 typically developing 20- to 26-month-old children took part in the study. All children were monolingual English speakers. There were 16 children in the 20-month age group ($M = 20$ months 13 days, range = 19 months 11 days to 21 months 5 days; 8 girls). An additional 3 20-month-old children were excluded due to failure to complete the task ($n = 2$) or experimenter error ($n = 1$). There were also 16 children in the 26-month age group ($M = 26$ months 13 days, range = 25 months 19 days to 27 months 0 days; 8 girls). An additional 2 26-month-old children were excluded due to equipment failure ($n = 1$) or failure to complete the task ($n = 1$). These sample sizes are in line with previous research using a similar methodology (Twomey, Ma, & Westermann, 2018) and provide more than 80% power at the $p < .05$ level to detect an effect size of 0.56 in mutual exclusivity (referent selection) tasks (Bergmann et al., 2018; Lewis & Frank, 2018). Families were recruited by contacting parents who had previously indicated interest in participating in child development research. Parents' travel expenses were reimbursed, and children were offered a storybook to thank them for participating. Written informed consent was provided by the participants' parents.

Prior to the study, parents completed the Oxford CDI (Hamilton, Plunkett, & Schafer, 2000), a British English adaption of the widely used MacArthur–Bates Communicative Development Inventory (Fenson et al., 1994). Vocabulary scores for 3 20-month-old children were not available because their parents failed to return the questionnaire. These missing values were replaced by the mean score. The 20-month-old group produced a mean of 127 words (range = 17–413) and understood a mean of 252 words (range = 104–413). The 26-month-old group produced a mean of 179 words (range = 158–386) and understood a mean of 347 words (range = 217–416). All vocabulary scores were within the normal range (Floccia, 2017; Frank, Braginsky, Yurovsky, & Marchman, 2017). As expected, the 26-month-old children had larger receptive and productive vocabularies than the 20-month-old children [receptive: $t(30) = 3.81$, $p < .001$; productive: $t(30) = 4.61$, $p < .001$)].

Stimuli and design

During their visit to the lab, children took part in referent selection trials, which were presented on a computer screen, and retention trials based on their selection of the actual three-dimensional (3D) objects. Visual stimuli for referent selection trials consisted of digital photographs of known and novel objects. For each participant, the 12 referent selection pictures were randomly grouped into sets of 3, with each set comprising one novel object and two familiar objects, so that the objects comprising each set were consistent for each participant but varied across participants. Novel objects were a plastic tripod, a wooden roller, a wooden dumbbell. and a plastic tea strainer, the same novel objects used with a similar age group in a previous study (Hilton & Westermann, 2017). Known objects were toy versions of the following vehicles, animals, and household items: car, motorbike, elephant, fish, pig, ball, fork, and spoon. Each picture was of similar size on the screen (∼700 × 800 mm). Each novel object was assigned one of four pseudowords (*cheem*, *koba*, *sprock*, or *tannin*) chosen to be plausible pseudowords in English and having been used in previous word learning studies (Halberda, 2006; Horst & Samuelson, 2008; Markson & Bloom, 1997; Samuelson & Horst, 2007). For each trial, a short video was created. Each video began by showing the set of pictures bouncing onto the screen, accompanied by a short bouncing sound effect, in order to focus children's attention on the screen at the beginning of the trial. Once the objects had finished bouncing (2000 ms after the start of the video), the audio stimulus automatically began playing. Audio stimuli consisted of three labeling phrases spoken by a male native British English speaker in infant-directed speech. The target object label appeared in the final position of each labeling phrase ("Look, there's a _____! Where's the _____? Wow, it's a _____!"). The three labeling phrases were in the same order on all trials. Label onsets were 2500, 5200, and 9100 ms after stimulus onset, and the final label offset was at 10,000 ms. Once the auditory stimulus had finished playing, the objects stayed on the screen for a further 2000 ms before disappearing and leaving the screen clear for the next trial.

All participants took part in 12 referent selection trials. Each set of pictures was presented three times; on 2 trials children heard the novel label (*novel trials*), and on 1 trial children heard one of the two familiar object labels (randomly selected; *familiar trials*). The order in which the sets were presented was randomized. The location of each object (on the left, in the center, or on the right) was pseudorandomized across trials, ensuring that the target did not appear in the same location on more than 2 successive trials, and the order of trial types was pseudorandomized, ensuring that a trial type (i.e., novel or familiar label) was not repeated more than three times in a row.

Seven 3D objects were used for retention trials. Three randomly selected familiar objects (e.g., toy duck, car, and fork) acted as stimuli for the initial warm-up trials, and the four novel objects of which children saw images during referent selection were stimuli on test trials.

