

Exploring the Sensitivity to Non-connective Signals of Coherence Relations: The Case of French Speaking Teenagers

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Abstract

Coherence relations between elements of discourse can be signaled by linguistic devices such as connectives and/or non-connective signals. While the use and comprehension of connectives have been studied in different categories of speakers, less is known about the functioning of non-connective signals of coherence relations, especially in younger populations. In the current series of three experiments, we aim to examine the sensitivity of French-speaking teenagers to the non-connective signals of the list relation (adjectives of quantity such as *plusieurs* ‘several’ and *différents* ‘various’), combined with connectives varying in frequency and signaling two types of coherence relations (addition: *en plus*, *en outre*; consequence: *donc*, *ainsi*). Our results reveal that, as early as in teenage years, speakers are sensitive (i.e., they produce list continuation sentences) to non-connective signals of list relation (Experiments 1, 2, 3). Furthermore, the inference of list relation is not significantly changed when a non-connective signal is combined with the more frequent additive connective *en plus* (Experiment 2). However, this inference is inhibited by the less frequent additive connective *en outre* (Experiment 3), and is almost completely hindered by the consequence connectives *donc* (Experiment 2) and *ainsi* (Experiment 3). Overall, these results show that non-connective list signals are an important source for the inference of the list relation, even in the presence of more salient and prototypical signals of coherence such as connectives.

Keywords: discourse connectives, non-connective signals, coherence relations, French, teenagers.

1 Introduction

Coherence is an important property of meaningful discourse (Sanders et al., 1992). Between discourse segments, coherence hinges on the ability to infer an appropriate coherence relation, such as causality or contrast. There are various linguistic elements that help speakers to infer an appropriate coherence relation. Connectives, i.e., words like *because* or *nevertheless*, are one of the most studied signals of coherence relations (e.g., Bloom et al., 1980; Champaud & Bassano, 1994; Blything, Davies & Cain, 2015), with studies focusing on speakers from various age groups (see e.g., Blything & Cain, 2016; Evers-Vermeul & Sanders, 2009; Nippold et al., 1992) and linguistic competences (see e.g., Crosson et al., 2008; van Silfhout et al., 2015; Volodina & Weinert, 2020).

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Many coherence relations, however, are not marked by a connective but rather conveyed implicitly. In the Penn Discourse Treebank (PDTB 3), about 41% of the relations are not marked by connectives (Webber et al., 2019). Liu (2019), examining the distribution of signals across four different text genres, namely academic articles, how-to guides, interviews, and news articles, from the Georgetown University Multilayer (GUM) corpus (Zeldes, 2017), also found that connectives signal only 16% of relations as opposed to 84% of relations marked by other signal types. Similarly, in the mono-genre RST Discourse Treebank (Carlson et al., 2002), only about 11% of coherence relations are signaled exclusively by connectives, whereas approximatively 75% of relations are marked by other, non-connective types of coherence signals (Das & Taboada, 2018). In fact, Das and Taboada (2018) identified at least seven types of non-connective coherence markers in this corpus, such as lexical, semantic, morphological, syntactic, graphical, genre, and numerical features (for other approaches to the annotation of different signal types, see Knaebel & Stede, 2022; Liu & Zeldes, 2019; Zeldes & Liu, 2020). For instance, such syntactic features as the present participial clause in (1) can signal the relation of manner; and the antonyms in (2) are the semantic signals of the contrastive relation (Das, 2014).

(1) Wyse has done well, establishing a distribution business.

(2) ... higher bidding narrows the investor's return, while lower bidding widens it.

Although the corpus studies underscore the importance of alternative coherence signaling besides connectives, less is known about the inference of coherence relations from these types of signals (but see Brown & Fish, 1983; Scholman et al., 2020). Moreover, very few studies (except for Crible, 2021; Crible & Demberg, 2021; Crible & Pickering, 2020; Grisot & Blochowiak, 2021; Schwab & Liu, 2020) have assessed how different types of signals interact with each other. Lexical (Schwab & Liu, 2020) and syntactic (Crible & Pickering, 2020) cues, for instance, were found to reinforce inference of a particular coherence relation signaled by polyfunctional connectives, such as *but* or *and*. However, it is not clear whether the interaction between non-connective signals and connectives would be the same if the latter were monofunctional, specialized in marking one type of coherence relation. In comparison to non-connective signals, connectives are more salient markers of coherence, as the signaling of coherence relations is their primary function, and they are often used in a prominent clause-initial position. In contrast, non-connective signals often occupy less prominent syntactic positions and are not specialized in signaling coherence relations. Therefore, an important question is whether the inference from non-connective signals, such as the lexical or semantic features from Das and Taboada (2018), is still generated on top of the contribution of a stronger cue of coherence relations, such as a connective.

As little as we know about the functioning of non-connective signals of coherence relations in adults, even less is known about the sensitivity to these signals in younger populations. In other words, we do not know whether and how young speakers are guided by non-connective signals in their production of coherence relations. To the best of our knowledge, only Au (1986) examined the sensitivity of preschool children to the implicit causality verbs and showed that already at the age of 5, speakers could perceive whether it is an agent or a patient who is causing a certain event in a sentence. However, teenage years seem not to have been studied, even though this period is found to be important for the development of an adult-level linguistic competence (Berman, 2004).

Moreover, even adult speakers show variation in their linguistic competence in general (Kidd et al., 2018) and in the sensitivity to non-connective signals of list relations in particular (Scholman et al., 2020). Thus, Scholman et al. (2020) demonstrated that the ability of adult speakers to infer the relation of list from the expressions of quantity like *a couple*, *a few*, *multiple*, and *several* varied according to the speakers' degree of exposure to print (as measured by the Author recognition test). In order to explore this relation further, we will extend the study of non-connective list signals on a younger population, who has even less linguistic experience than adults and is probably still acquiring a sensitivity to such signals. We therefore expect that, when both a non-connective signal (e.g., expressions of quantity) and a connective are present in a sentence, speakers of all ages, but especially young ones, should be more influenced by

connectives than by the non-connective signals, as connectives represent more salient and specialized cues of coherence.

2 The role of non-connective signals for coherence marking

There are various types of non-connective signals that can mark different coherence relations. Many have studied the role of lexical cues for the inference of causal relations (e.g., Au, 1986; Koornneef & Van Berkum, 2006; Pyykkönen & Järvikivi, 2010; Rohde & Horton, 2014). Pyykkönen and Järvikivi (2010), for instance, showed that in the sentences *John feared Bill because ...* and *John frightened Bill because ...*, the implicit causality verbs *fear* and *frighten* immediately activate verb-based reference toward either the second or the first participant of the action, respectively. Kehler (1994) and Lascarides & Asher (1993) revealed the importance of morphological features, such as the combination of verb tenses, for signaling order of the occurring events. For example, in (3), the usage of the past simple in the first sentence and past perfect in the second one suggests that the event presented in the second clause (swimming in the lake) preceded the one shown in the first clause (illness).

