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Is children's referential informativity associated with their visual or linguistic abilities?

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Abstract 4-year-old and 7-year-old children took part in a referential communication task. Their referring expressions were measured for informativity, and their eye movements were analysed to investigate whether fixations to a contrast object predict referential informativity. Performance on a battery of standardised tests was also measured. In line with previous work, we found a developmental trajectory towards greater informativity as children mature. The eye tracking data suggest that even though 4-year-olds engage in comparison activity to a similar extent as 7-year-olds and adults, their scanning behaviour is not linked to their ensuing referential informativity. Like adults, older children appear to make greater use of information gleaned from their visual scanning, supported by their more advanced linguistic skills. Results support a processing-based (cf. pragmatic-based) account of referential informativity.

Keywords: Reference, referential communication, informativity, language production, language acquisition, eye tracking.

1. Introduction

In learning to communicate effectively children must learn to refer to objects unambiguously by using at least minimally informative referring expressions (e.g., *the small apple* to refer to the smaller of a pair of apples). In doing so, they must consider the referential context, for example its visual, social, and functional aspects, such that their addressee can identify their intended referent. The ability to produce informative expressions develops throughout early childhood, with children first passing through a phase of habitual underinformativity in which they produce expressions such as *the apple* in a two-apple context, before they master the ability to produce felicitous referring expressions (hereafter REs) at around 7 years of age (Davies & Katsos, 2010; Matthews, Lieven & Tomasello, 2007; Sonnenschein, 1982).

The developmental trajectory of referential communication has been investigated by a substantial collection of studies (for reviews see Dickson, 1982; Graf & Davies, 2014). This body of work has put forward several explanations for early underinformativity, for example, difficulties in understanding that a RE must describe differences between target and distracter items (Whitehurst, 1976; Whitehurst & Sonnenschein, 1981); performance-related demands (Matthews et al., 2007); lack of perspective-taking (Nadig & Sedivy, 2002, i.a.), as linked to executive function skills (Nilsen & Graham, 2009).

The existing literature on the development of reference has focused on children's concurrent cognitive and linguistic capabilities but has not yet comprehensively addressed the question of how *visual scanning behaviour* might affect referential informativity (appealed for by Deutsch & Pechmann, 1982: 178; investigated in adults by Brown-Schmidt & Tanenhaus, 2006, and recently in 4-5 year-olds by Nilsson, Catto & Rabagliati, 2014). Pechmann (1989: 98) suggested that incomplete visual scanning may be a reason for failures in informativity, but did not provide developmental data to support this. The current study speaks to this gap by examining the relationship between children's eye movements and the form of their REs. It combines experimental methods from language production and those using eye movements as an index of cognitive processes, and reveals differences in the rate at which children between 4 and 7 years

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of age integrate information from the visual scene into their referential choices. In line with previous work, it also measures children's cognitive and linguistic profiles. We ask three main research questions:

1. What is the developmental trajectory in informativity when children refer to objects in simple and more complex visual scenes? *H1: 4-year-old children will largely be underinformative in this simple referential task, especially in complex displays, whereas 7-year-olds will provide more informative expressions, though not to the same extent as the adult comparison group.*

2. Do children who tend to provide underinformative referring expressions have a common linguistic / cognitive profile? *H2: Children who tend to provide underinformative referring expressions have a common linguistic / cognitive profile.*

3. *a)* What is the pattern of fixations before informative vs. underinformative referring expressions as a function of age? *b)* What is the pattern of fixations during informative vs. underinformative referring expressions as a function of age? *H3a. For all age groups, the contrast object will be fixated more frequently before informative referring expressions than before underinformative referring expressions. H3b. For all age groups, the contrast object will be fixated more frequently during informative referring expressions than during underinformative referring expressions.*

2. Method

Design. The experiment had a mixed design. For measuring the form of REs from participants' **production data** (Section 3.1), the experiment had a 2x2x2 design (age group x contrast x display complexity). Age group was between-participants (4-year-olds; 7-year-olds). Contrast (present or absent = two referents vs. one referent from the same noun category) and display complexity (four or eight objects) were within-participants. The dependent variable was utterance type: underinformative, informative, or overinformative[3]. For measuring the relationship between **eye movements and informativity** (Section 3.3), the contrast variable was dropped from the analysis, that is, only contrast-present items were included since this analysis focused on looks to the contrast object (which was of course absent in the contrast-absent condition). Utterance type was included as an independent variable. The dependent variable was the presence of fixations to the contrast object during two time windows (pre- and during-utterance).

