

## Number attraction effects in production: Errors and speech rate profiles narrow a production-comprehension contrast

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Systematic errors, such as number attraction errors, provide a window into the incremental process of language production. In number attraction, nearby or intervening material interferes with normal agreement processes, as in (1). Previous studies show that subject-verb (S-V) number agreement errors are elicited in the same environments where listeners are susceptible to agreement grammaticality illusions in comprehension [1,2,3,4]. Interestingly, although reflexive-antecedent (R-A) agreement attraction effects are weak or non-existent in comprehension [5,6,7,8], R-A agreement demonstrates attraction susceptibility in the standard laboratory error elicitation paradigm [9,10]. In this paradigm, participants hear a preamble and are instructed to repeat and complete it as a full sentence. This paradigm involves both comprehension and production as well as a memory task, which could result in sentence completion strategies that differ from naturalistic production. We introduced a novel paradigm (cf. [11]) to investigate whether previously-observed S-V and R-A agreement error patterns hold in a more natural task. In a series of four experiments, we compared attraction susceptibility of the two dependency types in both paradigms, measuring error rates and using a forced-aligner [12] to look for attraction effects in timing even in trials with no errors. We found that while error patterns and time-course in attraction environments are similar for S-V agreement in both paradigms, there is a distinct contrast for R-A agreement in the two paradigms.

**Exp1:** Participants were introduced to three types of alien and the nonce action *mimming*; when an alien mims, its antenna lights up. In the task, participants watched and described scenes of mimming (Fig1), using spatial prepositions to disambiguate which alien(s) performed the action. We manipulated the number of the aliens in the scenes so that the NPs in the SubjP either matched or mismatched in number (Table1). We found standard agreement attraction effects, reflected in higher error rates and probabilities in mismatch conditions (Fig3a). Even in correct trials, attraction effects could be seen in slowdowns localized immediately prior to verb onset.

**Exp2:** In the second experiment, mimming was introduced as a transitive action; aliens could either mim themselves (causing their own antennae to light up) or mim others (causing the other aliens' antennae to light up) (Table1; Fig2). Agreement errors on reflexive pronouns were infrequent, with no significant mismatch effect (Fig3b). Speech rate analysis of correct trials found no evidence of increased slowdowns prior to reflexive onset in mismatch environments.

**Exp3:** The SubjPs of the target sentences from Exp1 were used to create preambles for a preamble elicitation paradigm (Table2). Both the error patterns (Fig3c) and speech rate analysis of correct sentences paralleled the findings of Exp1.

**Exp4:** The reflexive sentences from Exp2 were used to create stimuli for a preamble paradigm (Table2). Participants produced more agreement errors than in Exp2 (though the rate was lower than in [9,10]), with errors significantly more likely in the mismatch conditions (Fig3d). Speech rate analysis revealed slowdowns localized prior to reflexive onset in the mismatch conditions.

**Conclusion:** Drawing on both error rates and timing effects, we show that elicitation paradigm changes attraction susceptibility for R-A but not S-V agreement. Verb errors in our paradigm align with previous results (more errors in mismatch conditions, with evidence of markedness effect), and timing analysis reveals attraction effects even when no error is present, supporting the verb response time effects in [13] with a more natural paradigm. Our data suggest minimal R-A attraction susceptibility in production, parallel to comprehension findings. The contrast in attraction susceptibility of the two dependencies in our paradigm suggests that they are computed differently or at different points in the production process; for instance, the reflexive form may be driven directly by the message or lemma level, whereas verb forms are computed through an inflection process referencing the SubjP, or the reflexive may be selected before the constituent structure has been built that makes the local NP available as an attractor. Reflexive errors may be more common in the preamble paradigm if speakers plan the reflexive only after repeating the preamble, requiring them to reference the SubjP when the local NP is available in the constituent structure; pre-reflexive gaps across conditions were significantly longer in Exp4 than Exp2, supporting the hypothesis that the natural agreement process is disrupted.

(1) \*The key to the cabinets are on the table.

**Table 1: Exp1 & Exp2 Sample Sentences**

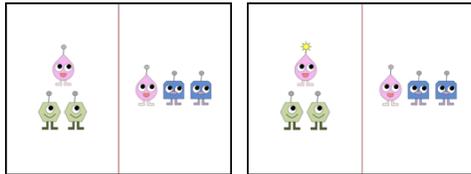
Condition	Sub-Condition	Exp1 Sample Sentence	Exp2 Reflexive Sample Sentence	Exp2 Transitive Sample Sentence
Match	SS	The bluey above the greeny is mimming	The bluey above the greeny mimmed itself	The bluey above the greeny mimmed it
Match	PP	The pinkies below the greenies are mimming	The pinkies below the greenies mimmed themselves	The pinkies below the greenies mimmed them
Mismatch	SP	The greeny to the left of the blueys is mimming	The greeny to the left of the blueys mimmed itself	The greeny to the left of the blueys mimmed them
Mismatch	PS	The blueys to the right of the pinky are mimming	The blueys to the right of the pinky mimmed themselves	The blueys to the right of the pinky mimmed it

SS = singular head NP, singular local NP; PP = plural head NP, plural local NP  
 SP = singular head NP, plural local NP; PS = plural head NP, singular local NP

