What memory retrieval tells us about intervention effects

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The proposal, in a nutshell. Intervention effects in Object-headed Relative Clauses of the kind discussed in Friedmann et al. (2009) can be rephrased within a top-down, left-right grammatical model (Chesi 2012, 2014) which implements non-local (filler-gap, filler-first, Fodor 1978) dependencies by means of a (last-in-first-out) memory buffer regulated by a cue-based retrieval mechanism (McElree et al. 2004, Van Dyke et al. 2006).

Background. It has been experimentally tested that both in understanding and in producing Subject vs. Object RCs, adults and children show an asymmetric performance, with Subject RCs (S-RCs), (1a), generally easier to process than Object RCs (O-RCs) (1b) (Kung & Just 1991: self-paced reading; Warner & Marastos 1978: probe-task; Just et al. 1996: brain activity, a.o.; see Arosio et al. 2011, Contemori & Belletti 2013 for a review):

(1) a. The banker [that _ praised the barber] climbed the mountain (Gordon et al. 2001)
b. The banker [that the barber praised _] climbed the mountain

Critical data. O-RC difficulty can be mitigated by varying the type of RC subject:

(1) b'. The banker that *Ben* *praised* _ climbed the mountain (Gordon et al. 2001)
b''. The banker that *you* *praised* _ climbed the mountain

Self-paced reading experiments show that the critical verb region ("praised") is read faster when a pronoun (*P*) is processed in the RC subject position, (1b''), slower when it is a proper name (*N*), (1b'), and even slower when it is a definite description (*D*), (1b). All the possible combinations of *D/N/P* in head and RC subject position have been tested by Warren & Gibson (2005), with the following results:[1]

condition	*D-D*	*D-N*	*D-P*	*N-D*	*N-N*	*N-P*	*P-D*	*P-N*	*P-P*
r.t.(SE) ms	365(19)	319(12)	306(14)	348(18)	347(21)	291(14)	348(18)	311(15)	291(13)

Table 1. reading time (r.t.) and Standard Errors (SE) at verb segment (RC_head-RC_subject).

Memory-load accounts (Gibson 1998, Warren & Gibson, 2002, 2005 a.o.) explain (part of) these contrasts by postulating an "integration cost" (Gibson 1998) associated to new discourse referents: since pronouns do not introduce new discourse referents and names are referentially lighter than full *D*s (Warren & Gibson 2005), memory-load accounts predict faster reading time at the RC verb when the subject is a pronoun and slightly longer reading time when it is a proper name. However, this account incorrectly predicts faster reading time for the *N-N* condition ('it was Patricia who Dan *avoided* at the party') than for the *D-D* condition ("it was the lawyer who the businessman *avoided* at the party), but no significant difference emerges.

Intervention-based account. The intervention-based accounts (Gordon et al. 2001, Friedmann et al. 2009, Belletti & Rizzi 2013 a.o.) explain the symmetry in the *D-D* and *N-N* matching conditions in terms of featural similarity. Friedmann et al. (2009) assume that whenever movement-related features are shared between a filler, *X*, (e.g. the RC head) and a structural intervener, *Z*, (e.g. the RC subject), the relation between *X* and its gap, *Y*, gets disrupted in a way that is proportional to the kind (and number) of features involved. Assuming that the 'lexical restriction' (Friedmann et al. 2009:72) is expressed by distinct features in definite descriptions, *proper names* and *pronoun* (*N* for common nouns, *Nprop* for proper names, and null *N* for pronouns), the intervention-based accounts predict that the matching conditions, *D-D* and *N-N*, are comparable, and the *P-P* condition is easier, since *N* is null. Notice, however, that the crucial assumption that only features triggering movement cause intervention (Friedmann et al. 2009:83) forces the lexical restriction, that is internal to the DP, to have a fundamental role in movement and this might be incompatible with standard bottom-up, feature-

[1] Sample item: 'it was D/N/P who D/N/P *avoided* at the party'; where, D = 'the lawyer'/'the businessman'; N = 'Patricia'/'Dan'; P = 'you'/'we'); reading times are provided by Warren p.c. (cf. Warren & Gibson 2005:360).

driven movement (but see Belletti & Rizzi 2013 for a relevant proposal compatible with the bottom-up perspective). Moreover, other asymmetries remain unexplained, e.g. the *D-P* vs. *P-D* condition.