Participants. Table 1 contains participant profile information. All were monolingual native speakers of British English. 24 adults were also recruited for a separate study with a similar methodology (see Davies & Kreysa, in prep.), and acted as the comparison group herein.

Materials and Procedure:

Referential communication task. The stimuli consisted of 44 displays of everyday objects, grouped into semantically related sets, e.g., animals, food, household objects, clothes. 16 displays were critical items, 24 were fillers and four formed the practice block. Of the critical items, half of the displays contained four objects and half contained eight objects, constituting simple and complex displays respectively (see Figure 1 for example displays). Half of the critical displays contained a no-contrast display with only one referent of each noun category (e.g., a ball, a doll, a teddy and a car) and half contained a contrast display featuring two referents of the same noun category (e.g., a large apple, a small apple, a sausage and a sandwich), one of which was the target thus requiring modification for disambiguation. Target objects differed from their contrast mates by size (large vs. small). These 16 critical items all appeared in four pseudorandomised lists, counterbalanced for target attribute and for block order, meaning that half the participants saw for example, the small apple as the target while the other half of the participants saw the large apple as the

[3] Because overinformativity was rare in the data (2% of all utterances by the younger children and 8% by the older children), statistical comparisons are restricted to rates of optimal informativity vs. underinformativity.

target. No target object appeared more than once throughout the experiment, and the position of the target and the contrast object was rotated around each slot within the four- and eight-object displays. Stimuli were presented and eye movements were recorded using Tobii Studio software. The sequencing of each trial was as follows: a fixation cross was displayed for one second, a preview of the displays (target not highlighted) was displayed for three seconds for four-object displays and for four seconds for eight-object displays. A fixation cross in the form of a red star then appeared on screen within the preview for one second, then the fixation star disappeared and the target was highlighted with a red frame around the object for five seconds, during which time the participant produced their utterance of the form ‘click on the X’.

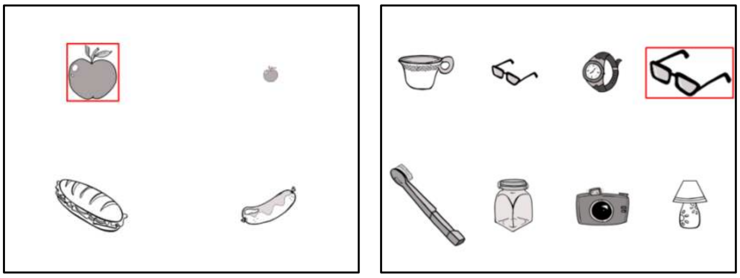

Figure 1. Visual stimuli. Left hand panel shows a four-object item; right hand panel shows an eight-object item. Both panels are two-referent displays, target highlighted.

Participants were seated in front of a Tobii X120 remote desk-mounted eye tracker and monitor, with the experimenter seated at a laptop nearby. The two monitors were not mutually visible. A five-point calibration was performed, then participants were instructed as follows: *We’re going to play a game. Your job is to help me find some pictures. You'll see some pictures on the screen. I can see them too, but they’re not in the same place on my screen. Look at the pictures on your screen. A red box will appear around one of them for you. You should tell me to click on that picture, like "click on the number 7". You'll also see a red star - you should always try to look at the red star when it appears. We’ll practice a few times first and then we'll play the game.* We emphasised that their role was to tell the experimenter to click on the highlighted item. During the experiment, the experimenter clicked a mouse to signal that they had found the referent roughly one second after the offset of the participant’s utterance, regardless of the form of RE used. No other feedback was given.