- (3) Jane fell ill. She had swum in the cold lake.

There is also evidence about non-connective signals used in other coherence relations. For instance, Crible and Pickering (2020) found a facilitating effect of syntactic parallelism in combination with the connectives *but* or *and* for marking the relation of addition and contrast (4), as sentences with parallel structures were read faster than sentences without parallelism across a series of self-paced reading experiments. Schwab and Liu (2020) observed in a self-paced reading task that the lexical cues *true* and *sure*, like in the example (5), helped readers to anticipate the upcoming concessive relation, as reflected by shorter reading times at the post-critical region. Moreover, Crible (2021) demonstrated in a series of four self-paced reading experiments that verbal negation, introduced in the first sentence, facilitates processing of the concessive relation, removing the difference in processing cost between the more complex concessive relation and the less complex result relation.

- (4) Nick always eats in low-budget restaurants and/but Grace always eats in fancy places (Crible & Pickering, 2020, p. 8).
 (5) James likes to run. True/sure, he has a treadmill in the living room, but he often jogs in parks (Schwab & Liu, 2020, p. 106).

Crible and Demberg (2021) argued that resultative verbs, as in (6), and antonyms as in (7), respectively generate inferences of consequence and contrast relations. Yet, the inference power of these non-connective signals was not as important as that of connectives signaling the same relations. As for temporal relations, Grisot and Blochowiak (2021) reported in a bilingual French-English corpus study that pluperfects signal backward temporal relations, simple past marks forward temporal relations, and imperfectives convey synchronous temporals.

- (6) Males have been proven to be more skilled at sports. It allows them to win in mixed competitions (Crible & Demberg, 2021, p. 320).
 (7) The Belgian government decided to create a new tax on solar panels. The French government decided to remove the existing tax (Crible & Demberg, 2021, p. 321).

Less is known, however, about the inference generation of an additive relation. Still, Scholman et al. (2020) examined expressions of quantity such as *a couple*, *a few*, *multiple*, and *several*, and found that they activate the inference of list relation – a particular type of a more generic additive relation – in adult speakers. In addition, the corpus study by Péry-Woodley et al. (2017) showed that the relation of list, or enumeration, can be expressed by a variety of enumerative structures of different length and graphical aspect, such as multiparagraph structures and bullet lists. Interestingly, it also showed that these structures often have a similar organization. They predominantly start with a trigger, which often includes a lexical cue. The trigger element is followed by a series of items, which in turn can be followed by a closure element.

These findings are particularly insightful, because additive relations are one of the relations that are the least signaled by connectives and are conveyed by the greatest variety of non-connective signals (Das & Taboada, 2018). It even seems that speakers' comprehension of additive

relations is hindered when an additive connective is present between two sentences (Kleijn et al., 2019), as in (8). This effect is different from other types of relations such as cause or contrast that elicit better comprehension scores when marked by connectives. A possible reason of this hindering effect, as suggested by Kleijn et al. (2019), is that additive connectives draw excessive attention to the coherence relation and elicit an overinterpretation of the intended relation in contrast to a simple juxtaposition. Other signals become therefore interesting to investigate, especially to better understand how additive relations work.

- (8) Not everyone can register in the Donor Register: you must be at least twelve years old and in addition you must be a registered citizen of a Dutch municipality (Kleijn, 2018, p. 216).

Another important contribution would be to examine the interaction between non-connective signals of coherence relations and connectives. Only few studies have attempted to explore this interaction, reporting findings for a limited number of coherence relations, namely contrast (Crible & Demberg, 2021; Crible & Pickering, 2020), consequence (Crible & Demberg, 2021), and concession (Schwab & Liu, 2020). However, more work is needed to describe how this interaction works for other types of coherence relations. In this respect, it would be useful to provide evidence on the interaction between non-connective signals and connectives signaling a less studied additive relation. For instance, assessing the interaction between non-connective list signals, additive and consequence connectives for readers' propensity to generate inferences of list relations would enable us to evaluate whether these relations are still inferred from non-connective signals. Importantly, one could document whether they are inferred even in the presence of stronger coherence signals such as connectives marking the same or a different type of relation. In all, it would constitute an interesting extension to the study by Scholman et al. (2020). Moreover, examining speakers' sensitivity to non-connective list signals and their interaction with connectives in teenagers would allow us to fill a gap in literature on non-connective signaling in teenage years and to generalize the results of Scholman et al. (2020) to other age groups.

It is also possible that even connectives conveying the same type of coherence relation but varying in frequency may have a different impact on the generation of inferences. For instance, even adults have difficulties using (Tskhovrebova, Zufferey & Gygax, 2022; Zufferey & Gygax, 2020b) and identifying correct and incorrect uses (Zufferey & Gygax, 2020a) of the infrequent connectives *aussi* 'therefore' and *en outre* 'in addition'. In consequence, since speakers appear to be less confident about the usage of less frequent connectives, these connectives may also generate weaker inferences of a certain coherence relation, even combined with non-connective signals. An overview of research on the competence with connectives in teenage years will allow us to make predictions on the sensitivity to non-connective signals in combination with connectives (of different frequency) in this age group.

3 Teenagers' competence with connectives

Teenage years are an important period of linguistic development between the emergence and mastery of language (Berman, 2004). Language development in teenagers continues on lexical, semantic, syntactic, and pragmatic levels (see, e.g., Nippold, 2008). The mastery of connectives, in turn, is at the interface between lexical, syntactic and pragmatic skills, which are actively developing during this period, and therefore occupy a central role in the development of a full-fledged linguistic competence.

Previous research has shown that, on average, teenagers' competence with any type of connectives is inferior to that of adult speakers (Nippold et al., 1992; Tskhovrebova, Zufferey & Gygax, 2022; Zufferey & Gygax, 2020b). Nippold et al. (1992) assessed the competence of English-speaking teenagers aged 12 to 15 and young adults aged 19 to 23 with connectives mostly used in written language, such as *furthermore* and *nevertheless*, in a connective insertion task and a sentence continuation task. The authors found that young adults performed significantly better than teenagers in both tasks. A similar result was obtained in two studies examining the usage of four French connectives bound to the written modality but varying in frequency (Tskhovrebova, Zufferey & Gygax, 2022; Zufferey & Gygax, 2020b). Both studies

demonstrated that even high-school students aged 16 to 18 did not reach the performance of adults in the connective cloze task across all connectives, suggesting that proficiency with connectives continues to develop through the late teenage years. Moreover, research on competence with connectives in L2, i.e., for speakers with a lower level of linguistic proficiency and can be in that respect compared to teenagers, shows that language learners also have difficulties detecting incorrect uses, even for very frequent connectives. The study of Wetzel et al. (2022) reported, for instance, that German-speaking learners of French did not react to the erroneous uses of the frequent French connective *alors* ‘so’ in a self-paced reading task.