Procedure

Shyness questionnaire

During their visit, parents completed the shyness scale of the ECBQ (Putnam et al., 2006). The ECBQ is a standardized parent-report measure of 18- to 36-month-old children's emerging temperament, and the shyness scale asks parents to rate from 1 to 7 (1 = *never*, 7 = *always*) how often over the previous 2 weeks their children had demonstrated shy-type behaviors (e.g., "When playing with unfamiliar children, how often did your child seem uncomfortable?"). The average score across the 12 questions (Cronbach's $\alpha = .86$) for each child was calculated, resulting in a score between 1 (*not at all shy*) and 7 (*extremely shy*). To avoid demand biases in parents' responses, three other questions taken from one other unrelated subdimension (perceptual sensitivity) were included in the questionnaire.

Referent selection trials

During referent selection, children were seated centrally 50 to 70 cm in front of a computer screen on their parent's lap. A Tobii X120 eye tracker located beneath the screen recorded children's eye gaze, and a video camera above the screen recorded parents and children throughout the procedure. Parents were instructed not to look at the screen or speak to their children as the videos were playing so as to avoid influencing their children's behavior, and the experimenter monitored the testing session via a camera to ensure that this instruction was followed. Prior to the experiment starting, children's eye gaze was calibrated using a 5-point calibration procedure. A child-friendly animation (a wobbling duck) was displayed in the four corners and center of a 3 × 3 grid accompanied by a jingling sound, and calibration accuracy was checked and calibration was repeated if necessary. Once the calibration procedure was completed, the referent selection trials were presented.

Data coding and cleaning

The sampling rate of the eye tracker was 60 Hz, and the raw data files were exported from Tobii Studio (Version 3.4) and analyzed in R (R Core Team, 2017). Three rectangular areas of interest (AOIs) were defined as the three areas of the screen where the stationary stimuli were displayed. All AOIs measured 385 by 408 pixels. AOI 1 covered the object on the left-hand side of the screen, AOI 2 covered the object in the middle, and AOI 3 covered the object on the right-hand side. There was a margin of 107 pixels between AOIs. Continuous gaze within an AOI was counted as a fixation. If continuous gaze within an AOI was interrupted for less than 60 ms, this interruption was recoded as a continuation of that fixation because the interruption was most likely due to eye blinks rather than children rapidly reorienting their attention (see Yu & Smith, 2011). All analyses were conducted on children's looking times from 233 ms after the first label onset to allow for saccade preparation (Canfield & Haith, 1991; Haith, Hazan, & Goodman, 1988) until 12,000 ms when the objects disappeared from the screen.

Retention trials

After the 12 referent selection trials, children took a 5-min break by playing in an adjacent room, in line with Horst and Samuelson (2008). Children then took part in retention trials during which they sat on their parent's lap at a table opposite the experimenter. Retention trials consisted of a three-alternative forced-choice task in which participants were required to select a target object from an array in response to a target word requested by the experimenter, a typical task used to measure children's mapping of words to objects (e.g., Waxman and Booth, 2001; Dysart, Mather, & Riggs, 2016; Samuelson & Horst, 2007). Prior to the retention test trials, a series of warm-up trials was presented to ensure that children understood the task and were responding appropriately to the experimenter's requests. On each warm-up trial, children were presented with three randomly selected familiar objects side by side on a tray divided into three sections. These familiar objects had previously acted as competitor objects during referent selection. After allowing children to look at the objects for 3 s, the experimenter requested one of the objects (e.g., "Where's the car?") before sliding the tray forward and allowing children to make their choice by pointing at or retrieving the object. On the next trial, the objects were rearranged out of sight of the children and another object was requested. These trials continued until children had correctly selected the target object on three consecutive trials. Across the initial three trials, each object was requested once and the target object appeared in each location on the tray once. On any further trials, the position of the target was randomly determined. To encourage participation, children's correct responses were praised and corrections were offered when children did not at first select the correct object.

Following the warm-up trials, the retention trials began. The procedure for retention trials was identical to that for warm-up trials except that no praise or corrections were offered so as to avoid biasing children's responses. Instead, once children had selected an object, the experimenter replied "thank you" in a neutral tone, replaced the object, and then began the next trial. Across the 4 retention trials each novel object acted as the target once, and on each trial two other randomly selected novel objects acted as competitors. Pictures of these same novel objects had been presented during referent selection, and the experimenter requested the target object using the novel word with which it had appeared during referent selection. The order of trials and the position of the target on the tray were randomized.

