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Locality in the acquisition of object A'-dependencies: insights from French

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Children's difficulties with dependencies involving movement of an object to the left periphery of the clause (object relative clauses/RCs and wh-questions), have been explained in terms of intervention effects arising when the moved object and the intervening subject share a lexical N feature (Friedmann, Belletti & Rizzi 2009). Such an account raises various questions: (1) Do these effects hold in the absence of a *lexical N feature* when the object and the intervener share other relevant features? (2) Do *phi-features* with a semantic role modulate such effects? (3) Does the degree of feature overlap determine a gradience in performance? We addressed these in three sentence-picture matching studies with French-speaking children (4;8 to 6;3), by assessing comprehension of (1) subject and object RCs headed by the demonstrative pronouns *celui/celle* and matching or mismatching in number; (2) object RCs headed by a lexical N and matching or mismatching in animacy; (3) object *who-* and *which-*questions. Our results show that mismatches in number, not in animacy, enhance comprehension of object RCs, even in the absence of a lexical N feature, and confirm previous findings that object *who-*questions yield better comprehension than object *which-*questions. Comparing across studies, the following gradation emerges with respect to performance accuracy: disjunction > intersection > inclusion. The global interpretation of these findings is that fine-grained phi-features determining movement are both sufficient and necessary for locality, and the degree of overlap of these features can capture the pattern of performance observed in children, namely higher accuracy as featural differences increase.

1 Introduction

Amongst the tasks faced by the child during acquisition, there is the task of building structural representations as well as establishing dependencies within these representations, both of which can be complex (Jakubowicz 2005). The theoretical frameworks developed by Rizzi and colleagues, namely Syntactic Cartography (Rizzi 2004), Truncation (Rizzi 1993/1994) and Relativized Minimality/RM (Rizzi 1990; 2004) offer key insights into these issues. Contributions by Friedmann et al. and De Lisser et al. (this volume) explore the relevance of Cartography and Truncation for the acquisition of structure, and here we turn to RM, which deals with dependencies derived by moving a constituent to the left periphery.

It is well-known that certain A'-dependencies, dependencies in which the moved element targets what is called an A-bar (or non-argument) position, are mastered earlier than others. For instance, children understand and produce object relative clauses (ORC) and object which-questions (OWH) (1) later than subject relative clauses (SRC) and subject which-questions (SWH) (2) (English: Brown 1971; De Villiers et al. 1979; French: Labelle 1990; Portuguese: Corrêa 1995; Spanish: Pérez-Leroux 1995; German: Adani et al. 2013; Italian: Contemori & Belletti 2014; Chinese: Hu et al. 2016). In these and subsequent examples, an underline is used to indicate the gap corresponding to the canonical position of the fronted element.

(1) a. Show me the man [that the boy is pulling ___]. ORC
b. Which man is [the boy pulling ___]? OWH

(2) a. Show me the boy [that ___ is pulling the man]. SRC
b. Which boy [___ is pulling the man]? SWH

At first sight, it seems that what poses challenges for children is a longer dependency involving non-canonical word ordering (object-subject-verb). However, it has been observed that certain long dependencies resulting in non-canonical orders are unproblematic, namely 'free' object A'-dependencies (3), i.e. those dependencies where the head of the chain is an operator that is not lexically restricted (where a 'chain' represents the formal object created by the moved element and its trace).

(3) Show me who [the boy is pulling ___].

Children's difficulties with dependencies such as given in (1) have been explained in terms of their intervention effects (Friedmann, Belletti & Rizzi 2009). These effects arise when the object moving to the left periphery crosses an intervening subject with which it shares a feature, here lexical N. The similarity in the +N feature between the head of the chain and the intervener would be responsible for giving rise to a locality violation in child grammar. More precisely, the set relation of inclusion between the features of the moved element and those of the intervener results in a configuration too difficult for children to compute, and although it is accessible for adults, it nevertheless remains complex, as can be seen by subtler measures than accuracy, such as reading times (see e.g. Gordon et al. 2004). These phenomena are reminiscent of those captured by the principle of RM (Rizzi 1990; 2004; Starke 2001; Grillo 2008; Friedmann et al. 2009).

The RM principle (4) in its initial form focused on ruling out relations between X and Y in the presence of a hierarchical intervener Z of the exact same type as X, exemplified in (5) for the +WH (i.e. interrogative) feature:

(4)		**Intervener**	
	X	**Z**	**Y**
	A	A	<A>

+WH +WH
(5) *__What__ [do you wonder **who** is pulling___]?

In (5) we observe that an intervener ('who') bearing *identical* morphosyntactic features to the head ('what') renders the structure ungrammatical. In contrast, an intervener whose features are properly *included* in those of the head of the chain (1) merely complicates computation for adults, while it causes the computation to crash for immature systems. Both adults and children find easy those chains with a featurally *disjoint* head and intervener, as seen in (3), i.e. when no feature is shared. This leaves open the question of what happens in the case of configurations where the features of the intervener are only partially included in the set of features specifying the head, i.e. when the features on the two constituents *intersect*. Various studies have shown that the difficulty children have with object relatives involving an overlap in the N feature can be alleviated by the manipulation of more fine-grained features associated with N. Indeed, children fare well with an intersection relation such as in the ORC in (6) (Adani, van der Lely, Forgiarini & Guasti 2010), where the intervener mismatches in a phi-feature, here number/+Num (note that +R (i.e. relative) represents the scope-discourse or 'criterial' feature attracting the RC head to the corresponding A'- position):

(6) +R+N+**Sg** +N+**Pl**
The man that the boy**S** are pulling

In sum, just as a mismatch in lexical restriction facilitates comprehension, a number mismatch between the lexically-restricted head of the relative and the embedded lexically-restricted subject has also been shown to improve comprehension at different phases of development, as reported for Italian children from 5 to 9 years of age (Adani et al. 2010; Arosio et al. 2011; Manetti et al. 2017). However, not all features are equal in creating featural intersection: it has been argued that a featural mismatch can facilitate comprehension only if a feature functions as an attractor for movement in a given language (Belletti et al. 2012; Friedmann et al. 2017). As such, the impact of featural mismatches is expected to vary cross-linguistically. This has been observed to be the case: the effect of gender mismatch plays a role in children's comprehension of ORCs in Hebrew, while this same mismatch does not significantly affect the comprehension of ORCs in Italian (Belletti et al. 2012). When comparing these languages, the first thing to note is that in Hebrew (7a) the verb agrees in gender with the subject (the verb "draws" is marked masculine since the doctor drawing is male), while in Italian (7b) this is not the case (the verb does not contain any gender marking on it).

(7) a. HEBREW she-mecayer
that-**draws-Masc**
b. ITALIAN disegna
draws

In light of this, a more nuanced view of RM effects emerges: what makes a feature relevant for locality would be whether the feature in question belongs to the feature set triggering movement, by being morphologically expressed in the inflection of the finite tensed verb. If features need to be active as properties of the probe[1] in order to enter into the computation of locality effects, it follows that Hebrew-speaking children of the same age range cannot capitalize on overt case marking, realized on the DP, to improve parsing of object dependencies (Friedmann et al. 2017).