Considering the findings on the mastery of connectives by less experienced speakers, we suggest that teenagers may also be less proficient with non-connective signals of coherence relations, and thus less sensitive to them when they are used either alone or combined with connectives. This may be true, but not for all teenagers, as some individual factors may be decisive in determining whether they have a lower sensitivity to non-connective signals or not. For example, in adult populations, exposure to print, as measured by an author recognition test (Stanovich & West, 1989), has been shown to modulate reader’s mastery of connectives (Zufferey & Gygax, 2020a) and sensitivity to non-connective signals (Scholman et al., 2020). Degree of general exposure to print could therefore be an important factor, modulating the inference generated by non-connective signals in combination with connectives, also in teenage populations.

4 Our set of experiments

In the current set of experiments, we aim to address the gaps identified in previous research on non-connective signals of coherence relations. Our goal is to extend the study by Scholman et al. (2020) on a younger cohort of teenagers and to examine their sensitivity to non-connective signals of the list relation (Experiment 1) in combination with connectives varying in frequency and signaling two types of coherence relations (Experiments 2 & 3). More specifically, we assess French-speaking teenagers’ sensitivity to the adjectives of quantity *plusieurs* ‘several’ and *différents* ‘various’, and how this sensitivity is modulated by the presence of connectives signaling the relations of addition and consequence. This way, we aim to examine whether a list inference, generated by a non-connective signal, is strong enough to trigger list continuations on top of the inference generated by connectives. The additive connectives were chosen because addition does not compete with the logic of the list relation. In fact, additive relations represent a generic type of relations that include several subtypes, among them the relation of list. In contrast, the consequence connectives were selected because consequence represents a separate class of coherence relations, which is competing with the logic of the list relation (see Table 1 for a summary of all the signals used in the set of experiments). We use the following definitions for the three coherence relations included in our experiments:

1. Sentences are linked with a list relation when the second sentence enumerates one or several events related to the content of the first sentence;
2. Sentences are linked with an additive relation when the second sentence expands and elaborates on the content of the first sentence, except for instances of enumeration that are included in the category of list relations;
3. Sentences are linked with a consequence relation when the second sentence describes an event caused by an activity presented in the first sentence.

	Non-connective signals	Connectives	
		Additive	Consequence
Experiment 1	<i>plusieurs</i> ‘several’ <i>différents</i> ‘various’	–	–
Experiment 2		<i>en plus</i>	<i>donc</i>
Experiment 3		<i>en outre</i>	<i>ainsi</i>

Table 1. All the connectives and non-connective signals used in our set of experiments.

Based on the results of Scholman et al. (2020), we predict that participants will produce more list continuations after reading items containing adjectives of quantity in all experiments.

However, it is possible that teenagers will be less sensitive than adults to such signals, due to a lower level of linguistic competence. We also expect that after reading sentences including both a list signal and an additive connective (Experiments 2 and 3), the proportion of list continuations should not decrease, but rather increase or remain unchanged because an additive connective is not in contradiction with the relation of list. Moreover, we predict that the combination of a list signal and a consequence connective will decrease the percentage of list continuations, as this type of connective expresses a non-compatible relation of consequence, and this will override the inference generated by a less salient and more polysemous (in the sense that it is not specialized only in coherence marking) non-connective signal of list (Experiments 2 and 3). Finally, we expect that the general effect from the less frequent connectives (Experiment 3) will be lower than from the more frequent connectives (Experiment 2).

To identify whether the sensitivity to these signals in young speakers also varies depending on individual differences in linguistic competence, we assessed the participants' degree of exposure to print, as measured by adapted French versions of the author recognition test (Tskhovrebova, Zufferey & Tribushinina, 2022; Zufferey & Gygax, 2020a).

5 Experiment 1

5.1 Participants

Fifty-three teenagers ($M_{\text{age}} = 14.18$, $SD = 1.66$, Range: 12–18) and twenty adults ($M_{\text{age}} = 31.36$, $SD = 11.35$, Range: 21–63) took part in the experiment. All of them were native French speakers. The experiment among teenagers was carried out in secondary and high schools of the French-speaking part of Switzerland, and was performed online via a weblink. Adults were recruited online on the Prolific© platform (Prolific, Oxford, UK).

5.2 Materials and procedure

5.2.1 Story-continuation task

In this experiment, participants had to write a continuation to a series of pairs of sentences. In each pair, the first sentence introduced an agent and the context it was in, and either included a list signal (the adjectives of quantity *plusieurs* ‘several’ or *différent* ‘various’) or not. The second sentence started with a pronoun coreferential with the agent of the first sentence, and developed the situation. Example (9) illustrates an experimental item in the list and non-list conditions.

(9) List condition:

La comédienne a planifié plusieurs rendez-vous pour la journée. Elle a prévu d'aller voir son agent.

‘The actress scheduled several appointments for the day. She planned to meet her agent.’

Non-list condition:

La comédienne se préparait à la maison. Elle a prévu d'aller voir son agent.

‘The actress was getting ready at home. She planned to meet her agent.’

The second sentence was identical across both *list signal* conditions. We did not simply remove the adjectives of quantity from the first sentence of the condition without list signal, but also changed the verb for several reasons. First, we wanted to prevent list and non-list items from being perceived as repetitions of the same sentence after reading multiple task items in a row, which could be the case if we just omitted the list signal. Second, we wanted to make sure that participants would perceive list and non-list items as different sentences and treat them as such across the whole task, but without making it obvious that the presence or absence of these non-connective signals were the focal point of the task. Third, we wanted to ensure that list and non-list items were similar in terms of the expectations that they would create. Our objective was to

build neutral sentences in the non-list condition, without any obvious non-connective cues of coherence (such as implicit causality verbs, for instance).

The choice of the adjectives *plusieurs* and *différents* was based on several criteria. First, they have the same function in French as previously examined English expressions of quantity from the study of Scholman et al. (2020). Second, both *plusieurs* and *différents* belong to the same part of speech (indefinite adjectives) and are used in the same syntactical position before nouns. Third, they refer to an indefinite number of things or events in contrast to other indefinite adjectives of quantity like *quelques*, which normally is used to describe a small number of things, or *nombreux* and *multiple*, which refer to large numbers of things or events. Finally, both adjectives are frequent in French with 447.03 (for *plusieurs*) and 144.79 (for *différent*) occurrences per million words.