Results

Looking during referent selection

To establish whether shyness and trial type affected overall looking time, we submitted raw looking times to a linear mixed-effects model (LMEM) with main effects of shyness score (mean centered), competitor or target fixation (hit type; for all models, dummy coded: target = 1, Competitor 1 = 0, Competitor 2 = 0), and trial type (for all models, dummy coded: familiar = 1, novel = 0) and their interactions, by-participant random intercepts and slopes, and by-target random intercepts and slopes. Results are reported in Table 1 with significant predictors highlighted in bold. Initial analyses revealed no main effect of, or interactions with, age group, so we collapsed across this factor. All LMEMs were conducted using the *lme4* package Version 1.1–12 in R Studio Version 3.2.4 (R Core Team, 2017) and had maximal random effects structures simplified until convergence (Barr, Levy, Scheepers, & Tily, 2013). The *p* values for fixed effects were obtained using sequential likelihood ratio tests.

Overall, children looked more at the competitors than at the target (negative main effect of hit type), but children's attention to targets and competitors differed according to trial type (significant hit type × trial type interaction). Follow-up post hoc tests were performed on the hit type × trial type interaction using the *multcomp* package Version 1.4–7 (Hothorn, Bretz, & Westfall, 2008), revealing that on familiar label trials children looked at the target more than at competitors ($z = 4.87$, $p < .001$), but this difference was not found on novel label trials ($z = -0.79$, $p > .99$), as shown in Fig. 1.

Table 1 also shows an interaction between shyness score and hit type. As can be seen in Fig. 2, this interaction could likely be explained by a negative relation between shyness and target looking, whereas no relation is visible between shyness and competitor looking. To examine whether this interpretation was supported by the data, we analyzed looking to the competitors and looking to the target in separate LMEMs. The results revealed that shyness was indeed related to target object looking [beta = 0.27, $SE = 0.12$, $t = -2.34$, $\chi^2(1) = 4.95$, $p = .026$] but not to competitor object looking [beta = 0.12, $SE = 0.11$, $t = 1.08$, $\chi^2(1) = 1.18$, $p = .28$]. This finding demonstrates that shyer children

Table 1
Results of linear mixed-effects model for referent selection trials.

	Beta	*SE*	*t*	χ^2	*df*	*p*
Trial type	−0.52	0.14	−3.66	0.77	1	.38
Hit type	**−0.20**	**0.14**	**−1.43**	**10.84**	**1**	**<.001**
Shyness	0.071	0.11	0.64	0.073	1	.79
Hit type × Trial type	**1.79**	**0.24**	**7.32**	**51.47**	**1**	**<.001**
Shyness × Trial type	0.16	0.14	1.07	1.18	1	.28
Shyness × Hit type	**−0.41**	**0.14**	**−2.89**	**13.28**	**1**	**<.001**
Hit type × Trial type × Shyness	−0.045	0.25	−0.18	0.033	1	.85

Note. Significant predictors are in bold.

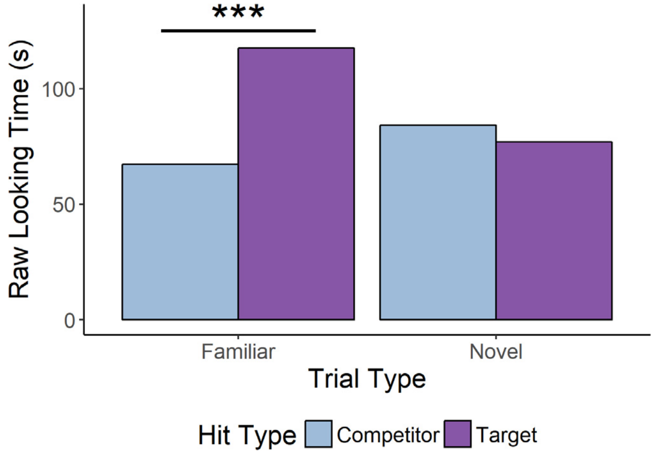

Fig. 1. Raw cumulative looking times split by trial and hit type. $^{***}p < .001$.