Thus, the selective effect of features refines our understanding of RM in children (Belletti et al. 2012), along the lines of the featural relations indicated in (8). Children show good performance not only with disjunction, but also with intersection relations, so essentially those relations in which the intervener differs from the moved object in at least one relevant feature (represented as 'D' in (8) below), as was the case of gender in Hebrew. The determining factor which makes such a feature relevant for the computation of locality is that it forms part of the clausal inflectional head. In sum, the global picture which emerges for the comprehension of object-moved dependencies pinpoints problems with identity and inclusion, and facility with non-inclusion configurations, in which there is an intersection or a disjunction relation between the featural specifications of the moved object X and the embedded subject Z. Along these lines,

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[1] Probe and goal are technical terms used to express syntactic relations formed in feature checking, where a probe searches for a goal in its c-command domain: "Feature checking resolves to pairs of heads <H, H′> […]. For optimal computation, one member of the pair must be available with no search. It must, therefore, be the head H of the construction α under consideration, α = {H, XP}. Call H a probe P, which seeks a goal G within XP;… " (Chomsky 2004: 113).

there appears to be a binary split between structures that children can handle compared to those they cannot.

(8)

		Intervener			
	X	***Z***	***Y***	***Adults***	***Children***
Identity	A	A	<A>	*	*
Inclusion	A,B	B	<A,B>	ok	*
Intersection	A,C	C,D	<A,C>	ok	ok
Disjunction	A	B	<A>	ok	ok

This account gives rise to several questions, which remain to be empirically verified. For instance, the feature yielding inclusion has been argued to be N, while the different intermediate levels of intersection are determined by finer-grained features like number and gender. As number and gender are morpho-syntactic features associated with N, it would be desirable to explore whether all these set-theoretic relations can be captured at their more fine-grained level, in which case there would be no need to postulate a more global lexical N feature in order to encompass cases of inclusion. That is, inclusion would simply be the result of inclusion of all of the morpho-syntactic features associated with N, while intersection would be created when a subset of these differ. In addition, children's performance might also be nuanced from very poor to very good depending on the level of featural overlap. If this is indeed the case, it would be reminiscent of acceptability judgments for which structures can range in their deviance (see for example Villata et al. 2016). We would thus expect children to fare worse on inclusion than intersection, and in turn worse with intersection than disjunction, rather than to show a binary split between inclusion on the one hand, and intersection and disjunction on the other. The studies presented here attempt to shed light on these questions via a series of experimental investigations manipulating features in object-dependencies so as to empirically assess if and how they modulate children's performance. The aim of this body of work is to refine our grasp of featural Relativized Minimality.

1.1 Research questions

The present studies address the following three research questions:

A. Do inclusion configurations arise in the absence of a *lexical N feature*, provided other relevant features are similar between the head and the intervener?

We evaluated subject and object relative clauses headed by the demonstrative pronouns *celui/celle* and matching or mismatching in number features with the intervening subject (Study 1). *Celui/celle* represent the perfect candidates to explore the relevance of the N feature because they are specified for *phi*-features such as gender, number and animacy, but do not contain a lexical

N restriction (since they are made up of a demonstrative *ce* and a pronominal element *lui*/'him' and *elle*/'her') and thus can mismatch in this respect with the intervening subject.[2] This helps to pinpoint whether or not N is necessary to create inclusion or, on the contrary, whether inclusion can be created simply in the presence of finer-grained features. In the latter case, the coarser N-feature level would become simply an abbreviation for the bundle of *phi*-features associated with it, which would be the only features relevant for the computation of locality. Therefore, if children's difficulty is the result of intervention triggered by features which are finer grained than lexical N, then good performance should emerge in (non-intervention) subject relatives headed by *celui/celle*, while difficulty (due to an inclusion configuration) should arise selectively with object relatives involving a match in phi-features such as number between the relative head and the intervening subject. This difficulty in object relative clauses should however dissipate when the head of the dependency mismatches in number with the intervener (due to an intersection relation).

B. Do *phi-features* with semantic impacts (e.g. relevance for theta-role assignment), despite not triggering movement, create intersection relations?

To address this question, we examined the comprehension of object relative clauses headed by a lexical N, which matched or mismatched in animacy with the RC-internal subject (Study 2). Some studies have claimed that a mismatch in animacy facilitates the comprehension of object dependencies for older children (see Arosio et al. 2011 for 9-year-old Italian-speaking children, Bentea et al. 2016 for French-speaking children over 6). Other studies suggest the animacy mismatch may only be relevant for younger children, not older children (see Adani 2010 reporting no effect for German-speaking children over 5, versus an effect between 3 and 5 reported in Adani et al. 2017). Finally, some authors detect no effect for a mismatch in animacy across ages (Martini 2019). Clearly more needs to be understood about the impact of this feature. Here, so as to compare the potential effects of features triggering movement with those without this status, we focus on children of the age when phi-features such as number or gender have been reported to be relevant, namely before age 6 years.

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[2] For production, Hamann & Tuller (2015) examined the frequency of relative clauses without a lexical restriction on the head in French-speaking children's spontaneous production, by comparing typically-developing children (6-, 8-, 11- and 14-year-olds) and children with Developmental Language Disorders (10- to 12-year-olds). Hamann & Tuller found that children also produce RCs headed by *celui/celle/ceux*, which they group together with RCs headed by *une*, *tellement*, *tout ce*, *plein*, although it is not clear whether all these RC types could form a cohesive group. For instance, *celui* and *ce* or *plein* RCs may behave differently if fine-grained features like number and specificity impact performance. Given this, together with the fact that most of these ORCs seem to contain a personal or expletive pronoun as subject, we cannot directly compare our results to those of this work.

C. Does *a distinctness hierarchy* determine performance accuracy (Rizzi 2018)?

To investigate whether the three set-theoretic relations (i.e. disjunction, intersection and inclusion) lead to a gradation with respect to the degree of improvement in children's accuracy or whether comprehension of intersection relations patterns with disjunction, along the lines of the binary split illustrated in (8) above, we compared the results of Study 3 that assessed the comprehension of disjunction (object *who*-questions) and inclusion configurations (object *which*-questions) to those from Study 1 that assessed the comprehension of intersection relations created by the mismatch in number in object relatives headed by *celui/celle*.

2 Participants

Overall, eighty-seven children at public primary schools in the Geneva area, Switzerland, participated in the studies (see **Table 1** for more detailed participant information). The research was approved by the Department of Public Instruction, the state authority overseeing schools in the canton of Geneva. The children's participation in the studies was voluntary and parental written consent was obtained prior to testing, in accordance with the Declaration of Helsinki. Participants ranged in age from 4;7 to 6;3 and had no history of language delay or impairment. We chose to focus on this age group to compare across studies which explored the relevance of features for RM, and also which investigated the features we are concerned with in this paper, namely number, animacy, and lexical N.

3 Materials, Procedure and Results

Each of the three studies involved a character-selection task in which children had to identify the correct character in an image with three (Study 1) or four (Studies 2–3) characters

	Total No.	**Age range (in years)**	**Age range (in months)**
Study 1	34 (17 male)	4;7–5;9	55–69 (M = 62.30; SD = 4.46)
Study 2	27 (10 male)	4;8–5;11	56–71 (M = 63.06; SD = 4.59)
Study 3	26 (16 male)	4;10–6;3[3]	58–76 (M = 65.78; SD = 5.16)

Table 1: Participant information by study.