In total, there were 20 items, with two conditions per item (with and without list signal). Each type of list signal was inserted equally frequently across all list conditions. Participants were asked to provide a continuation with at least one sentence that had to be complete, grammatically correct, and contain at least three words. All participants saw all the items, both with and without list signal. It was important that participants saw both types of items to examine whether it was the presence of a list signal that affected their inference generation and that the latter was not due to individual bias towards a specific relation.

Coding Procedure

Continuation sentences were annotated for the analysis as *list*, *additive*, *consequence* or *other*, depending on their relation to the cue sentence. We defined as *list* continuations those sentences that contained an enumeration of one or several events related to the content of the first cue sentence. Examples (10) – (12) illustrate list continuations that participants wrote in the list condition for item (9).

- (10) Et elle a prévu de passer d'autres castings.
'And she planned to do more castings.'
- (11) Puis elle prévu d'aller faire un coucou à ses grand-parent¹.
'Then she planned to go and say hello to her grandparents.'
- (12) Elle doit aussi aller se faire une teinture chez le coiffeur.
'She also has to get her hair dyed.'

There were several completion sentences that expressed not only list, but also temporal (11) or contrast (13) relations at the same time. In such cases, continuations were labelled as *list*, as the focal point of this set of experiments was to identify sentences conveying the idea of enumeration in relation to the prompt.

- (13) Task sentences:
La journaliste a fait différents commentaires sur le film. Elle a apprécié le jeu de l'actrice principale.
'The journalist made various comments about the film. She appreciated the acting of the lead actress.'
Continuation:
Elle a moins aimé la qualité des dialogues.
'She liked the quality of the dialogues less.'

We coded as *additive* those continuations that provided new information or more details about the first or the second task sentences, including exemplification and sub-events, but excluding the instances of enumeration, which were included in the category of list relations. In the continuations (14) and (15), for instance, participants do not list any other activities planned by the actress for the day as in (10) – (12), but rather add a new fact about an actress (14) or her agent (15). For this reason, these continuations were labelled as additive rather than list. We did not make a further distinction about additive and elaboration relations, as it was not relevant for our set of experiments.

- (14) Task sentence (list condition):

¹ We kept the faulty original spelling of participants in French examples.

La comédienne a planifié plusieurs rendez-vous pour la journée. Elle a prévu d'aller voir son agent.

'The actress scheduled several appointments for the day. She planned to meet her agent.'

Continuation:

Elle a reçu beaucoup d'argent.

'She received a lot of money.'

(15) Continuation:

Celui-ci a annulé au dernier moment.

'The latter cancelled at the last moment.'

When a continuation phrase described an event caused by an activity presented in the task item, it was tagged as a *consequence* relation. Example (16) illustrates a consequence continuation that was written by one of the participants after a task item in the list condition. The fact that the girl's mother gave her an ice cream is considered here to be a consequence of her good performance at school.

(16) Task sentence (list condition):

La fille a reçu plusieurs bonnes notes à l'école. Elle a réussi l'examen d'histoire.

'The girl received several good marks at school. She passed the history exam.'

Continuation:

Donc sa maman l'a récompensé avec une glace.

'So her mother rewarded her with an ice cream.'

All the remaining relations were labelled as *other*. This category included several types of discourse relations, such as temporality, contrast, cause, and goal, which were not further distinguished, as it was not essential for the goals of the present investigation.

If a participant provided several continuation sentences, discourse relations between the provided continuations were not labelled, since it was outside of the scope of the present set of experiments. Our focus was on discourse relations between the prompt and the completion sentence. Out of 8114 continuations², 10% were annotated together by one of the authors and an independent experienced coder. It is important to mention that, when we deal with the annotation of discourse relations, multiple, non-self-excluding interpretations can be possible and not always all of these interpretations are noticed and taken into account by coders. However, the agreement rate between the two coders on this continuation sample was 95% ($\kappa=.82$; Gwet's $AC_1=.92$), which granted the remaining of the continuations to be divided in half and annotated independently. Note that all instances where one coder had doubts were cross-checked by the other coder.

5.2.2 Author recognition tests

To assess teenagers' degree of exposure to print, we used an adapted version of the author recognition test (ART) (Tskhovrebova, Zufferey & Tribushinina, 2022), since the ART is not only sensitive to cultural differences (e.g., Stainthorp, 1997) but also to age (e.g., Cunningham & Stanovich, 1990). This version of the ART (*ART-F-CL*) was based on the names of French-speaking authors who are considered to be classics according to three Swiss and French national libraries and bookshop chains. The list included 40 author names and 40 names of unknown people, which were randomly mixed. The participants had to select only those names that they knew to be authors. The instruction mentioned that some of the names were not authors, and that one point would be removed if the participants checked a wrong name. For each correct answer, the participants were given 1 point, and for each wrong one -1. The maximum possible score therefore was 40 and the minimum -40, as we computed the general score summing up the points for correct and incorrect answers.

For the adult control group, we used a different version of the ART, which was developed by Zufferey and Gygax (2020a, <https://osf.io/yxj8q/>) and was based on the names of best-selling and prize-winning authors (*ART-F*). The ART-F replicated the design of the

² The details about annotation are reported for the data from all three experiments.

original English ART (Stanovich & West, 1989). The number of items and the calculation of the final score was the same as for the teenage version of the task, described before. The reliability of the tests was quite high, as indicated by their Cronbach's alphas which are close to or greater than .90 (ART-F-CL: .88 [.85–.91]; ART-F: .92 [.86–.94]).

The participants fulfilled the tasks always in the same order, starting with the story-continuation task and finishing with the ART. Once the participants gave an answer and proceeded to the next question, they could not go back and correct their initial response.

5.3 Analysis

Continuation sentences were analyzed by fitting generalized mixed-effects logistic regression models on the binary variable (list versus non-list relation), using the R software (RStudio Team, 2015). We tested models with the *glmer* function of the *lme4* package (Bates et al., 2015) and made model comparison with the *anova()* function, using a forward-testing approach. We added main and interaction fixed effects one at a time, and each model with an added factor was compared to a previous model that did not have the included factor. P-values of the final model were obtained with the *summary()* function from the *lmerTest* package (Kuznetsova et al., 2014). The statistical significance level was set at <5% and is indicated by bold marking in the corresponding tables. In total, we created three models: the first one only for teenage participants, the second one only for adults, and the third one for both age groups. In addition, for each separate analysis, we performed a pairwise comparison between list signal (absent versus present) and connectives used in the task with the *lsmeans()* function of the *emmeans* package in R (Lenth, 2020).