Standardised tests. Three tests of linguistic and cognitive abilities were administered to correlate participants’ profiles with their informativity in the referential communication task. As an index of receptive language ability, the British Picture Vocabulary Scale (BPVS-III) was used, normed for 3 – 16 year-olds (Dunn, Styles & Sewell, 2009). For visual search efficiency, the Bug Search task from the WPPSI-IV battery was used (Wechsler, 2013). This is a processing speed subtest for ages 4;0 – 7;7 and measures participants’ perceptual speed, short-term visual memory, cognitive flexibility, visual discrimination, and concentration whilst they match images within a field of five to a reference image. As a measure of perspective-taking ability within a discourse context, the Short Narrative subtest from the DELV-ST (Diagnostic Evaluation of Language Variation), recommended for use with 4 – 9 year-olds (Seymour, 2003). The whole testing session lasted approximately 30 minutes.

3. Results

3.1 Referential communication task: Production data

In an analysis of all production data (contrast and no contrast conditions; four and eight object displays), 4-year-olds were numerically equivocal in the informativity of their REs (42% underinformative and 52%

informative) whereas 7-year-olds were more optimal in their referential choices (23% underinformative and 68% informative).

For the contrast items only, across the two levels of display complexity, 4-year-olds were largely underinformative in their referential choices (83% underinformative and 12% informative) whereas 7-year-olds were more equivocal (46% underinformative and 53% informative). Adults were largely informative at a mean rate of 79% (see Figure 2). A mixed ANOVA found a main effect of age on informativity: 4yo mean = 12% (SE = 5), 7yo mean = 53% (SE = 6), $F(1, 44) = 24.22$, $p < .001$, $\eta^2 p = .36$. There was a main effect of display complexity: four-object mean = 43% (SE = 5), eight-object mean = 21% (SE = 4), $F(1, 44) = 42.24$, $p < .001$, $\eta^2 p = .49$. There was also a significant interaction between age and complexity in that increased complexity compromised informativity for the 7-year-olds to a greater extent than the 4-year-olds, $F(1, 44) = 18.12$, $p < .001$, $\eta^2 p = .29$. This is likely driven by floor effects in the younger group. Within-group pairwise comparisons were performed using Wilcoxon signed-rank tests with a Bonferroni correction applied, resulting in a significance level set at $p < 0.025$. For the 4-year-olds, mean rates of informativity in the four-object condition (15%, SD = 29) were significantly higher than in the eight-object condition (8%, SD = 24), $Z = -2.33$, $p = .020$, $r = -.45$). For the 7-year-olds, mean rates of informativity in the four-object condition (71%, SD = 38) were similarly significantly higher than in the eight-object condition (35%, SD = 30), $Z = -3.34$, $p = .001$, $r = -.77$). Within-complexity pairwise comparisons were performed using Mann Whitney tests with the same correction applied. For the four-object displays, mean rates of informativity by the 4-year-olds (16%, SD = 29) was significantly lower than by the 7-year-olds (71%, SD = 38), $U = 78.0$, $z = -4.26$, $p < .001$. For the eight-object displays, mean rates of informativity by the 4-year-olds (8%, SD = 24) was significantly lower than by the 7-year-olds (36%, SD = 30), $U = 97.5$, $z = -4.01$, $p < .001$.

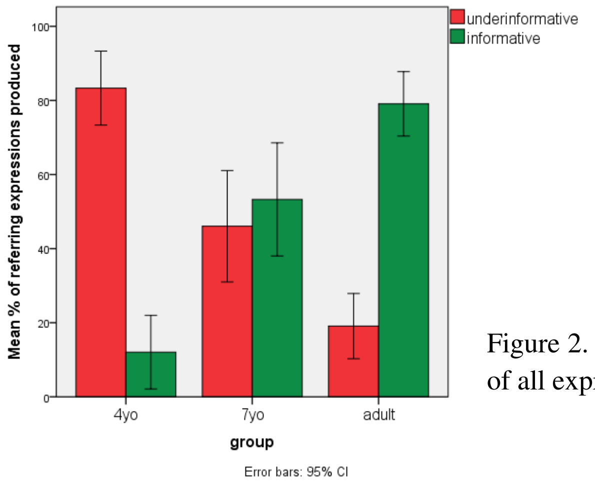

Figure 2. Mean rates of informativity of REs as a percentage of all expressions produced; contrast condition only.