[3] This group only included four 6 year-old-children. As no difference in response accuracy emerges if we only include the results of the 4- and 5-year-old children in Study 3, we are also reporting the results of the four 6-year-old children included in this study.

involved in the same action, once as Agent and once as Patient. All the test sentences contained transitive verbs. The trials in each study were pseudo-randomized across two lists. The order of trials between lists also varied, so as to neutralize potential effects due to item order.

The participants in each of the three studies were tested individually in a quiet room at their school. The testing session started with a familiarisation phase in which the experimenter explained the task and practiced precise pointing with the children in four practice trials. Each session lasted approximately 15 to 30 minutes and children could take breaks if needed. Overall, the children were enthusiastic to take part in the study and they each received stickers upon completion of the task.

As for the analysis of the results, response accuracy in each study was determined by the choice of correct character. The dependent response variable had a binary value: 1, if the participant pointed to the correct character identified by the test sentence (this was always the Patient of the action in Studies 2 & 3); 0, if the participant pointed to the wrong character. We analysed the proportion of accurate responses with generalised linear mixed-models. All analyses were conducted using the *lme4* package (Bates, Mächler, Bolker, & Walker 2015) in R (R Core Team 2019)) and figures were produced using the package *ggplot2* (Wickham 2016). The fixed factors in each analysis were coded using repeated contrasts which test consecutive factor levels against each other (Schad, Vasishth, Hohenstein & Kliegl 2020) and the continuous variables (Age) were centred to the mean. The random effect structure included intercepts for participants and items, as models with more complex random effects structures did not converge. In order to sustain model convergence, we also specified the *bobyqa* optimizer in the *glmer* function. Figures and averages of results are shown in untransformed measures for ease of interpretation, but statistical analyses were always performed on log-transformed measures.

3.1 Study 1: Inclusion and intersection without a lexical N feature?

3.1.1 Materials

Study 1 examined the impact of number mismatch on SRC (9a & 10a) and ORC (9b & 10b) headed by the demonstrative pronouns *celui/celle*. These constituents do not contain a lexical N restriction, but are specified for features like gender and number (*celle*$_{\text{FEM.SG}}$; *celles*$_{\text{FEM.PL}}$; *celui*$_{\text{MASC.SG}}$; *ceux*$_{\text{MASC.PL}}$). While the feminine forms have the same pronunciation, the singular and plural masculine forms are pronounced differently. In addition, as illustrated in the Introduction, one particularity of number agreement on the verb in French is that it can be silent or audible depending on the verb. However, since previous findings on the effect of number mismatch in French relative clauses (Bentea & Durrleman 2017) have shown that the audibility or inaudibility of the number cue on the verb does not impact comprehension, in this study we have not controlled for audibility of number agreement.[4]

Participants saw 40 trials, with 10 trials per condition. The RC head and the intervener always matched in gender, with half of the items containing two feminine referents and the other half two masculine referents, in both the number match and the number mismatch conditions. In the number mismatch conditions, the head of the relative (i.e. the demonstrative pronoun) was always plural (*celles* or *ceux*), while the intervening subject was always singular. Two pictures were associated with each target sentence: one introducing the referents for *celui/celle* (**Figures 1A** & **2A**) and one depicting three characters taking part in the same action with reversed Agent-Patient roles (**Figures 1B** & **2B**). Note that both the lead-in and the images in the mismatch conditions always depicted two pairs of characters of the same type (e.g. pairs of two elephants), to ensure that children associate the demonstrative pronouns to a plural antecedent. In addition to the test sentences, participants also saw 10 fillers, for a total of 50 trials per list. Fillers were simple sentences containing prepositional phrases in every experiment of the body of work presented here (**Figure 3**). While the correct answer for the test sentences

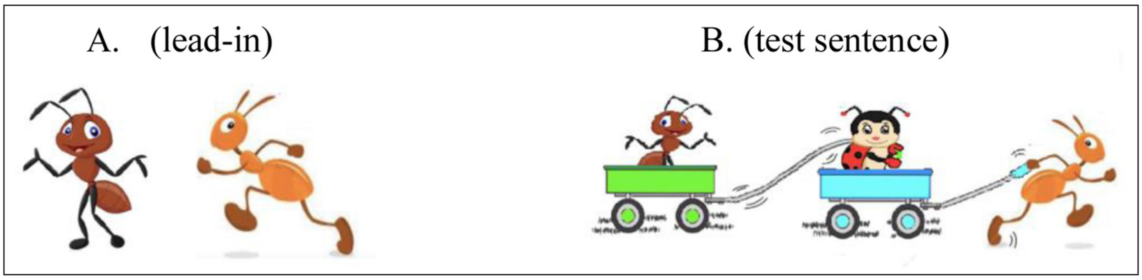

Figure 1: Example of images paired with target sentences in the number match condition.

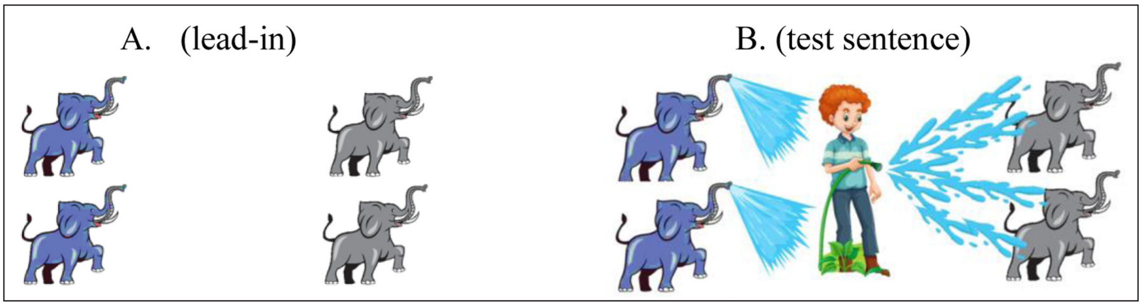

Figure 2: Example of images paired with target sentences in the number mismatch condition.

[4] However, future work could do so and seek to replicate the findings of Bentea & Durrleman (2017) with *celui/celle* relatives, while also including other age groups.

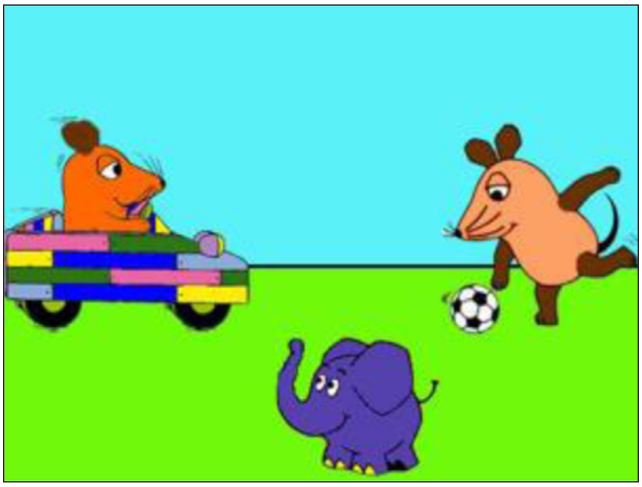

Figure 3: Example of image paired with a filler.

was always one of the characters on the left or on the right, the correct answer for the fillers was always the character in the middle. The position of the correct characters for the test items was counterbalanced between trials.