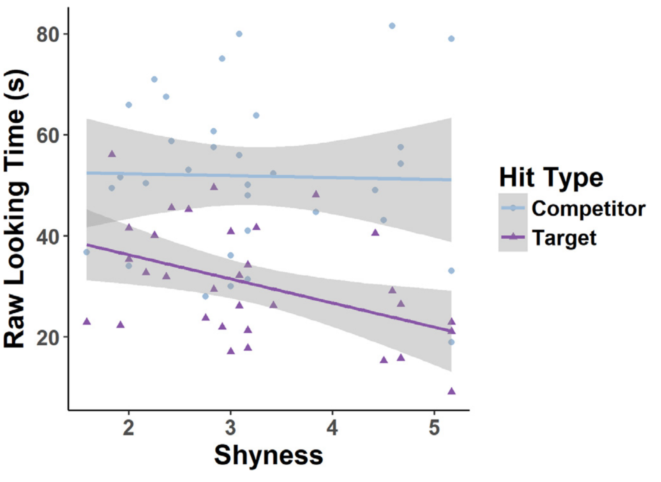

Fig. 2. Children's shyness scores plotted against their total looking at the competitors and at the target across referent selection. For illustration, lines are linear regressions and shaded areas are standard errors of the mean.

looked less at the target object during labeling in comparison with less shy children. However, shyness was not associated with children's attention to the competitor objects.

Retention trials

We next wanted to examine whether shyness and target looking during referent selection predicted retention scores. To do this, raw looking time to each novel target during referent selection was calculated. Retention trials were scored as 1 if children correctly retained the novel word–object mapping and as 0 if they did not. Trials on which no response was offered ($n = 5$) were excluded from the analyses. Given the previously observed differences in retention of word–object mappings between our two age groups (Bion et al., 2013), age group was reintroduced as a predictor in these models (dummy coded: 20-month group = 0, 26-month group = 1). Therefore, we submitted retention scores to a binomial LMEM with fixed effects of age, shyness score, and novel target looking during referent selection and by-participant and by-target random intercepts. Results are presented in Table 2 with significant predictors highlighted in bold. The positive main effect of target looking is evidence that looking to the target during labeling supports retention of the label–object association. However, children overall failed to retain any word–object mappings at levels better than chance, $t(30) = 1.25$, $p = .22$. The absence of a main effect of shyness suggests that retention and shyness were not directly related. However, because the results from the referent selection trials indicate that shyness modulates attention during labeling, this result leaves open the possibility that shyness could affect word learning. We return to this point in the Discussion.

Table 2
Results of linear mixed-effects model for retention trials.

	Beta	*SE*	*z*	χ^2	*df*	*p*
Age group	0.43	0.78	0.56	0.14	1	.70
Shyness	−0.44	0.76	−0.58	1.17	1	.28
Target looking	**0.23**	**0.14**	**1.67**	**4.38**	**1**	**.036**
Age × Shyness	0.64	0.89	0.72	0.68	1	.41
Age × Target looking	−0.12	0.16	−0.72	0.036	1	.85
Shyness × Target looking	0.23	0.18	1.26	0.20	1	.65
Age × Shyness × Target looking	−0.24	0.20	−1.23	1.66	1	.20

Note. Significant predictors are in bold.

Discussion

The current work set out to examine whether shyness affects the processes modulating attention during labeling and children's subsequent word learning. In line with previous research, we found that familiar labels encouraged target looking, whereas novel labels led to equal competitor and target looking. Critically, however, we found that shyness was linked to a reduction in children's attention to the target object regardless of whether it was familiar or novel. Furthermore, although we found no evidence of retention at the group level, we found that individual infants' increased attention to the target during referent selection was positively related to retention of the novel word–object mappings.

As expected, we found differences in looking depending on whether a familiar or novel label was heard. On familiar label trials, children were processing an already-learned word–object association and so showed heightened attention to the target object in comparison with competitors. Such behavior is in line with previous research showing that children focus attention on known objects that are being labeled (Fernald, Pinto, Swingley, Weinbergy, & McRoberts, 1998). In contrast, we also found that on hearing a novel label, children spread their attention equally across the competitors and the target, likely because the novel label trials entail disambiguation, requiring children to first rule out competitors as potential referents before mapping the novel label to the novel object (Halberda, 2006). This finding offers converging evidence that initial attention to competitors is a crucial aspect of novel word disambiguation (Axelsson et al., 2012; Halberda, 2006; Horst et al., 2010).

Importantly, shyness reduced children's attention to the target object, regardless of whether the target was novel or familiar. This finding suggests that shyness modulates children's attention to labeled objects generally, and this is in line with Hilton and Westermann's (2017) finding that shyness affected not only children's formation of novel word–object associations but also their selection of familiar referents. Interestingly, shyness did not affect overall looking time to the object array, suggesting that shyness did not reduce attention to the task but, critically, modulated attentional patterns across the potential referents. Thus, the current work supports the theory that shy children's reduced performance during referent selection is related to their reduced attention to the target object rather than to a failure to engage with the task (Hilton & Westermann, 2017).