This analysis at first was performed separately for teenagers and adults, and then together for all participants. Age groups were first analyzed separately, given that our primary aim was to shed light on teenage sensitivity to non-connective list signals – and given that ART was different across age groups. We also present general analyses considering all groups together, yet without including ART. In order to facilitate reading, we report all the details of the model selections in the Online Appendix³. Moreover, separate models for teenagers and adults are also included in the Online Appendix, since the degree of exposure to print, as measured by ART-F-CL and ART-F, did not predict the variation in the sensitivity to list signals.

5.4 Results and discussion

Our final model included List Signal (absent versus present) and Group (teenagers versus adults) as fixed factors (both main and interaction effects), and Item and Participant as random intercepts (see Table 2 and Figure 1). The results demonstrate that both teenagers and adults were sensitive to list signals, as revealed by an estimated increase of $1.95 \pm \text{SE } 0.33$. However, there was a significant interaction between the factors Group and List signal, demonstrating that teenagers were on average less sensitive to list signals than adults. Finally, in the condition without list signal, the production of list continuations did not vary between the two groups of participants. The two separate analyses within each age group confirmed the effects found in the general analysis and did not reveal any significant inter-individual variation, related to the degree of exposure to print and age.

This result replicates the finding of Scholman et al. (2020) on the sensitivity to list signals, applied both to adult and young speakers of French. In the next experiment, we aim to examine further the effect from the adjectives of quantity. More precisely, we assess whether participants are still sensitive to these non-connective signals, even if the task items include both adjectives of quantity and different types of connectives, which are more salient and prototypical signals of coherence relations.

³ The URL of the Online Appendix is provided in the Data Availability Statement.

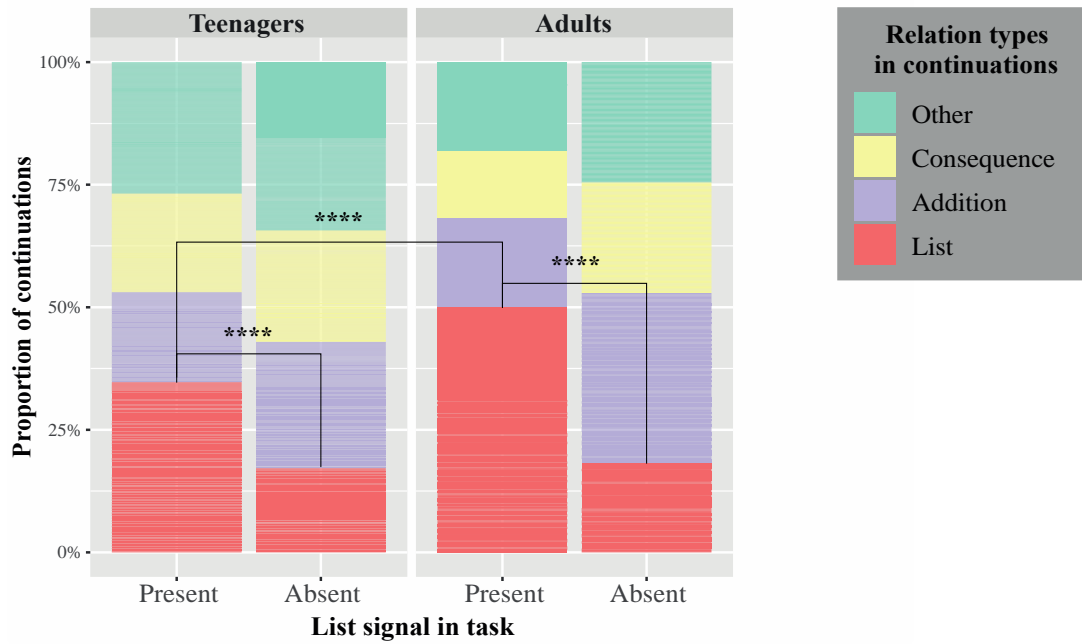


Figure 1. Proportions of different types of relations in the continuation sentences in Experiment 1 (see Table S1 in Online Appendix for the exact values).

	Estimate	SE	z	p
All participants				
(Intercept)	-1.92	0.36	-5.37	<.001
List signal	1.95	0.33	5.85	<.001
Teenagers	-0.22	0.36	-0.63	0.529
List signal*Teenagers	-0.75	0.23	-3.29	0.001
Teenagers				
(Intercept)	-2.18	0.29	-7.51	<.001
List signal	1.20	0.31	3.92	<.001
Adults				
(Intercept)	-1.96	0.34	-5.76	<.001
List signal	2.00	0.43	4.64	<.001

Table 2. Model's estimates for the best fitting models in Experiment 1.

Note. In the model for all participants, conditional $R^2\Delta=.36$, marginal $R^2\Delta=.08$; for teenagers, conditional $R^2\Delta=.35$, marginal $R^2\Delta=.05$; for adults, conditional $R^2\Delta=.40$, marginal $R^2\Delta=.13$.

5.5 Additional analysis of the distribution of connectives in list continuations

We noticed that in this experiment, where connectives were not included in the prompt passage, participants added their own connectives in 80% of list continuations. When we fitted the generalized mixed-effects logistic regression model on the binary variable (absence versus presence of the connective in the list continuation), adding the factors of list signal (absence versus presence in the task item) and group (adults versus teenagers) did not improve the model's fit (list signal: $\chi^2(1) = 0.22$, $p < .638$; group: $\chi^2(1) = 0.22$, $p < .638$). In other words, the

insertion of the connective in list continuations was not predicted by the presence or the absence of the adjectives of quantity in the task sentence for both groups of participants.

However, it seems that the position in which teenagers and adults used connectives in their productions was different. Teenagers inserted connectives in sentence-initial position in 70% of the cases against only 31% for adults. In contrast, sentence-medial or sentence-final position takes up 14% of continuations produced by teenagers against 50% for adults. In the remaining 16% (for teenagers) and 19% (for adults) of continuations, participants did not use any connective. Among teenagers, the most popular connective was sentence-initial *et* ‘and’ (48%), followed by sentence-medial *aussi* ‘also’ (11%), and sentence-initial *mais* ‘but’ (6%), and *puis* ‘then’ (5%). Adults used most often sentence-medial connectives *aussi* ‘also’ (24%) and *également* ‘also’ (18%), sentence-initial *et* ‘and’ (10%), sentence-medial *ensuite* ‘then’ (7%), and sentence-initial *puis* ‘then’ (5%). Examples (17) and (18) illustrate the use of some of these connectives.