(9) a. **SRC (number match)**

				+R –N + **Fem** + **Sg**				+N + **Fem** + **Sg**
Voilà	des	fourmis.	Montre-moi	celle	qui	tire	la	coccinelle.
Here	some	ants.	Show-me	this/that-her	that	pulls	the.$_{\text{FEM.SG}}$	ladybug

'Here are some ants. Show me the one that is pulling the ladybug.'

b. **ORC (number match)**

				+R –N + Fem + **Sg**			+N + Fem + **Sg**	
Voilà	des	fourmis.	Montre-moi	celle	que	la	coccinelle	tire.
Here	some	ants.	Show-me	this/that-her	that	the.$_{\text{FEM.SG}}$	ladybug	pulls

'Here are some ants. Show me the one that the ladybug is pulling.'

(10) a. **SRC (number mismatch)**

				+R –N + Masc + **Pl**				+N + Masc + **Sg**
Voilà	des	éléphants.	Montre-moi	ceux	qui	arrosent	le	garçon.
Here	some	elephants.	Show-me	this/that-them	that	splash	the.$_{\text{MASC.SG}}$	boy

'Here are some elephants. Show me the ones that are splashing the boy.'

b. **ORC (number mismatch)**

				+R –N + Masc + **Pl**			+N + Masc + **Sg**	
Voilà	des	éléphants.	Montre-moi	ceux	que	le	garçon	arrose.
Here	some	elephants.	Show-me	this/that-them	that	the.$_{\text{MASC.SG}}$	boy	splashes

'Here are some elephants. Show me the ones that the boy is splashing.'

(11) Touche la souris dans la voiture.
‘Touch the mouse in the car’

3.1.2 Results

Figure 4 plots the results obtained for subject and object relative clauses headed by the demonstrative *celui/celle* and containing a match or mismatch in number between the demonstrative and the RC-internal subject. To recall, in the mismatch conditions, the RC head was *ceux* or *celles* and referred to a plural antecedent, while the subject was a lexically-restricted noun in the singular. The results indicate that children gave more accurate responses to SRCs (M = 81%) as compared to ORCs (M = 67%) in the number match condition. The number mismatch conditions show overall higher response accuracy, with ORCs (M = 78%) comprehended on a par with SRCs (M = 80%). Moreover, in the mismatch condition, children are equally accurate with ORCs headed by *celles* (78%) and *ceux* (79%), indicating that the similar pronunciation in the case of singular and plural feminine demonstrative (*celle/celles*) does not hinder performance with mismatched ORCs.

The main effects included in the model were Structure Type (SR vs OR) and Number (Match vs Mismatch). The model also tested for an interaction between Structure Type and Number. **Table 2** reports the output of the model, with the statistically significant effects highlighted in bold:

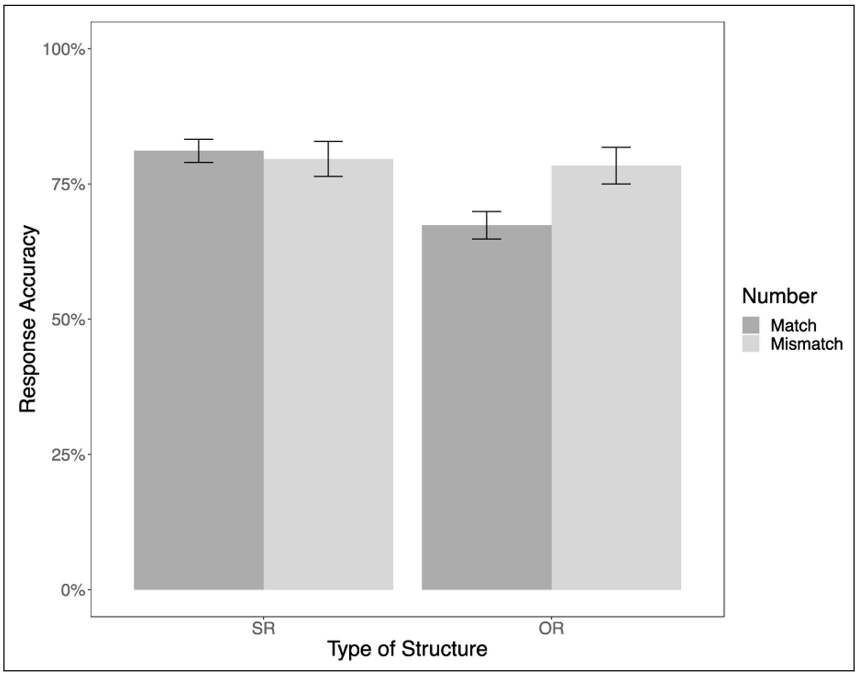

Figure 4: Percentage of correct responses for each experimental condition. The bars represent the standard error to the mean. SR = subject relative; OR = object relative.

Fixed effects	Estimate	SE	z-value	p-value
(Intercept)	1.529	0.267	5.725	< .001
StructureType: *SR* vs *OR*	**–0.482**	**0.182**	**–2.634**	**.008**
Number: *Match* vs *Mismatch*	0.171	0.250	0.683	.494
Age	0.068	0.056	1.223	.221
StructureType × Number	**1.044**	**0.367**	**2.845**	**.004**
StructureType × Age	–0.057	0.040	–1.441	.149
Number × Age	–0.072	0.040	–1.798	.072

Table 2: Model output for Study 1 (formula: glmer (CorrectCharacter ~ StructureType + Number + Age + StructureType:Number + StructureType:Age + Number:Age + (1|Participant) + (1|Item), family = binomial, control = glmerControl(optimizer = "bobyqa"), data)).

There was a significant main effect of Structure Type ($p = .008$) which shows that children are significantly less accurate with object relatives than with subject relatives, even in instances when the RC head is a demonstrative pronoun *celui/celle*. The significant interaction between Structure Type and Number ($p = .004$) and subsequent pairwise comparisons reveal (i) that there is no significant difference in performance between subject relatives with or without a mismatch in number ($\beta = 0.352$, $SE = 0.317$, $z = 1.110$, $p = .267$), while object relatives were significantly less accurate in the number match as compared to the number mismatch conditions ($\beta = -0.692$, $SE = 0.305$, $z = -2.272$, $p = .023$); and (ii) that SRCs are comprehended significantly better than ORCs in the match condition ($\beta = 1.005$, $SE = 0.214$, $z = 4.706$, $p < .001$), whereas no significant difference emerges between SRCs and ORCs in the mismatch condition ($\beta = 0.0391$, $SE = 0.298$, $z = 0.131$, $p = .895$).

3.1.3 Interim discussion

Our findings for the *celui/celle*-headed relatives in French indicate that children do not have difficulties with the comprehension of such structures when there is no intervention configuration involved, as in the case of SRCs. However, response accuracy is significantly lower with *celui/celle*-headed object relatives, when the intervening RC-internal subject matches in *phi*-features such as number with *celui/celle*. Importantly, the presence of a number mismatch between the two elements significantly enhances performance on *celui/celle* object relatives. This suggests that the challenge in comprehension with RCs headed by *celui/celle* observed here, as well as in previous preliminary work (Bentea et al. 2016), cannot be attributed only to a difficulty in accessing the referent of the demonstrative pronoun. If performance with *celle/celui* were the result of this type of difficulty, then we would expect children to struggle with all structures involving the demonstrative. The results show instead that problems emerge specifically in configurations of matching *phi*-features between the *celle/celui* head and the intervener, which create inclusion configurations in the absence of a lexical restriction. A mismatch in the fine-grained number features facilitates parsing, and is thus relevant for the computation of locality beyond the presence of lexical N.