Given the complex interplay of attention during labeling, there are several potential mechanisms to explain the effect of shyness on target looking. Shy children's aversion to novelty (Kagan et al., 1988) may have caused children to look away from the novel object in favor of the familiar objects, but this explanation would also predict that shyness has no effect on target looking on familiar label trials. This was not what we found: Shy children looked less at targets on both trial types. Conversely, shyer children might have shown heightened attention to the novel object because we know that children attend more to stimuli that they find aversive (Field, 2006). However, this explanation does not support the finding that shyer children show reduced target looking on novel label trials. Because we know that shyness is linked to difficulty in engaging with novelty (Kagan et al., 1988), we argue that it is most likely that for shy children the novelty inherent in such a labeling episode (i.e., presence of a novel object and label, presentation in a novel voice) disrupts the ongoing attentional processes required to form the word–object association. This disruption is also pervasive enough to reduce shy children's ability to focus attention on the referent of a familiar label.

A critical contribution of the current work is that we found an effect of shyness on responses during referent selection even when no social interaction was required. Given shy children's aversion to novel social stimuli (Putnam et al., 2006), it is unsurprising that shy children show difficulty in responding to experimental tasks that are presented face to face (Crozier & Hostettler, 2003) and that shy children show differences in processing stimuli that are strongly associated with social interaction such as faces (Matsuda, Okanoya, & Myowa-Yamakoshi, 2013). The current work, however, finds a relation between shyness and attention during referent selection even when no explicit response is required and when no unknown adults are present. Thus, the relation between shyness and attention seems robust across contexts—even those contexts that do not require or prompt social interaction. This finding suggests that we must be vigilant to possible effects of shyness when designing and interpreting results of developmental research.

Unlike the referent selection trials, retention trials presented children with 3D objects. Nonetheless, a relationship between attention during referent selection and retention was found across this change in task: Although children overall looked equally across competitors and target on novel label trials, attention to the novel target was positively related to retention. Put differently, children who looked more to novel targets during labeling were more likely to retain the novel label–object mappings. Thus, results from the retention trials highlight the critical role of attention in predicting retention of newly formed word–object mappings, convergent with recent behavioral work (Kucker, McMurray, & Samuelson, 2018). The current study, therefore, suggests that although attention to competitors has been shown to affect children's ability to retain label–object mappings (Horst et al., 2010; Zosh, Brinster, & Halberda, 2013), it is those children who are better able to focus their attention on the target that are more likely to retain the label's meaning. This finding supports recent accounts of successful word learning as the product of two separate but related sets of processes: those processes that support disambiguation by driving elimination of competitors as potential referents, followed by those processes that support sustained attention to the target object, allowing for a robust association between the object and its label (see also Kucker, McMurray, & Samuelson, 2015). Interestingly, given the additional social component in the retention trials, we did not find a direct relation between shyness and retention. It is possible that this object selection measure, with a single data point per trial, was not sensitive enough to demonstrate a direct relation to shyness. Equally, although at the individual level retention was related to attention during referent selection, it is possible that the retention task resulted in a floor effect at the group level because it required children to transfer their learning from two-dimensional (2D) pictures of the objects to the actual 3D objects, something that we know is difficult for children overall (e.g., Krcmar, Grela, & Lin, 2007). These findings highlight the importance of exploring the processes underlying the relations among shyness, attention, and language development at the individual level as well as at the group level.

Although we found an effect of shyness on attention during referent selection, we found no effect of age, which is noteworthy given that existing literature suggests that referent selection behaviors undergo a shift sometime toward the end of the second year of life. For example, Bion et al. (2013) found that 18-month-old children showed no heightened attention to a novel object on hearing a novel label, whereas 24-month-old children did. However, in our study, at both 20 and 26 months of age children showed no heightened looking to the novel object on novel label trials. Whereas Bion et al. presented participants with one novel target alongside a familiar competitor, the current study presented two familiar competitors alongside each novel target. Thus, it is possible that the additional competitor in the current study increased the cognitive load of the task so that children needed more time to rule out competitors as potential referents, reducing the time spent looking at the novel object to chance levels. This discrepancy between the findings of the current study and those of Bion et al. serves as an important illustration of the role played by competitors during novel word disambiguation.

Overall, then, the current study demonstrates that shyness modulates the low-level attentional processes that unfold during word learning. Although future work is required to establish a direct link between shyness and retention, this finding may offer an explanation for shyer children's slower vocabulary development in comparison with less shy children (Spere, Schmidt, Theall-Honey, & Martin-Chang, 2004). Shyer children's reduced attention to objects during labeling could mean that they require more exposure to the object–label pairing so as to allow them greater opportunity to encode the association. Over and above the predominant explanations for the negative relation between children's shyness and vocabulary (i.e., reticence to demonstrate their language ability; Smith Watts et al., 2014), we identified a novel potential contributing factor: We showed that shyness also affects the early implicit processes that support one of the earliest stages of language learning.