(17) Task item:

L'acrobate a signé plusieurs contrats. Il va participer au festival du cirque à Grenoble.
‘The acrobat has signed several contracts. He will be taking part in the circus festival in Grenoble.’

Continuation provided by a teenager:

Et il va y gagner.

‘And he's going to win.’

(18) Task item:

La fille a reçu plusieurs bonnes notes à l'école. Elle a réussi l'examen d'histoire.
‘The girl got several good marks at school. She passed her history exam.’

Continuation provided by an adult:

Elle a aussi réussi l'examen d'anglais.

‘She also passed her English exam.’

6 Experiment 2

6.1 Participants

Fifty-four French native speaking teenagers ($M_{\text{age}} = 14.44$, $SD = 1.62$, Range: 12–17) and twenty-two adults ($M_{\text{age}} = 26.10$, $SD = 7.17$, Range: 18–43) participated in the second experiment. The recruitment modalities of both groups of participants were the same as in Experiment 1.

6.2 Materials and procedure

The ART tests were the same as in Experiment 1, while the story-continuation task was slightly modified. Participants were asked to fulfil an almost identical story-continuation task to the one in the first experiment, with the only difference that the second sentence was this time followed by a connective. The selected connectives *en plus* and *donc* respectively encode a relation of addition and consequence and are frequently used in French (respectively, 279.30 and 3'318.41 occurrences per million words⁴). Adding connectives allowed us to examine whether participants' sensitivity to list signals was modulated by the presence of a connective. Moreover, by including different types of connectives, we also aimed to study their effect on the generation of inference for the upcoming coherence relation. The additive connective is not in contradiction with the logic of enumeration conveyed by the lexical signal, as this connective encodes a more generic additive relation, and can also introduce a list relation (more specific). The connective *en plus* was a particularly suitable candidate for this experiment, as it is

⁴ The connectives' mean frequency was calculated by averaging their frequencies in oral and written language. The frequency in oral speech was calculated based on the oral sub-corpus of *Orféo* (Benzitoun et al., 2016). The frequency in writing was obtained based on three different corpora, namely *Le Monde* (Monde, 1987–2012), the French part of *Europarl* (Koehn, 2005), and *Frantext* (ATILF, 1998–2022), respectively representing journalistic, argumentative and literary genres.

frequent, monofunctional, and specialized in signaling additive coherence relations (Roze et al., 2012). In contrast, we expected that the connective of consequence should decrease the production of list continuations, as this connective cannot be used to introduce a list relation. Examples (19) and (20) illustrate the items used in Experiment 2.

(19) List condition:

La comédienne a planifié plusieurs rendez-vous pour la journée. Elle a prévu d'aller voir son agent. En plus, ...

‘The actress scheduled several appointments for the day. She planned to meet her agent. In addition, ...’

Non-list condition:

La comédienne se préparait à la maison. Elle a prévu d'aller voir son agent. En plus, ...

‘The actress was getting ready at home. She planned to meet her agent. In addition, ...’

(20) List condition:

Le médecin avait plusieurs lieux de travail. Il avait un cabinet à l'hôpital central. Donc, ...

‘The doctor had several places of work. He had an office at the central hospital. So, ...’

Non-list condition:

Le médecin était spécialisé dans les traitements contre le cancer. Il avait un cabinet à l'hôpital central. Donc, ...

‘The doctor specialized in cancer treatment. He had an office at the central hospital. So, ...’

6.3 Analyses

We started by making the same statistical analysis as in Experiment 1. However, in order to compare the effects from list signals and connectives between the task without connectives (Experiment 1) and the one with frequent connectives (Experiment 2), we made an additional comparative analysis separately for each connective.

6.4 Results

6.4.1 Sensitivity to connectives and list signals in Experiment 2

Our final model included Connective (*en plus* versus *donc*) as a fixed factor and Item and Participant as random intercepts (see Table 3). This result shows that, in contrast to the connective *donc*, the additive connective *en plus* predicted a greater number of list continuations, independently of the presence of the list signal and the age group.

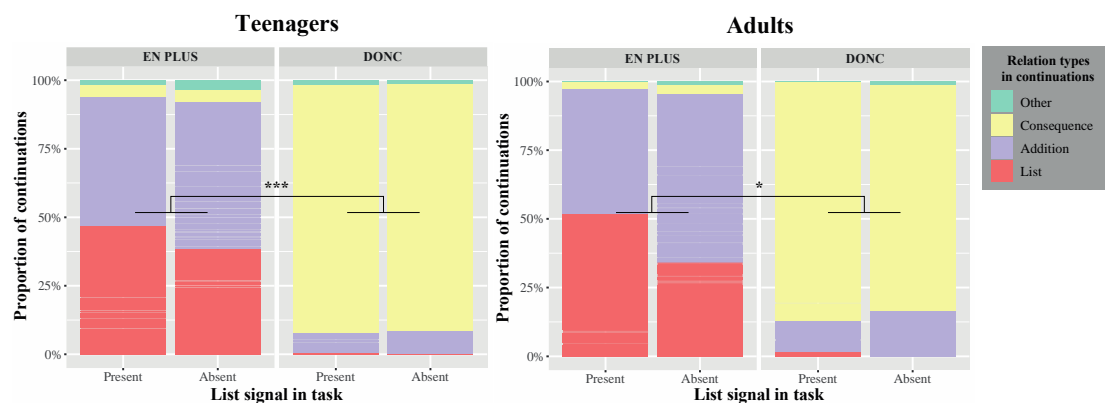


Figure 2. Proportions of different types of relations in the continuation sentences in Experiment 2.

	Estimate	SE	z	p
All participants				
(Intercept)	-6.49	0.52	-12.42	<.001
<i>En plus</i>	6.09	0.54	11.27	<.001
Teenagers				
(Intercept)	-6.75	0.64	-10.50	<.001
<i>En plus</i>	6.34	0.64	9.88	<.001
Adults				
(Intercept)	-6.52	0.91	-7.19	<.001
<i>En plus</i>	6.07	0.93	6.52	0.026

Table 3. Model's estimates for the best fitting model in Experiment 2.

Note. In the model for all participants, conditional $R^2\Delta=.71$, marginal $R^2\Delta=.59$; for teenagers, conditional $R^2\Delta=.74$, marginal $R^2\Delta=.63$; for adults, conditional $R^2\Delta=.75$, marginal $R^2\Delta=.56$.