The effect of number mismatch in the current study contrasts with those of Bentea & Durrleman (2017) who do not find this effect in French-speaking children of the same age. One reason behind this difference in results could be that Bentea & Durrleman (2017) manipulated number on the intervening subject, while in the present study number was manipulated on the head, that is, the moved object crossing the intervener. We acknowledge this limitation in our study and aim to address it in future work, however, it is worth underlining that other work has already examined number features in a fully crossed configuration in Italian and did not report an effect of directionality (Adani et al. 2010).

3.2 Study 2: Intersection with a semantic feature (animacy)?

3.2.1 Materials

Study 2 investigated the effect of an animacy mismatch on the comprehension of ORCs in French and aimed to replicate the findings in Bentea, Durrleman & Rizzi (2016) with a larger cohort, by focusing only on the 4 to 5-year-old group. The participants saw a total of 8 items (4 ORCs with a match in animacy, illustrated in (11a), and 4 ORCs with a mismatch in animacy, exemplified in (11b)). The noun phrases in each relative clause matched for gender and number, which was always singular. In the animacy mismatch conditions, the head of the relative clause was always inanimate, while the intervening subject was animate, thus including structures across conditions with similarly plausible theta-role assignments (i.e. steering clear of the potentially implausible contexts of 'inanimate subject and animate object'). The verbs used in the animacy match conditions were *embrasser* 'to kiss', *salir* 'to dirty', *secher* 'to dry', *suivre* 'to follow', and the verbs used in the animacy mismatch conditions were *arroser* 'to wet', *pousser* 'to push', *salir* 'to dirty', and *suivre* 'to follow'. **Figure 5** shows the images associated with the two conditions. The direction of the actions was changed across images and the position of the correct character varied between the four possible options. There were also 10 fillers consisting of simple sentences that contained prepositional phrases, as exemplified in (11), bringing the total number of items to 18. All children saw all the items which appeared in a randomised order across four lists, in order to control for potential effects related to the order of presentation of the items. Therefore, different items appeared at the beginning, in the middle, or at the end of each of the four lists. The lists started with one filler item and ended with two filler items, the remaining fillers being

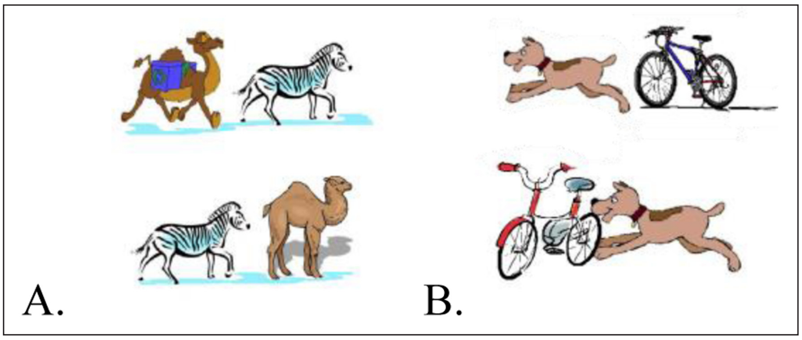

Figure 5: Example of images paired with the animacy match **(A)** and animacy mismatch **(B)** conditions.

interspersed with the target trials. The animacy match and animacy mismatched items were also interspersed such that children were never presented with two similar experimental items one after the other.

(12) a. **ORC animacy match**

+R+N+An[5] +N+An
Montre-moi le chameau que le zèbre suit.
Show-me the.$_{\text{MASC.SG}}$ camel that the.$_{\text{MASC.SG}}$ zebra follows
'Show me the camel that the zebra is following.'

b. **ORC animacy mismatch**

+R+N **–An** +N+**An**
Montre-moi le vélo que le chien suit.
Show-me the.$_{\text{MASC.SG}}$ bike that the.$_{\text{MASC.SG}}$ dog follows
'Show me the bike that the dog is following.'

3.2.2 Results

The results of Study 2 reveal similar response accuracy rates for object relative clauses matching (M = 60%) or mismatching (M = 64%) in animacy (**Figure 6**). This was also confirmed by the statistical analysis which showed that the main effect of Animacy (*Match* vs *Mismatch*) was not significant (p = .614) and that Age, which was used as a continuous variable in the model (see **Table 3** for full model output), did not impact comprehension.

[5] For ease of representation, we only indicate the +/- An(imate) feature, leaving aside the gender and number features that are also specified on the noun and which have been matched between the head and the intervener across all experimental items.

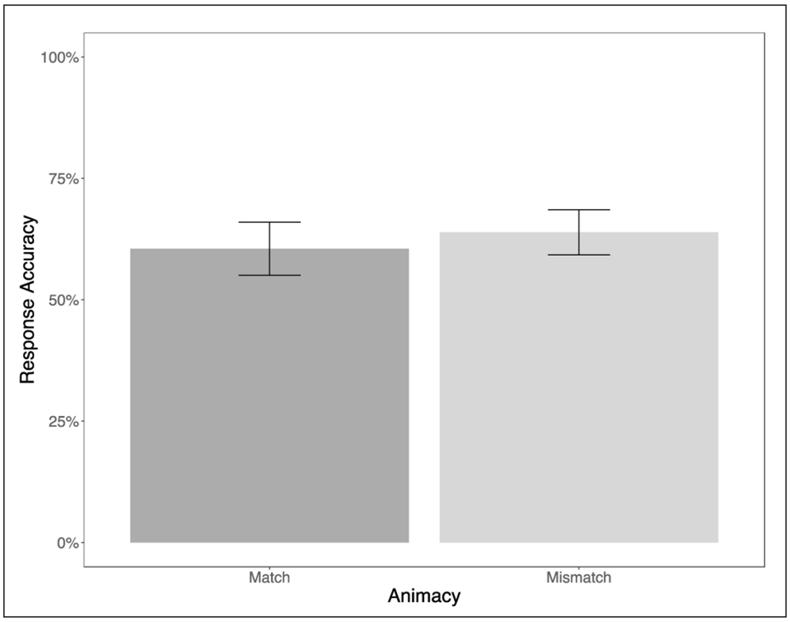

Figure 6: Percentage of correct responses for ORCs with a match or mismatch in Animacy. The bars represent the standard error to the mean.

Fixed effects	Estimate	SE	z-value	p-value
(Intercept)	0.581	0.236	2.462	.013
Animacy: *Match* vs *Mismatch*	0.171	0.339	0.504	.614
Age	0.033	0.060	0.559	.576
Animacy × Age	0.036	0.087	0.420	.675

Table 3: Model output for Study 2 (formula: glmer (CorrectCharacter ~ Animacy + Age + Animacy:Age + (1|Participant) + (1|Item), family = binomial, control = glmerControl (optimizer = "bobyqa"), data)).