As predicted by our first hypothesis, the younger children were largely underinformative when referring to objects for their addressee, whereas their older counterparts were less so, though not as informative as the adult comparisons. Both child groups produced more underinformative expressions when displays were complex (as did the adults), though this effect was more pronounced in the 7-year-olds.

3.2 Correlational analyses with standardised tests

A Pearson correlation coefficient was computed to assess the relationship between informativity of REs and performance on the standardised tests (see Table 1 for scores). Amongst the 7-year-olds, rates of underinformativity (contrast condition only) were negatively correlated with performance on receptive vocabulary test ($r = -.41$, $p = .08$), but not on visual search or perspective-taking measures. Among the 4-year-olds and the adult comparison group, there were no significant correlations between informativity and any of the standardised measures (all $ps > .1$; all $rs < .3$), though this may have been driven by floor and ceiling effects. These results partially support our second hypothesis that children who tend to provide underinformative referring expressions have a common linguistic / cognitive profile, in that they tentatively indicate that language ability may underpin informative referring as children mature.

	4 yos (n=27; 13 males)	**7 yos (n=19; 8 males)**	**adults (n=24; 4 males)**
age (y;m)	4;7 (0;5)	7;9 (0;6)	19 (1;5)
range	4;0 - 5;6	6;9 - 8;6	18 - 23
BPVS (raw)	74.1 (11)	110 (15.5)	161.3 (4.1)
range	54 - 99	84 - 140	151 - 167
BPVS (standardised)	109.3 (6.9)	103.1 (13.1)	111.4 (7.4)
range	91 - 124	81 - 126	96 - 124
DELV narrative	3.5 (1.6)	5.8 (1.3)	5.8 (1.2)
range	1 - 7	2 - 7	0 - 7
WPPSI-IV Bug Search (raw)	21.9 (8.7)	42.4 (8.3)	-
range	6 - 42	29 - 60	-

Table 1. Scores on background measures: mean (sd).

3.3 Eye movement data

Only the contrast condition was analysed in this section since the dependent variable is the number of fixations to the contrast object, which is absent in the no-contrast condition. Due to overall sampling validities of <40%, seven participants were excluded from the eye tracking analysis (three from the 7-year-old group). This left the remaining younger sample at n=23, mean age 4;8 years (SD 0;5), range 4;0 – 5;4, 12 males. The remaining older sample was n=16, mean age 7;10 (SD 0;7), range 6;9 – 8;6, 6 males. Separate analyses were run for the pre-utterance and the utterance time windows.

3.3.1 Contrast fixations during the pre-utterance time window

To investigate the relationship between speaker informativity and whether the contrast object had been fixated, we looked at the proportion of trials in which speakers did or did not fixate the contrast object before producing the two major utterances types (informative and underinformative). Trials were divided into those involving at least .3 of a fixation to the contrast object in the pre-utterance time window (individual fixations which spanned all three time windows were divided by 3) and those involving no fixations to the contrast in the same time window.

4-year-olds were overall more likely not to fixate (74%) than to fixate (26%) the contrast object in the pre-utterance time window, and they were much more likely (85%) to produce an underinformative than an informative utterance (15%)[4]. Importantly, the likelihood of producing an underinformative utterance after looking at the contrast object (32/42=76%) was comparable to the likelihood of producing an underinformative utterance without having looked at the contrast object (106/120=88%). Put another way, the likelihood of producing an informative utterance after looking at the contrast object (10/42=24%) was comparable to the likelihood of producing an informative utterance without having looked at the contrast object (14/120=12%). A chi-square analysis of the likelihood of producing informative and underinformative utterances missed significance ($\chi^2(1) = 3.64$, $p = .08$). This was the case for the four-object and eight-object items combined as well as when the two levels of display complexity were analysed

[4] These percentages vary slightly from those reported in the production results due to the exclusion of four participants from the eye tracking analysis.

separately (four-objects: $\chi^2(1)$ =.22, *ns*; eight-objects: $\chi^2(1) = 5.17$, $p = .06$) indicating that fixating the contrast object plays only a minor role for informativity in this age group. Thus, 4-year-olds are overwhelmingly underinformative regardless of fixation to the contrast.