**Table 2: Exp3 & Exp4 Sample Sentences**

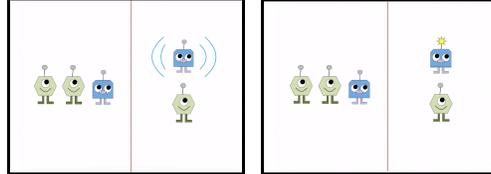
Condition	Sub-Condition	Exp3 Sample Preamble (completed with <i>is/are mimming</i> )	Exp4 Sample Preamble (completed with <i>itself/themselves</i> )
Match	SS	The bluey above the greeny...	The bluey above the greeny mimmed...
Match	PP	The pinkies below the greenies...	The pinkies below the greenies mimmed...
Mismatch	SP	The greeny to the left of the blueys...	The greeny to the left of the blueys mimmed...
Mismatch	PS	The blueys to the right of the pinky...	The blueys to the right of the pinky mimmed...

**Fig1: Exp1 trial scene**



Each scene contained two groups of aliens. Participants were given 1s of preview (left) before the action occurred in one of the two groups (right); after the action, the scene remained on screen for 3s. Participants were encouraged to finish speaking before the trial ended.

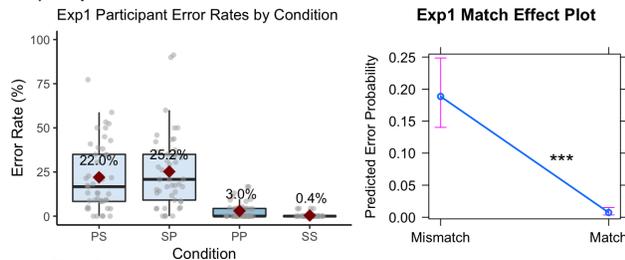
**Fig2: Exp2 trial scene**



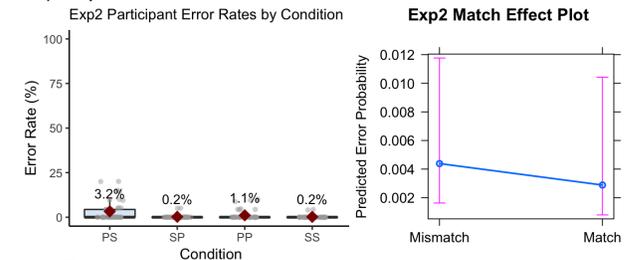
After 1s of preview, the alien(s) performing the mimming pulsed for 1s (left; pulsing represented with the blue lines), after which the same alien(s)' antenna(e) lit up (reflexive condition, pictured above; right) or a different alien(s)' antenna(e) lit up (transitive condition). After the antenna(e) lit, the scene remained on screen for 3s. Participants were encouraged to finish speaking before the scene disappeared.

**Fig 3: Error Rates & Probabilities**

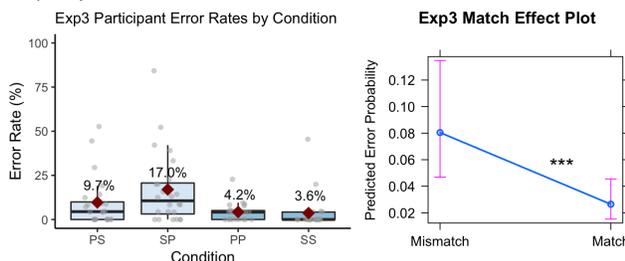
a) Exp1



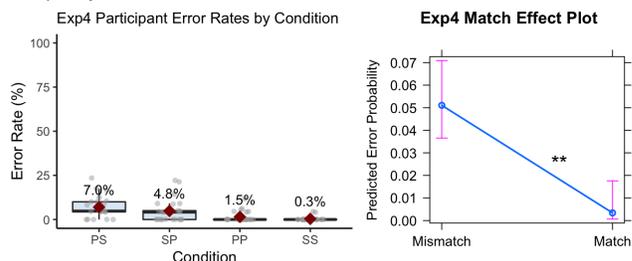
b) Exp2



c) Exp3



d) Exp4



**References:** [1] Bock, JK & Miller, CA. (1991). *Cog Psych*, 23, 45-93. [2] Bock, JK & Cutting, JC. (1992). *JML*, 31, 99-127. [3] Nicol, JL, Forster, KI, & Veres, C. (1997). *Psych Review*, 104, 266-300. [4] Pearlmutter, NJ, Garnsey, SM, & Bock, JK. (1999). *JML*, 11, 427-456. [5] Xiang, M, Dillon, B, & Phillips C. (2009) *Brain & Lang*, 108, 40-55. [6] Dillon, B, Mishler, A, Sloggett, S, & Phillips, C. (2013). *JML*, 69, 85-103. [7] Cunnings, I & Sturt, P. (2014). *JML*, 75, 117-139. [8] Parker, D & Phillips, C. (2017), *JML*, 94, 272-290. [9] Bock, JK, Nicol, J, & Cutting, JC. (1999). *JML*, 40, 330-346. [10] Bock, JK, Eberhard, KM, & Cutting, JC. (2004). *JML*, 51, 251-278. [11] Nozari, N & Omaki, A. (2018). *Annual Conference of the CogSci Society*, 40, 824-829. [12] McAuliffe, M, Socolof, M, Mihuc, S, Wagner, M, & Sonderegger, M. (2017). *Montreal Forced Aligner v1.0.0*. [13] Staub, A. (2009). *JML*, 60, 308-327.