3.2.3 Interim discussion

Our results for animacy contrast with those for number in Study 1 as children comprehend object relative clauses in which the head and the intervening subject matched in animacy on a par with object relative clauses in which the head and the intervening subject mismatched in this feature. Despite the featural mismatch, therefore, we do not get the effects associated with an intersection relation. Rather, in these cases, the featural specification of the two DPs appears to give rise instead to an inclusion relation, regardless of mismatch. This is in line with the findings reported in Bentea et al. (2016) for 5-year-old French-speaking children and shows that, despite being a semantic cue which should facilitate theta-role assignment, the mismatch in animacy for this age-group does not suffice to accurately parse the structure and arrive at the correct assignment of theta roles.

3.3 Study 3: A distinctness hierarchy – Disjunction > Intersection > Inclusion?

3.3.1 Materials

The previous two studies investigated children's performance on object dependencies that instantiate an inclusion and an intersection configuration between the moved object and the intervener. In order to determine whether a gradation in response accuracy can be established between the three set configurations generated by the grammar (i.e. disjunction, intersection, inclusion), Study 3 aimed to complete the picture by shedding light on how children fare with disjunction structures. To this effect, we compared children's comprehension of object *who*-questions (12a), which instantiate a disjunction configuration, to object *which*-questions (12b), giving rise to an inclusion relation between the moved object and the intervening subject. We administered a total of 14 items (7 items per condition). Like in Study 2, children were presented with two images simultaneously (**Figure 7**), in which the position of the correct character was counterbalanced among trials. All the nouns matched in gender and number, half were feminine, and half were masculine. The study also included 10 fillers, that consisted of simple sentences that contained prepositional phrases, as exemplified in (11), thus bringing the total number of items to 24.

(13) a. *Object 'who'-question*
+WH+N +N+Fem+Sg
Qui est-ce que la grenouille arrose[6] ?
Who ESK the.$_{FEM.SG}$ frog splashes
'Who is the frog splashing?'

b. *Object 'which'-question*
+WH+N+Fem+Sg +N+Fem+Sg
Quelle princesse est-ce que la grenouille arrose ?
Which.$_{FEM.SG}$ princess ESK the.$_{FEM.SG}$ frog splashes
'Which princess is the frog splashing?'

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[6] French also allows other strategies for question-formation (e.g. the wh-object can remain in-situ (i) or be fronted without subject-verb inversion (ii)), but the questions in this study only included wh-fronting with *est-ce que* (ESK):

(i) La grenouille arrose qui/quelle princesse ?
The.FEM.SG frog splashes who/which.FEM.SG princess

(ii) Qui/Quelle princesse la grenouille arrose ?
Who/Which.FEM.SG princess the.FEM.SG frog splashes
'Who/Which princess is the frog splashing?'

Figure 7: Example of image used to assess comprehension of object wh-questions.

3.3.2 Results

The findings summarised in **Figure 8** illustrate that children comprehend object *who*-questions very well (M = 90%) and that they are less accurate with object *which*-questions (M = 62%). The statistical analysis (the model output is summarised in **Table 4**) included Type of WH (*who* vs *which*) as fixed factor and Age as a continuous variable and shows that object *which*-questions yield significantly lower accuracy than object *who*-questions ($p < .001$).

3.3.3 Interim discussion

Study 3 revealed a highly significant boost in performance in structures where the moved element differs in all *phi*-features with respect to the intervener. This is the effect of disjunction, instantiated by object *who*-questions, as compared to an inclusion configuration, exemplified by object *which*-questions, as has been reported in previous work (e.g., Friedman et al. 2008 for Hebrew; De Vincenzi et al. 1999 for Italian).

A quick comparison with intersection, as assessed in Study 1 through the mismatch in the number feature on the head of the *celui/celle* object relative clause and the intervening subject, shows that there is a gradation in performance between the three sets of featural relations,

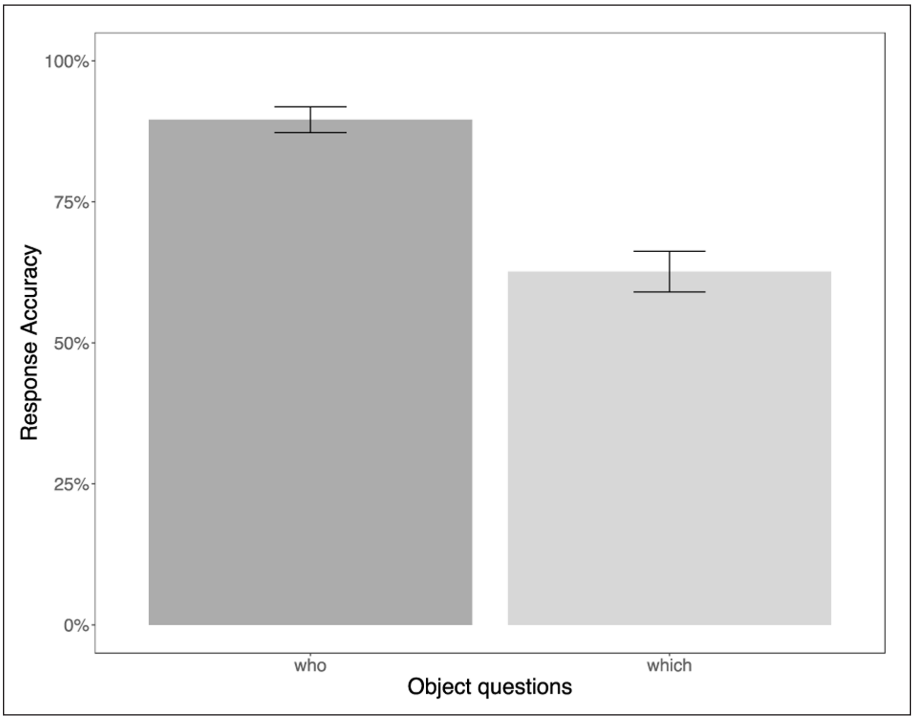

Figure 8: Percentage of correct responses for *who* and *which* object-questions. The bars represent the standard error to the mean.

Fixed effects	**Estimate**	**SE**	**z-value**	**p-value**
(Intercept)	1.579	0.326	4.844	<.001
Type of WH: *who* vs *which*	**–1.904**	**0.358**	**–5.313**	**<.001**
Age	0.023	0.030	0.763	.445
Type of WH × Age	–0.42	0.063	–0.660	.509

Table 4: Model output for Study 3 (formula: glmer (CorrectCharacter ~ Type of WH + Age + Type of WH:Age + (1|Participant) + (1|Item), family = binomial, control = glmerControl (optimizer = "bobyqa"), data)).

namely disjunction, intersection and inclusion. The data in Study 1 and Study 3 were fitted to a model with Featural Set-Relation (*Disjunction* vs *Intersection* vs *Inclusion*) as fixed factor and Participant and Item as random factors. As inter-group statistics show a significant difference in age between participants in Studies 1 and 3 ($t(51) = -3.463$, $p < .001$), Age was also included as a continuous variable in the model. **Table 5** summarizes the full model output, with significant effects highlighted in bold. Like in the analyses for each study, we used a repeated

Fixed effects	Estimate	SE	z-value	p-value
(Intercept)	1.718	0.239	7.171	<.001
Set-Relation: *Disjunction* vs *Intersection*	**–1.444**	**0.520**	**–2.776**	**.005**
Set-Relation: *Disjunction* vs *Inclusion*	**–2.140**	**0.461**	**–4.643**	**<.001**
Set-Relation: *Intersection* vs *Inclusion*	**–0.696**	**0.256**	**–2.712**	**.006**
Age	0.014	0.052	0.268	.788
Set-Relation $_{Disjunction\ vs\ Intersection}$ × Age	0.057	0.119	0.483	.628
Set-Relation $_{Disjunction\ vs\ Inclusion}$ × Age	0.141	0.107	1.314	.188
Set-Relation $_{Inclusion\ vs\ Intersection}$ × Age	0.083	0.055	1.521	.128

Table 5: Model output for comparison between Study 1 and Study 3 (formula: glmer (CorrectCharacter ~ FeaturalSet-Relation + Age + FeaturalSet-Relation:Age + (1|Participant) + (1|Item), family = binomial, control = glmerControl (optimizer = "bobyqa"), data)).

contrast specification for the fixed factor, thus allowing to compare each level of the variable with the preceding one.