7-year-olds were also more likely not to fixate (64%) than to fixate (36%) the contrast object in the pre-utterance time window, and they equally likely (52%) to produce an informative as an underinformative utterance (48%). Like adults, they were more likely to produce an underinformative utterance without having looked at the contrast object (49/78=63%) than to produce an underinformative utterance after looking at the contrast object (10/44=23%). Put another way, the likelihood of producing an informative utterance after looking at the contrast object (34/44=77%) was almost double the likelihood of producing an informative utterance without having looked at the contrast object (29/78=37%). A chi-square analysis revealed a significant association between informativity and contrast fixation, ($\chi^2(1) = 18.11$, $p < .001$), which also held when the two levels of display complexity were analysed separately (four-objects: $\chi^2(1) = 5.62$, $p < .05$; eight-objects: $\chi^2(1) = 10.77$, $p < .005$). This pattern of results suggests that contrast fixations lead 7-year-olds to produce informative REs.

The pattern shown by the older child sample was mirrored in the adults' data, who were more likely not to fixate (61%) than to fixate (39%) the contrast object in the pre-utterance time window, and who were more likely to produce an informative (79%) than an underinformative utterance (20%). Crucially, they were more likely to produce an underinformative utterance without having looked at the contrast object (52/187=28%) than to produce an underinformative utterance after looking at the contrast object (11/121=9%). In other words, they were more likely to produce an informative utterance after looking at the contrast object (110/121=91%) than to produce an informative utterance without having looked at the contrast object (7135/187=2%), $\chi^2(1) = 15.82$, $p < .001$. The same boosting effect of contrast fixation was found at both levels of complexity, that is in four-object displays ($\chi^2(1) = 5.83$, $p < .05$) and in the eight-object displays ($\chi^2(1) = 11.09$, $p < .005$).

The results from the 7-year-olds support hypothesis 3a in that the contrast object was fixated more frequently before informative REs than before underinformative REs, across both types of display complexity (as was also the case for the adult group). In contrast, the results from the 4-year-olds did not support our hypothesis. Instead, the younger children's looking behaviour in the pre-utterance region was independent of later informativity.

3.3.2 Contrast fixations during the utterance time window

We ascertained in Section 3.3.1 that younger children are no more likely to be informative whether or not they fixate the contrast before starting to speak, and conversely, that older children's informativity is boosted by fixating the contrast pre-utterance, like adults. In this section, we investigate whether later contrast fixations are linked to children's choice of RE. In line with the analysis of contrast fixations during the pre-utterance region, we looked at the proportion of trials in which speakers did or did not fixate the contrast object while producing the two main utterances types.

4-year-olds were overall more likely not to fixate (62%) than to fixate (38%) the contrast object in the utterance time window. Importantly, they were more likely to produce an underinformative utterance whilst not looking at the contrast object (92/101=91%) than whilst looking at it 46/61=76%). Put another way, looking at the contrast object raised the likelihood of 4-year-olds producing an informative RE (15/61=25%) relative to them not looking at it (9/101=9%), $\chi^2(1) = 7.41$, $p < .05$. This pattern is driven by the significant relationship between contrast fixations and informativity for the eight-object displays ($\chi^2(1) = 21.9$, $p < .001$) rather than the more simple four-object displays ($\chi^2(1) = .06$, ns). Thus, despite pre-utterance contrast fixations not playing a significant role in informativity for 4-year-olds, they do provide a boost to informativity once a young child has started to produce their RE in complex displays.

