Pronominal binding in weak crossover: An eye-tracking study

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[**Introduction**] Crossover effect arises when a (*wh*-)operator moves across a co-indexed pronoun. In this study, we focus on weak crossover (WCO) where the pronoun incurs no further violation of Binding Principle C (in contrast to strong crossover). In the literature, WCO violates a slew of syntactic constraints, most notably the Bijection Principle (Koopman & Sportiche, 1982). Despite numerous endeavors to explain WCO (e.g., Ruys, 2000; Shan & Barker, 2006; Safir, 1996, 2015), an empirical study using self-paced reading suggests that binding between a linearly earlier *wh*-operator and the pronoun is indeed attempted (Kush et al., 2017), which calls for a unified explanation. In this study, we used eye-tracking technique to explore the time course of pronominal binding in WCO. To foreshadow our conclusion, we found that pronominal binding in WCO occurred only in the later stage, but not in the early stage, in contrast with pronominal binding in complement clauses. This divergent processing pattern suggests that the syntactic constraint behind WCO guides binding and that cue-based retrieval only occurs during the later stage.

[**Methodology**] Two experiments are reported below, an offline grammaticality judgement (GJ) pre-test and an eye-tracking experiment. In the GJ test (1-7 Likert scale), *Clause Structure* (complement/WCO) and *Match Type* (gender match/mismatch) were manipulated. In the eye-tracking experiment, to control for the potential confounding (structural and lexical) effect on pronoun parsing, the factor *DP type* (pronoun/proper name) was included, resulting in a 2x2x2 factorial design. See (1a-h) for a target example. For the GJ test, 24 sets of target stimuli were distributed into 4 counterbalanced lists alongside 24 fillers; for eye-tracking, 48 sets of target stimuli plus 48 fillers were created. For tracking measures, *first fixation duration*, *first pass duration*, *regression path duration*, and *total reading time* measures were analyzed. Twenty-five and 21 English native speakers participated in these two studies, respectively. For numeric data (GJ rating scores, sentence RTs, eye-tracking measures), we fitted mixed-effect linear models; for categorical data (comprehension question accuracy), a mixed-effect logit model was fitted.

[**Results**] As shown in Table 1, the GJ results suggest that gender mismatch induced a penalty only in complement clauses but not in WCO structures, as indicated by the significant interaction of *Clause Structure* and *Gender Match* (β=0.98, SE=0.17, t=5.86, p<.001). For sentence RTs, the linear model showed a significant interaction of *Match Type* and *DP Type* (β=904.8, SE=402.6, t=2.248, p<.01). This suggests that the mismatch effect elicited longer RTs in the pronoun than in the proper name conditions, across both complement clauses and WCO structures. Furthermore, gender mismatch disrupted the reading process more often in the complement/pronoun condition, leading to significantly lower accuracy (67.48% vs. 84.31%). As for the eye-tracking measures, we report reading times of the pronoun first, then the spill-over NP region. On the target pronoun region, a significant interaction of *Match Type* and *DP Type* was found (β=48.08, SE=19.87, t=2.42, p<.05) for the *first fixation duration*, meaning the mismatch effect was different between (target) pronoun and proper name (control) conditions. Importantly, a significant three-way interaction was also found (β=-60.96, SE=28.12, t=-2.17, p<.05) for the same measure. Further pair-wise comparisons suggest that the mismatch penalty effect was significant in complement clauses but not in WCO structures and that the effect only existed for the pronoun conditions. No significant results were found for the *first pass duration* and the *regression path duration*, although, numerically, mismatched pronouns also elicited longer fixations in complement clauses during the *first pass* reading (303ms vs. 261ms). Finally, for the *total reading time*, a marginally significant interaction of *Match Type* and *DP Type* was found (β=66.23, SE=43.5, t=1.72, p<.1), suggesting that gender mismatch caused longer processing of pronouns regardless of the sentence structure.

As for the spill-over NP region, there was only a marginally significant *Match Type* and *DP Type* interaction (β=74.96, SE=48.68, t=1.74, p<.1) for the *total reading time*, driven by the gender mismatch effect in the complement/pronoun condition (528ms vs. 447ms).

[**Discussion**] The present study joins few other empirical works in investigating the online processing of pronominal binding in WCO (Kush et al., 2017 in English; Felser & Drummer, 2017 in German). The study has three major implications. *First*, evidence is provided that retrieval of pronouns for binding is subject to syntactic constraints in a very rapid fashion (either c-command constraint which enforces binding in complement clauses or bijection constraint which prohibits binding in WCO) and thus suggests that syntactic constraint is a stronger cue than gender congruency (Cunnings & Sturt, 2018). Previous pronominal binding in English WCO were found possibly because self-paced reading only reflects the later stage of processing (Sturt, 2003). *Second*, even though syntax has primacy during the early time window, cue-based retrieval mechanism (e.g. Bedecker & Straub; McElree et al., 2003; Lewis et al., 2006) still influences pronominal binding later. *Third*, if the delayed pronominal binding is due to non-syntax-related factors, the current results might pose a challenge to Falco (2007, 2009) who gave a *syntactic* treatment (under Relativized Minimality) to the specificity effect (i.e. improvement of ungrammaticality with D-linked *wh*-operators) in WCO.

Example stimuli (GJ test only has the first four conditions)

(1) a. Isabelle was wondering which man admitted that *his* manager had just found a solution. (Comp, match, *pronoun*)
b. Isabelle was wondering which woman admitted that *his* manager had just found a solution. (Comp, mismatch, *pronoun*)
c. Isabelle was wondering which man it seemed that *his* manager had just persuaded to quit. (WCO, match, *pronoun*)
d. Isabelle was wondering which woman it seemed that *his* manager had just persuaded to quit. (WCO, mismatch, *pronoun*)
e. Isabelle was wondering which man admitted that Fred's manager had just found a solution. (Comp, match, name)
f. Isabelle was wondering which woman admitted that Fred's manager had just found a solution. (Comp, mismatch, name)
g. Isabelle was wondering which man it seemed that Fred's manager had just persuaded to quit. (WCO, match, name)
h. Isabelle was wondering which woman it seemed that Fred's manager had just persuaded to quit. (WCO, mismatch, name)

Table 1. Descriptive statistics for eye-tracking measures.

Target pronoun region							*RTs and accuracy*	
			First fixation	First pass	Regression path	Total reading	*Sentence RT*	*Judgement*
Name	Complement	Match	160	336	912	426	6553	81.85%
		Mismatch	150	329	1024	424	6421	83.38%
	Weak crossover	Match	138	320	830	396	6011	84.25%
		Mismatch	140	309	951	379	6014	82.66%
Pronoun	Complement	Match	120	261	801	356	6065	84.31%
		Mismatch	**156**	*303*	956	**424**	**6841**	**67.48%**
	Weak crossover	Match	147	311	860	367	6452	74.67%
		Mismatch	136	286	815	**404**	**6779**	82.79%
Spill-over region							*Offline GJ test*	
			First fixation	First pass	Regression path	Total reading	Mean score	
Name	Complement	Match	156	349	1081	482	-	
		Mismatch	147	327	1111	462	-	
	Weak crossover	Match	159	349	1119	467	-	
		Mismatch	140	325	924	451	-	
Pronoun	Complement	Match	148	340	1031	447	5.29	
		Mismatch	148	338	952	**528**	**4.34**	
	Weak crossover	Match	152	331	915	475	3.97	
		Mismatch	145	321	963	479	4.00	