The analysis shows that (i) response accuracy for intersection configurations is significantly lower than for disjunction structures ($p = .005$); (ii) inclusion configurations are significantly less accurate than intersection configurations ($p = .006$) and also yield significantly lower accuracy than disjunction structures ($p < .001$).[7] **Figure 9** gives a visual representation of this gradation.

Here we compare children's results for object *who*-questions (disjunction) to their results for *celui/celle* object relatives mismatching in number (intersection) and to their accuracy rate for object *which*-questions and *celui/celle* object relatives with a number match (both these structures give rise to an inclusion relation). We observe a graded improvement between children's levels of performance, depending on the distinction in features – when all *phi*-features are disjoint, performance is much better than in the presence of a partial featural difference (i.e. number mismatch), which in turn is better than when there is a complete overlap in *phi*-features. In sum, the gradation in performance attested is as follows:

[7] Following an anonymous reviewer's suggestion, we have also computed effect sizes for the reported differences between response accuracy levels in the three set-theoretical relations, by calculating *Cohen's d*. Effect size values suggest a small to medium effect size for the difference in accuracy between disjunction and intersection structures ($d = .32$), as well as between intersection and inclusion structures ($d = .27$), and a medium effect size for the difference in accuracy between disjunction and inclusion structures ($d = .54$).

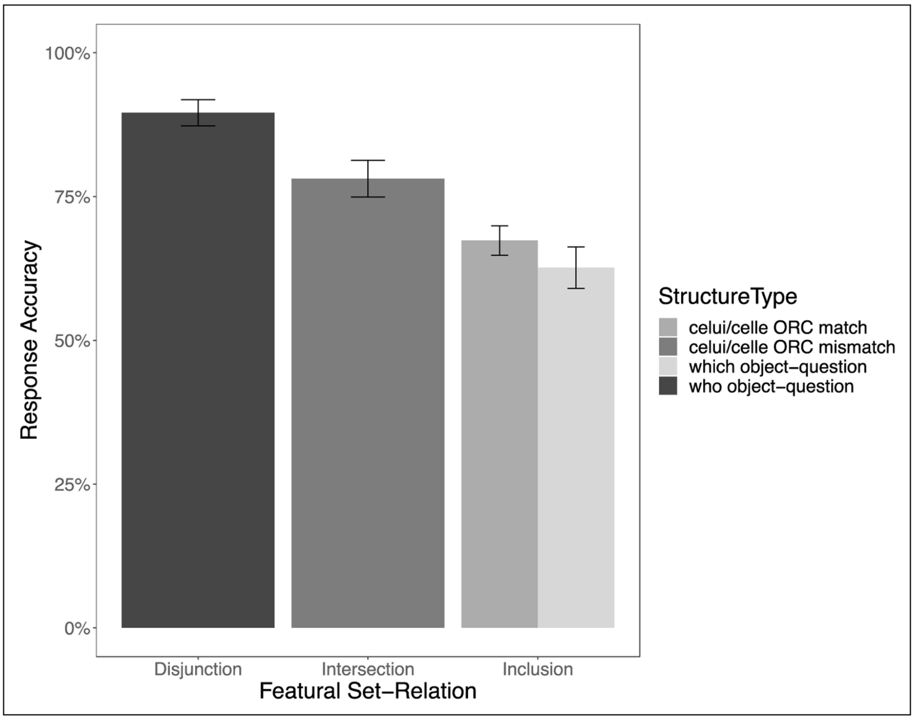

Figure 9: Percentage of correct responses for three featural configurations (disjunction, intersection, inclusion). The bars represent the standard error to the mean.

(14) Disjunction > Intersection > Inclusion

4 General Discussion

Different syntactic dependencies are mastered at different stages of acquisition, depending on whether or not intervention comes into play. The current work experimentally investigates the comprehension of A'-dependencies in children under the age of 6 in three studies, so as to uncover the features modulating intervention and thus yield insights into the grammatical principle of locality, RM (Rizzi 1990; 2004).

In Study 1, we were concerned with the status of the lexical N feature. In much previous work, inclusion has been claimed to be triggered by the presence of an overlap in this feature between the head of the dependency and the structural intervener, while intersection has been associated with mismatches in finer-grained features such as number and gender, i.e. *phi*-features associated with N. We noted that all prior work attributing inclusion to the N feature in fact contained a confound in that the featural overlap was both in lexical N and in associated *phi*-features, thus one cannot determine which of these could be responsible for the observed difficulty. Some studies report good performance for dependencies with a lexically-restricted head and a pronominal intervener, and suggest this amelioration could be attributed to the difference in the N feature between these elements, i.e. the removal of inclusion thanks to the dissociation in N. However, upon closer inspection, the pronominal intervener used in the structures tested in fact also differed in *phi*-features from the head of the chain. This was the case for instance in Friedmann et al. (2009). Indeed, the intervening pronoun used in the Hebrew experiment was an arbitrary, null pronoun triggering plural verbal inflection (see example (15)).

(15) Tare li et. ha-sus she-mesarkim oto (Friedmann et al. 2009)
show to-me ACC the-horse that-brush-**PL** him
'Show me **the horse**$_{.SG}$ that **they**$_{.PL}$ are brushing.'

As such, the intervener also differs here in terms of number from the head of the chain and this property would be predicted to facilitate parsing regardless of the difference in lexical N. Similarly, the improvement reported by Arnon (2010) for configurations with an intervening pronominal as compared to two NPs, also involved a difference in a *phi*-feature between the head N and intervening pronoun, namely that of person (example (16)). As the head of the chain and the intervener already differed on these finer, *phi*-features, performance should improve regardless of whether or not there is inclusion of the N feature, because this would involve an intersection relation. These results thus cannot directly address the role of N itself.

(16) What is the color of (…) **the girl**$_{.3P}$ that **I**$_{.1P}$ drew.