Early word learning is the product of a complex and dynamic set of cognitive processes, and we have come far in understanding the environmental factors that modulate these processes (e.g., Axelsson et al., 2012; Twomey et al., 2018). In the current study, we showed that shyness is an intrinsic factor that influences the attentional processes supporting word learning. Therefore, we must now consider the role of this and other individual differences in word learning so as to better understand why early language development is so variable.

Acknowledgments

This work was supported by the Economic and Social Research Council (ESRC) International Centre for Language and Communicative Development (LuCiD), an ESRC Future Research Leaders fellowship to K.E.T., and a British Academy/Leverhulme Trust Senior Researcher Fellowship to G.W. The support of the ESRC (ES/L008955/1 and ES/N01703X/1) is gratefully acknowledged.

References

Asendorpf, J. B., & Meier, G. H. (1993). Personality effects on children's speech in everyday life: Sociability-mediated exposure and shyness-mediated reactivity to social situations. *Journal of Personality and Social Psychology, 64*, 1072–1083. https://doi.org/10.1037/0022-3514.64.6.1072.

Axelsson, E. L., Churchley, K., & Horst, J. S. (2012). The right thing at the right time: Why ostensive naming facilitates word learning. *Frontiers in Psychology, 3*. https://doi.org/10.3389/fpsyg.2012.00088.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68*, 255–278. https://doi.org/10.1016/j.jml.2012.11.001.

Bergmann, C., Tsuji, S., Piccinini, P. E., Lewis, M. L., Braginsky, M., Frank, M. C., & Cristia, A. (2018). Promoting replicability in developmental research through meta-analyses: Insights from language acquisition research. *Child Development, 89*, 1996–2009. https://doi.org/10.1111/cdev.13079. Data downloaded on 11/10/2018.

Bion, R. A. H., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word–object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition, 126*, 39–53. https://doi.org/10.1016/j.cognition.2012.08.008.

Burchinal, M. R., Roberts, J. E., Nabors, L. A., & Bryant, D. M. (1996). Quality of center child care and infant cognitive and language development. *Child Development, 67*, 606–620. https://doi.org/10.1111/j.1467-8624.1996.tb01754.x.

Canfield, R. L., & Haith, M. M. (1991). Young infants' visual expectations for symmetric and asymmetric stimulus sequences. *Developmental Psychology, 27*, 198–208. https://doi.org/10.1037/0012-1649.27.2.198.

Crozier, W. R., & Badawood, A. (2009). Shyness, vocabulary and children's reticence in Saudi Arabian preschools. *Infant and Child Development, 18*, 255–270. https://doi.org/10.1002/icd.623.

Crozier, W. R., & Hostettler, K. (2003). The influence of shyness on children's test performance. *British Journal of Educational Psychology, 73*, 317–328. https://doi.org/10.1348/000709903322275858.

Dixon, W. E., & Hull Smith, P. (2008). Attentional focus moderates habituation–language relationships: Slow habituation may be a good thing. *Infant and Child Development, 17*, 95–108. https://doi.org/10.1002/icd.490.

Dysart, E. L., Mather, E., & Riggs, K. J. (2016). Young children's referent selection is guided by novelty for both words and actions. *Journal of Experimental Child Psychology, 146*, 231–237. https://doi.org/10.1016/j.jecp.2016.01.003.

Evans, M. A. (1987). Discourse characteristics of reticent children. *Applied Psycholinguistics, 8*, 171–184. https://doi.org/10.1017/S0142716400000199.

Evans, M. A. (1993). Communicative competence as a dimension of shyness. In K. H. Rubin & J. B. Asendorpf (Eds.), *Social withdrawal, inhibition and shyness in childhood* (pp. 189–212). Hillsdale, NJ: Lawrence Erlbaum.

Evans, M. A. (1996). Reticent primary grade children and their more talkative peers: Verbal, nonverbal, and self-concept characteristics. *Journal of Educational Psychology, 88*, 739–749. https://doi.org/10.1037/0022-0663.88.4.739.

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., ... Stiles, J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development, 59*(5). https://doi.org/10.2307/1166093.

Fernald, A., Pinto, J. P., Swingley, D., Weinbergy, A., & McRoberts, G. W. (1998). Rapid gains in speed of verbal processing by infants in the 2nd year. *Psychological Science, 9*, 228–231. https://doi.org/10.1111/1467-9280.00044.