6.4.2 Additional comparative analysis between Experiment 1 and Experiment 2 for the connective *en plus*

The final model for the analysis, comparing the production of list continuations after the task items without a connective (from Experiment 1) and after the items with the additive connective *en plus* (from Experiment 2), included List Signal (absent versus present), Connective (no connective versus *en plus*), and Group (adults versus teenagers) as fixed factors (both main and interaction effects), and Item and Participant as random intercepts (see Table 4 and Figure 3). The results from this analysis demonstrate that there was a main effect of List signal and of the connective *en plus* for the production of list continuations. However, when a list signal was present in the cue sentence, adults were on average more sensitive to it than teenagers. The post-hoc pairwise comparison revealed that there were significantly more list continuations after the sentences with list signals than without list signals, both when the connective *en plus* was present (log odds ratio=0.57, SE=0.28, $p=.045$) and absent (log odds ratio=1.51, SE=0.26, $p<.0001$). As a result, there was no significant change in the production of lists after the adjectives of quantity between the sentences followed by *en plus* and the sentences not followed by a connective (log odds ratio=0.13, SE=0.25, $p<.598$). However, when the adjectives of quantity were absent in the task sentences, there was a significant increase in the number of list relations in participants' responses after the sentences including the connective *en plus* compared to sentences without this connective (log odds ratio=1.07, SE=0.25, $p<.0001$).

The separate models for teenagers and adults had similar effects as the general model for all participants (see Table 4). The only difference was that teenagers produced significantly more list continuations after the sentences with list signals than after the sentences without list signals when the connective *en plus* was not present in the task (log odds ratio=1.14, SE=0.26, $p<.0001$). In contrast, adults wrote significantly more list continuations after the sentences with list signals than after the sentences without list signals both when the connective *en plus* was present (log odds ratio=0.85, SE=0.43, $p=0.046$) and absent (log odds ratio=1.91, SE=0.38, $p<.0001$). In other words, it seems that teenagers were sensitive to the adjectives of quantity only in the task items that were not followed by a connective, while adults were sensitive to the non-connective signals in both conditions, independently of the connective *en plus*.

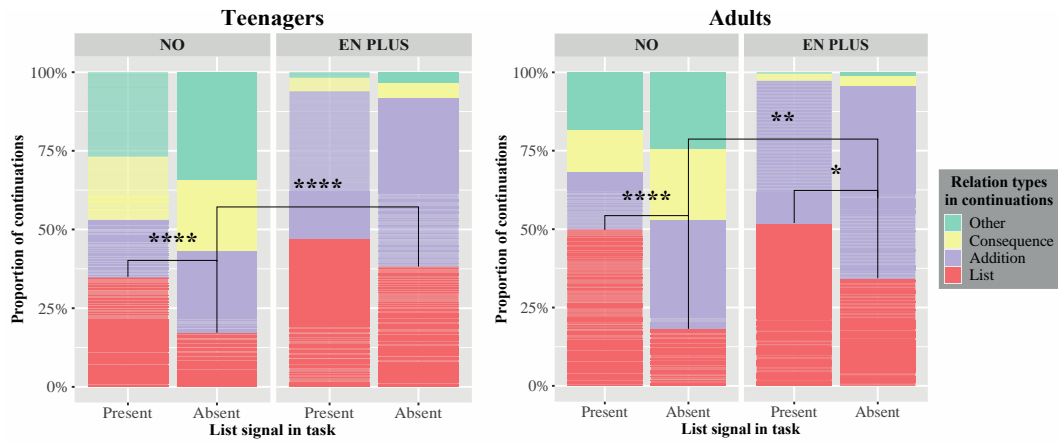


Figure 3. Proportions of different types of relations in the continuation after the task items without a connective (from Experiment 1) and after those with the connective *en plus* (from Experiment 2) across teenagers and adults.

	Estimate	SE	z	p
All participants				
(Intercept)	-1.85	0.34	-5.51	<.001
List signal	1.87	0.30	6.27	<.001
<i>En plus</i>	0.87	0.42	2.08	0.038
Teenagers	-0.22	0.35	-0.63	0.530
List signal* <i>En plus</i>	-1.10	0.30	-3.64	<.001
List signal*Teenagers	-0.73	0.22	-3.25	0.001
En plus*Teenagers	0.40	0.49	0.82	0.413
List signal* <i>En plus</i> *Teenagers	0.33	0.35	0.94	0.349
Teenagers				
(Intercept)	-2.09	0.26	-8.07	<.001
List signal	1.14	0.26	4.40	<.001
<i>En plus</i>	1.35	0.30	4.54	<.001
List signal* <i>En plus</i>	-0.82	0.22	-3.70	<.001
Adults				
(Intercept)	-1.89	0.31	-6.03	<.001
List signal	1.91	0.38	5.02	<.001
<i>En plus</i>	0.81	0.33	2.45	0.015
List signal* <i>En plus</i>	-1.06	0.37	-2.83	0.005

Table 4. Model's estimates for the best fitting model in the additional analysis, comparing the production of list continuations after the task items without a connective (from Experiment 1) and after those with the connective *en plus* (from Experiment 2).

Note. In the model for all participants, conditional $R^2\Delta=.34$, marginal $R^2\Delta=.07$; for teenagers, conditional $R^2\Delta=.35$, marginal $R^2\Delta=.06$; for adults, conditional $R^2\Delta=.37$, marginal $R^2\Delta=.10$.

6.4.3 Additional comparative analysis between Experiment 1 and Experiment 2 for the connective *donc*

The final model for the analysis, comparing the production of list continuations after the task items without a connective (from Experiment 1) and after the items with the consequence connective *donc* (from Experiment 2), included List Signal (absent versus present), Connective (no connective versus *donc*), and Group (adults versus teenagers) as fixed factors (both main and interaction effects), and Item and Participant as random intercepts (see Table 5 and Figure 4). This analysis reveals that the presence of the connective *donc* in Experiment 2 significantly decreased the proportion of list continuations in comparison to the task sentences without this connective from Experiment 1. In other words, both groups of participants were responsive to list signals only after the sentences without the connective *donc*, while the presence of the consequence connective almost completely prevented participants from writing list relations in their productions. The analyses within each age group confirmed the overall effects obtained in the general analysis.