Intervention-based account in memory retrieval terms. These problems dissolve if we adopt a top-down, left-right derivational view of movement (Chesi 2012, 2014) that is directly relevant also in processing, since it can precisely predict delays in self-paced reading depending on what happens and when. That is, in a (top-down, left-right) raising derivation of an O-RC, the RC head must be first merged in CP, then, its argumental features are stored in a memory buffer, waiting to be later re-merged in a properly selected position (i.e. the RC lexical verb). In the meanwhile, the RC subject is processed and is stored in memory, as well, waiting to be re-merged in an appropriate lexically selected position. Only when the RC verbal head is processed, its selectional requirements trigger the remerge of both the RC subject (this happen first, because of the last-in-first-out nature of the memory buffer) and the RC head (as direct object). Rephrasing the intervention-based account, I assume that the complexity of this computation is proportional to the number and kind of features that are stored in memory while the relevant arguments are retrieved to fill the selected positions. The proposed complexity metric takes into account the retrieval cost associated to memory access, depending on the number of items stored (*m*), the number of features characterizing the argument to be retrieved that are non-distinct in memory (*nF*) (i.e. also present in other objects in memory), mitigated by the number of distinct cued features (*dF*) (i.e. agreement and case features probed by the verb). This is the proposed "Feature-based Retrieval Cost" (C_{FRC}):

(2) $C_{FRC}(x) = \prod_{i=1}^{m_x} \frac{(1+nF_i)^{m_i}}{(1+dF_i)}$ (i.e. the product of the costs of any item retrieved at *x*)

Assume the following feature specifications: *D* = {+D, +num, N}, *N* = {+D, +num, N_{prop}} (with N vs. N_{prop} distinctiveness counting half, since expression of subcategorization) and *P* = {+D, +case, +pers, +num}. We already obtain a good fit in the most significant conditions:

condition	*D-D*	*D-N*	*D-P*	*N-D*	*N-N*	*N-P*	*P-D*	*P-N*	*P-P*
r.t.(SE) ms	365(19)	319(12)	306(14)	348(18)	347(21)	291(14)	348(18)	311(15)	291(13)
C_{FRC}(*avoided*)	16	12,25	3	12,25	16	3	9	9	1

In details, in the *D-D* matching condition (e.g. "it was the lawyer$_{\{+D,\ +num_sing,\ N\}}$ who the businessman$_{\{+D,\ +num_sing,\ N\}}$ *avoided…*"), the C_{FRC} at *avoided* is 16·1: 16 for retrieving "the businessmen", since *nF*=3, *m*=2 (because two *D*s are in memory at that retrieval time), and *dF*=0 (because no feature is cued by the verb distinguishing one *D* from the other); 1 for retrieving "the lawyer", since *nF*=0, *m*=1 and *dF*=0. The same C_{FRC}(*avoided*) = 16 applies to the *N-N* condition at the same region (e.g. "it was Dan$_{\{+D,\ +num_sing,\ Nprop\}}$ who Patricia$_{\{+D,\ +num_sing,\ Nprop\}}$ *avoided...*"). On the other hand, we expect a C_{FRC}(*avoided*) = 1 for the *P-P* condition (e.g. "it was you$_{\{+D,\ +pers_II,\ +num_sing,\ +case\}}$ who we$_{\{+D,\ +pers_I,\ +num_plur,\ +case_nom\}}$ *avoided...*"): for the subject pronoun, *nF*=1, *m*=2 and *dF*=3 (since number, person and case mismatches are always present and cued by the verb), while *nF*=0, *m*=1 and *dF*=0 for the object pronoun. Also for the *D-N* (3) and *D-P* conditions (4), the C_{FRC} makes coherent predictions (in both cases, object retrieval has always a cost of 1, since *nF*=0, *m*=1, *dF*=0):

(3) *N* retrieval at the RC verb: *nF*=2.5, *m*=2, *dF*=0 (N_{pro} vs. N counts as half)
C_{FRC}(*avoided*) (*D-N* condition) = 12,25

(4) *P* retrieval at the RC verb: *nF*=2, *m*=2, *dF*=2 (person and case are cued)
C_{FRC}(*avoided*) (*D-P* condition) = 3

Selected References:

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