One study controlling for *phi*-features in object relative clauses between a lexically-restricted head and an intervening pronoun did not note an improvement in 5-year-old German-speaking children, while comprehension was enhanced when the intervening subject was marked for a different person (Haendler et al. 2015). Hence in Study 1 we also carefully controlled for phi-features between the head and the intervener, while distinguishing only in lexical N, via object relative clauses headed by a demonstrative pronoun in French: *celui/celle*. We observed that children did not improve performance when *phi*-features were matched between the ORC head and the intervening subject, however object relatives headed by these demonstrative pronouns (*celles* and *ceux*) yielded performance on a par to subject relatives once a mismatch in number was established between the head and the intervener. Note that, although the plural demonstrative *celles* has the same pronunciation as the singular demonstrative *celle*, the more accurate performance on ORCs with a number mismatch confirms that the similar pronunciation is not a confound for the results. Our findings therefore reveal that N restriction is not the underlying source of difficulty for comprehension. Rather, features more minute than categorical N suffice to give rise to intervention effects. As a result, we conclude that inclusion is established by matching phi-features, and intersection by a difference in these phi-features, while a more gross feature such as lexical N does not seem to be relevant for the computation of locality.

Study 2 turned to better defining these finer-grained features, and more specifically to determining whether or not they could be of a semantic nature, such as animacy. Indeed some studies claim that in order to count for locality, and more specifically for the triggering of an intersection configuration, features need to be attractors for movement by being realized on the probe (Belletti et al. 2012). Other authors report ameliorating effects of animacy in certain configurations and certain age-groups (Bentea et al. 2016; Adani et al. 2015). While this feature may arguably be relevant for movement depending on certain views (Bentea et al. 2016), it remains entirely absent from the probe in French and thus serves to shed light on how crucial this specific property is for rendering a feature relevant for locality. Our results indicate that, at the same point in development when children capitalize on the number feature to establish intersection relations, they fail to do so on the basis of animacy mismatch. This suggests that animacy does not have the same impact on the computation of locality as *phi*-features realized on a probe, confirming the importance of this notion for RM.

Nevertheless, animacy may provide cues on theta-role assignment and thus facilitate parsing (Lowder and Gordon 2014), which would explain that some studies have detected an effect. However, in most of the previous studies investigating children's performance on ORCs with a mismatch in animacy, the sentence is semantically non-reversible and the only plausible interpretation is one in which the animate subject is the agent. Thus, improved performance with ORCs headed by an inanimate noun could stem either from the inanimate feature of the first noun, or from the semantic non-reversibility of the RC-internal verb as in *the book that the boy is holding* (see also O'Grady (2011) who also raises the issue of the confound between animacy and semantic reversibility). In the current investigation, our materials were specifically designed to put the inanimates on a par with animates in terms of their roles as plausible Agents, as all RCs were semantically reversible, and consequently diminished the possibility for children to use the animacy mismatch to simplify theta-role assignment. As such, the findings shed clearer light on the role played only by the morpho-syntax of animacy, independently of thematic cues. Clearly the impact of this feature is less than that of features realized on a probe, as has also been suggested by work on production in both children (Martini 2019) and adults (Belletti & Chesi 2014). RM picks out the features relevant for the computation of locality depending on their function as attractors for movement. As animacy is not such a feature in French, it is not relevant for RM and a mismatch in animacy cannot give rise to the easier intersection relation which we observe for a mismatch in number (Study 1).

Study 3 took as a point of departure the idea that the relevant level of featural overlap leading to different set theoretic relations could have an empirical effect on children's performance. We thus compared across studies to determine to what extent a gradation along these lines could be observed (see **Figure 9**) and contrasted performance on object *who*-questions to performance on *celui/celle* object relatives mismatching in number and to performance on object *which*-questions and *celui/celle* object relatives with a number match. Object *who*-questions represent a clear case of featural disjunction as the moved wh-phrase only bears a +WH feature and is not specified for *phi*-features like gender and number. These structures yield the highest level of comprehension accuracy in children, showing that children have no difficulties with disjunction. *Celui/celle* object relatives with a mismatch in number are examples of featural intersection in which the head of the relative and the intervening subject mismatch in a syntactically relevant feature for locality, namely number. Such intersection structures are associated with an intermediate level of accuracy. Object *which*-questions and *celui/celle* object relatives with a number match give rise to inclusion configurations because the set of *phi*-features on the intervener is included in and matches the featural set specifying the moved constituents (the *which*-phrase and *celui/celle*). Performance for these structures is on a par and is associated with the lowest accuracy level. This follows from a construal of intervention locality in terms of featural RM, a system that penalizes structures with an intervention configuration determined by the degree of similarity between the moved element and the intervener (Rizzi 2018).

It is important to note that our work presents various limitations. For instance, three separate groups of participants were recruited for the three studies, while testing the same children across Studies 1 and 3 would have allowed us to report what proportion of individual children displayed the gradation in comprehension facilitation according to the type of set-theoretic relations. In addition, our work focussed on comprehension, while our predictions are relevant for both comprehension and production. Although previous findings from other studies suggest that the same conclusions may be reached to those reported here (Belletti et al. 2012; Belletti & Chesi 2014; Haendler 2015; Martini 2019), future research would allow to confirm this by testing the same participants across the tasks and across both comprehension and production modalities. Finally, the three experiments across which we compared children's performance include different syntactic structures, i.e. demonstrative headed relatives, plain headed relatives and wh-questions, thus the comparison between the rates of accuracy in these different structures may not be straightforward since other factors such as embedding and the presence of a demonstrative might play a role. However, a careful consideration of the results illustrate that these were not relevant factors for the computation of locality. Indeed, subject constructions are better across the board than object structures, regardless of whether relatives or questions were considered, so embedding clearly does not seem to impact performance. In addition, lexically-restricted (*which*-)questions pattern with relatives headed by a demonstrative (*celui/celle*) relative, suggesting that the presence of a demonstrative cannot account for our findings either. In sum, the degree of overlap of *phi*-features better captures the pattern of performance observed, namely more accuracy is observed as featural differences become more pronounced.

5 Conclusion

This paper is concerned with refining the linguistic theory of locality. The findings we report reveal that matching *phi*-features more minute than categorical N suffice to create both inclusion and intersection configurations. As these arise in the absence of a lexical N restriction, a similarity in N cannot be the underlying source of difficulty in the comprehension of object dependencies, just as a difference at this categorical level is not required to improve comprehension either. Rather, finer-grained features such as number are sufficient for the computation of locality.

Our results also reveal that only mismatches in number lead to intersection relations in French-speaking children, in contrast to animacy, although animacy has a clear semantic impact.[8] This suggests that features that participate in attraction as a property of the probe are necessary to give rise to intersection relations, while other features are irrelevant for locality, despite their providing other cues (Belletti et al. 2012; Friedmann et al. 2017). If the only features impacting locality are those triggering movement, various predictions for future work follow. For instance, case and gender mismatches in French are not expected to improve performance either, because despite morphological reflexes, neither is a feature of the probe. Similarly, while animacy is not relevant for locality in French, it would be expected to influence performance in other languages where the inflectional system does encode animacy, e.g. the Algonquian language of Plains Cree (see Bianchi 2006). This prediction is yet to be tested.

Comparing across studies, set theoretic relations explained the level of children's success, showing the following gradation with respect to the degree of improvement in children's accuracy: disjunction > intersection > inclusion. This follows from a construal of intervention locality in terms of featural Relativized Minimality, a system that penalizes structures with an intervention configuration determined by the degree of similarity between the target and the intervener (Rizzi 2018).

[8] The effect of number seems to be relevant for comprehension at an earlier age than the effect of animacy. Of course, in light of other studies, we acknowledge that it remains an open question whether at another point in development, animacy would become relevant.

Competing Interests

The authors declare that they have no competing interests.

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