Fernald, A., Zangl, R., Portillo, A. L., & Marchman, V. A. (2008). Looking while listening: Using eye movements to monitor spoken language comprehension by infants and young children. In I. A. Sekerina, E. Fernandez, & H. Clahsen (Eds.), *Developmental psycholinguistics: On-line methods in children's language processing* (pp. 97–135). Amsterdam: John Benjamins.

Field, A. P. (2006). Is conditioning a useful framework for understanding the development and treatment of phobias? *Clinical Psychology Review, 26*, 857–875. https://doi.org/10.1016/j.cpr.2005.05.010.

Floccia, C., 2017. Data collected with the Oxford CDI over a course of 5 years in Plymouth Babylab, UK. Data downloaded November 10, 2018, from http://wordbank.stanford.edu/.

Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2017). Wordbank: An open repository for developmental vocabulary data. *Journal of Child Language, 44*, 677–694. https://doi.org/10.1017/S0305000916000209.

Haith, M. M., Hazan, C., & Goodman, G. S. (1988). Expectation and anticipation of dynamic visual events by 3.5-month-old babies. *Child Development, 59*, 467–479. https://doi.org/10.2307/1130325.

Halberda, J. (2006). Is this a dax which I see before me? Use of the logical argument disjunctive syllogism supports word-learning in children and adults. *Cognitive Psychology, 53*, 310–344. https://doi.org/10.1016/j.cogpsych.2006.04.003.

Hamilton, A., Plunkett, K., & Schafer, G. (2000). Infant vocabulary development assessed with a British Communicative Development Inventory. *Journal of Child Language, 27*, 689–705.

Hart, B., & Risley, T. R. (2003). The early catastrophe: The 30 million word gap by age 3. *American Educator, 27*(1), 4–9. Retrieved from https://www.bilingualpreschool.org/wp-content/uploads/2016/08/The-Early-Catastrophe-The-30-Million-Word-Gap-by-Age-3.pdf.

Hilton, M., & Westermann, G. (2017). The effect of shyness on children's formation and retention of novel word–object mappings. *Journal of Child Language, 44*, 1394–1412. https://doi.org/10.1017/S030500091600057X.

Hirsh-Pasek, K., Adamson, L. B., Bakeman, R., Owen, M. T., Golinkoff, R. M., Pace, A., ... Suma, K. (2015). The contribution of early communication quality to low-income children's language success. *Psychological Science, 26*, 1071–1083. https://doi.org/10.1177/0956797615581493.

Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Development, 74*, 1368–1378. https://doi.org/10.1111/1467-8624.00612.
Hoff-Ginsberg, E. (1991). Mother–child conversation in different social classes and communicative settings. *Child Development, 62*, 782–796. https://doi.org/10.1111/j.1467-8624.1991.tb01569.x.
Horst, J. S., & Samuelson, L. K. (2008). Fast mapping but poor retention by 24-month-old infants. *Infancy, 13*, 128–157. https://doi.org/10.1080/15250000701795598.
Horst, J. S., Scott, E. J., & Pollard, J. A. (2010). The role of competition in word learning via referent selection. *Developmental Science, 13*, 706–713. https://doi.org/10.1111/j.1467-7687.2009.00926.x.
Hothorn, T., Bretz, F., & Westfall, P. (2008). Simultaneous inference in general parametric models. *Biometrical Journal, 50*, 346–363. https://doi.org/10.1002/bimj.200810425.
Kagan, J., Reznick, J., & Snidman, N. (1988). Biological bases of childhood shyness. *Science, 240*, 167–171. https://doi.org/10.1126/science.3353713.
Kagan, J., & Snidman, N. (1991). Temperamental factors in human development. *American Psychologist, 46*, 856–862. https://doi.org/10.1037/0003-066X.46.8.856.
Kelly, D. J. (1998). A clinical synthesis of the "late talker" literature: Implications for service delivery. *Language, Speech, and Hearing Services in Schools, 29*, 76–84. https://doi.org/10.1044/0161-1461.2902.76.
Krcmar, M., Grela, B., & Lin, K. (2007). Can toddlers learn vocabulary from television? An experimental approach. *Media Psychology, 10*, 41–63. https://doi.org/10.1080/15213260701300931.
Kucker, S. C., McMurray, B., & Samuelson, L. K. (2015). Slowing down fast mapping: Redefining the dynamics of word learning. *Child Development Perspectives, 9*, 74–78. https://doi.org/10.1111/cdep.12110.
Kucker, S. C., McMurray, B., & Samuelson, L. K. (2018). Too much of a good thing: How novelty biases and vocabulary influence known and novel referent selection in 18-month-old children and associative learning models. *Cognitive Science, 42*(Suppl. 2), 463–493.
Kucker, S. C., & Samuelson, L. K. (2012). The first slow step: Differential effects of object and word-form familiarization on retention of fast-mapped words. *Infancy, 17*, 295–323.
Lewis, M., & Frank, M. (2018). Mutual exclusivity: A meta-analysis. Manuscript in preparation.
Markson, L., & Bloom, P. (1997). Evidence against a dedicated system for word learning in children. *Nature, 385*, 813–815. https://doi.org/10.1038/385813a0.
Matsuda, Y.-T., Okanoya, K., & Myowa-Yamakoshi, M. (2013). Shyness in early infancy: Approach–avoidance conflicts in temperament and hypersensitivity to eyes during initial gazes to faces. *PLoS One, 8*(6), e65476. https://doi.org/10.1371/journal.pone.0065476.
Oshima-Takane, Y., Goodz, E., & Derevensky, J. L. (1996). Birth order effects on early language development: Do secondborn children learn from overheard speech? *Child Development, 67*, 621–634. https://doi.org/10.1111/j.1467-8624.1996.tb01755.x.
Paul, R., & Kellogg, L. (1997). Temperament in late talkers. *Journal of Child Psychology and Psychiatry, 38*, 803–811. https://doi.org/10.1111/j.1469-7610.1997.tb01598.x.
Pérez-Edgar, K., & Fox, N. A. (2005). A behavioral and electrophysiological study of children's selective attention under neutral and affective conditions. *Journal of Cognition and Development, 6*, 89–118. https://doi.org/10.1207/s15327647jcd0601_6.
Putnam, S. P., Gartstein, M. A., & Rothbart, M. K. (2006). Measurement of fine-grained aspects of toddler temperament: The Early Childhood Behavior Questionnaire. *Infant Behavior and Development, 29*, 386–401. https://doi.org/10.1016/j.infbeh.2006.01.004.
R Core Team (2017). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/.
Rothbart, M. K. (1981). Measurement of temperament in infancy. *Child Development, 52*, 569–578. https://doi.org/10.2307/1129176.
Rowe, M. L. (2008). Child-directed speech: Relation to socioeconomic status, knowledge of child development and child vocabulary skill. *Journal of Child Language, 35*, 185–205. https://doi.org/10.1017/S0305000907008343.
Samuelson, L. K., & Horst, J. S. (2007). Dynamic noun generalization: Moment-to-moment interactions shape children's naming biases. *Infancy, 11*, 97–110. https://doi.org/10.1080/15250000709336872.
Slomkowski, C. L., Nelson, K., Dunn, J., & Plomin, R. (1992). Temperament and language: Relations from toddlerhood to middle childhood. *Developmental Psychology, 28*, 1090–1095. https://doi.org/10.1037/0012-1649.28.6.1090.
Smith Watts, A. K., Patel, D., Corley, R. P., Friedman, N. P., Hewitt, J. K., Robinson, J. L., & Rhee, S. H. (2014). Testing alternative hypotheses regarding the association between behavioral inhibition and language development in toddlerhood. *Child Development, 85*, 1569–1585. https://doi.org/10.1111/cdev.12219.
Spere, K. A., Schmidt, L. A., Theall-Honey, L. A., & Martin-Chang, S. (2004). Expressive and receptive language skills of temperamentally shy preschoolers. *Infant and Child Development, 13*, 123–133. https://doi.org/10.1002/icd.345.
Swingley, D. (2011). The looking-while-listening procedure. In E. Hoff (Ed.), *Research methods in child language: A practical guide* (pp. 29–43). Hoboken, NJ: Wiley-Blackwell.
Twomey, K. E., Ma, L., & Westermann, G. (2018). All the right noises: Background variability helps early word learning. *Cognitive Science, 42*, 413–438. https://doi.org/10.1075/is.17.1.05two.
Waxman, S. R., & Booth, A. E. (2001). Seeing pink elephants: Fourteen-month-olds' interpretation of novel nouns and adjectives. *Cognitive Psychology, 43*, 217–242. https://doi.org/10.1006/cogp.2001.0764.
Worobey, J., & Lewis, M. (1989). Individual differences in the reactivity of young infants. *Developmental Psychology, 25*, 663–667. https://doi.org/10.1037/0012-1649.25.4.663.
Yu, C., & Smith, L. B. (2011). What you learn is what you see: Using eye movements to study infant cross-situational word learning. *Developmental Science, 16*, 165–180.
Zosh, J. M., Brinster, M., & Halberda, J. (2013). Optimal contrast: Competition between two referents improves word learning. *Applied Developmental Science, 17*, 20–28. https://doi.org/10.1080/10888691.2013.748420.