7-year-olds were slightly more likely not to fixate (56%) than to fixate (44%) the contrast object in the utterance time window. Like adults, they were equally likely to produce an underinformative utterance whilst not looking at the contrast object (35/68=51%) as they were to produce an underinformative utterance whilst looking at the contrast object (24/54=44%). In other words, they were equally likely to produce an informative utterance whilst looking at the contrast object (30/54=56%) as they were to produce an informative utterance whilst not looking at the contrast object (33/68=49%), $\chi^2(1) = 0.60$, ns. The same pattern of results was found in the analysis split by display complexity, that is, 7-year-olds were equally as likely to be informative regardless of whether or not they were fixating the contrast object in both four-object displays ($\chi^2(1) = 0.48$, ns) and in eight-object displays ($\chi^2(1) = .32$, ns).

The pattern shown by the older child sample was mirrored in the adults' data, who were equally likely not to fixate (58%) as to fixate (42%) the contrast object in the utterance time window. Adults were equally likely to produce an underinformative utterance whilst not looking at the contrast object (35/179=20%) as they were to produce an underinformative utterance whilst looking at the contrast object (28/129=22%). In other words, they were equally likely to produce an informative utterance whilst looking at the contrast object (101/129=78%) as they were to produce an informative utterance whilst not looking at the contrast object (144/179=80%), $\chi^2(1) = 0.21$, ns. The same pattern of results was found in the analysis split by display complexity, that is, adult speakers were equally as likely to be informative regardless of whether or not they were fixating the contrast object in both four-object displays ($\chi^2(1) = 0.37$, ns) and in eight-object displays ($\chi^2(1) = 1.57$, ns).

As in the pre-utterance contrast fixation analysis in Section 3.3.1, older children and adults pattern similarly whilst younger children show a different relationship between contrast fixations and informativity. In the utterance time window, younger children's informativity benefits from fixations to the contrast object, whereas fixating (or not fixating) the contrast object whilst speaking did not influence older children's and adults' concurrent tendency to produce informative expressions, with no effect of display complexity.

Thus hypothesis 3b (that the contrast object will be fixated more frequently during informative REs than during underinformative REs) is supported for the younger children but not for the older children and adults. This suggests that late looking can boost informativity in younger children in the same way that pre-utterance contrast fixations do for their older counterparts. In contrast, 7-year-olds' and adults' informativity does not benefit from these later contrast fixations.

4. Discussion and conclusions

We have replicated previous studies which found a developmental shift from underinformativity to full informativity as children mature from 4 to 7 years of age (Davies & Katsos, 2010; Matthews et al., 2007; Whitehurst & Sonnenschein, 1981, i.a.). Our correlational analyses using a range of linguistic and cognitive tests revealed a link between informativity and language ability (as indexed by a receptive vocabulary test) in the older children, suggesting that it is the modified noun structure which may be the most challenging aspect of this task for the younger children.

One area of ability which we did not measure and which may yield significant effects is executive functioning; a set of skills which has recently been found to boost children's perspective taking and associated referential informativity (Nilsen & Graham, 2009; Nilsen, Varghese, Xu & Fecica, 2015). These studies suggest that greater inhibitory control and working memory skills enable children to use their communicative partner's perspective. In future work we would like to investigate whether such skills can also boost more comprehensive visual scanning and/or the integration of information from contrast objects with referential choice. The 4-year-olds in our study only fixated the contrast object before speaking on 26% of trials, which indicates a somewhat automatic 'see-the-target, say-the-target' strategy. This lack of attention on non-target items may be related to inhibitory control. However, the 7-year-olds and adults only fixated the contrast on 36% and 39% of trials respectively, yet produced higher frequencies of informative REs than their younger counterparts, suggesting that the incidence of pre-utterance contrast fixations (with or without more sophisticated executive skills) are not the whole story with regard to informativity. Further research is needed to investigate the relative influence of i) contrast fixations and ii) the integration of contrast information (in addition to language ability) on informativity across development.

Our eye tracking results show that the younger children's pre-utterance contrast fixations do not strongly influence their informativity unlike their older counterparts (cf. Nilsson et al. 2014), allowing us to rule out incomplete visual scanning as a reason for early underinformativity (cf. Deutsch & Pechmann, 1982; Pechmann, 1989). Language ability emerges as a stronger constraint on informativity: children must be in a state of linguistic readiness in order to produce fully informative referring expressions, though this is likely to be boosted by their visual scanning behaviour.

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