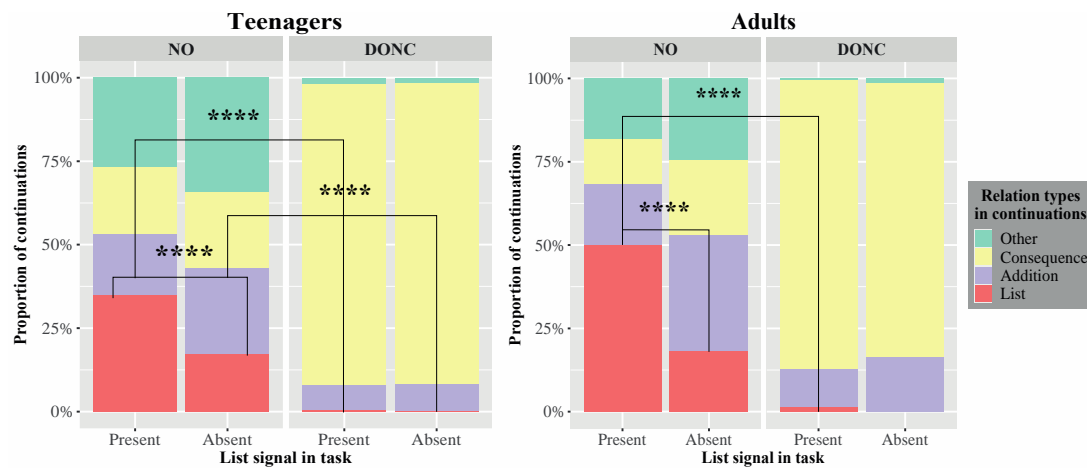


Figure 4. Proportions of different types of relations in the continuation after the task items without a connective (from Experiment 1) and after those with the connective *donc* (from Experiment 2) across teenagers and adults.

	Estimate	SE	z	p
All participants				
(Intercept)	-1.92	0.36	-5.31	<.001
List signal	1.95	0.34	5.80	<.001
<i>Donc</i>	-17.05	7.89	-2.16	0.031
Teenagers	-0.23	0.36	-0.63	0.528
List signal* <i>Donc</i>	11.84	7.88	1.50	0.133
List signal*Teenagers	-0.75	0.23	-3.24	0.001
<i>Donc</i> *Teenagers	12.33	7.88	1.57	0.118
List signal* <i>Donc</i> *Teenagers	-12.63	7.89	-1.60	0.109
Teenagers				
(Intercept)	-2.18	0.29	-7.45	<.001
List signal	1.20	0.30	3.94	<.001
<i>Donc</i>	-4.88	1.06	-4.62	<.001
List signal* <i>Donc</i>	-0.70	1.25	-0.56	0.577
Adults				
(Intercept)	-2.04	0.36	-5.59	<.001
List signal	2.06	0.40	5.21	<.001
<i>Donc</i>	-16.90	86.55	-0.20	0.845
List signal* <i>Donc</i>	11.90	86.54	0.14	0.891

Table 5. Model's estimates for the best fitting model in the additional analysis, comparing the production of list continuations after the task items without a connective (from Experiment 1) and after those with the connective *donc* (from Experiment 2).

Note. In the model for all participants, conditional $R^2\Delta=.76$, marginal $R^2\Delta=.68$; for teenagers, conditional $R^2\Delta=.56$, marginal $R^2\Delta=.40$; for adults, conditional $R^2\Delta=.90$, marginal $R^2\Delta=.86$.

6.4.4 Discussion

The results of this experiment revealed that the presence of the connectives *en plus* 'in addition' and *donc* 'so' affected the sensitivity to the adjectives of quantity of French speakers. The consequence connective *donc* completely overrode the inference from the non-connective signals of the list relation in both groups of participants. As for the additive connective *en plus*, the effects were not the same for the two age groups. Teenagers were sensitive to the adjectives of quantity only in the items that were not followed by the connective *en plus*, while adults remained sensitive to the non-connective signals, independently of the additive connective. However, this finding should be interpreted with caution, as it is based on the comparison between two experiments.

In the next experiment, we examine whether the frequency of the connectives following the task items may be an additional factor affecting the sensitivity to the non-connective signals. More precisely, we assess whether the presence of the less frequent additive and consequence connectives *en outre* 'in addition' and *ainsi* 'therefore', respectively, would produce the same effects on the generation of list inferences as the equivalent frequent connectives. It was found

in previous studies, for instance, that certain infrequent connectives, such as *en outre* ‘in addition’ and *aussi* ‘therefore’, are particularly challenging both for teenagers and adults (Tskhovrebova, Zufferey & Gygax, 2022; Zufferey & Gygax, 2020 a,b). This difficulty may stem from the fact that infrequent connectives are mostly used in written modality, and extensive exposure to the written language happens later than that to the oral language, coming with schooling process (Nippold, 2004; 2008). It is only starting from secondary school that teenagers become autonomous readers and start to be exposed to written texts of various genres (Nippold, 2004; 2008). As a result, connectives that appear mostly in writing, and thus have on average lower frequency, may be mastered less well than those that are often used in oral language.

Hence, in Experiment 3, we included the connectives *en outre* and *ainsi* to assess their effect on the generation of list inferences, as these connectives are mostly used in writing and have a lower frequency. The additive connective *en outre* can be considered as equivalent to *en plus*, as it signals the same coherence relation, but has a much lower average frequency (46.52 versus 279.30 occurrences per million words, respectively). The consequence connective *ainsi* can be considered as equivalent to *donc*, but it is much less frequent (178.61 versus 3'318.41 occurrences per million words, respectively). We include the connective *ainsi* instead of the previously tested *aussi*, as the latter is polyfunctional and can convey both relation of addition and that of consequence (Roze et al., 2012). Including two monofunctional connectives (*en outre* and *ainsi*) allowed us to disentangle two coherence relations and avoid possible confusions.

7 Experiment 3

7.1 Participants

In the third experiment, we recruited 50 French native speaking teenagers ($M_{\text{age}} = 14.34$, $SD = 1.94$, Range: 12–19) and 21 adults ($M_{\text{age}} = 28.64$, $SD = 10.43$, Range: 20–57). The recruitment process of both groups of participants were the same as in Experiment 1.

7.2 Materials and procedure

The ART tests were again the same as in Experiment 1, while the story-continuation task slightly differed. Experiment 3 was almost identical to Experiment 2, and differed only in the choice of connectives. Instead of more frequent connectives, the cue passage included one of the two less frequent connectives, namely *en outre* ‘in addition’ and *ainsi* ‘therefore’.

7.3 Analyses

Statistical analyses were the same as in Experiment 2.

7.4 Results

7.4.1 Sensitivity to connectives and list signals in Experiment 3

The final model for all participants included List Signal, Connective (*en outre* versus *ainsi*), and Group as fixed factors (main and interaction effects), Item and Participant as random intercepts, and Connective as random slope by Participant (see Table 6 and Figure 5). This result shows that, similar to the Experiment 2, the additive connective *en outre* predicted a greater number of list continuations than the consequence connective *ainsi*. However, in contrast to the Experiment 2, teenagers on average wrote fewer list continuations after *en outre* than adults. The separate analyses for teenagers and adults confirmed the trends from the general analysis and did not reveal variation, predicted by the ARTs.

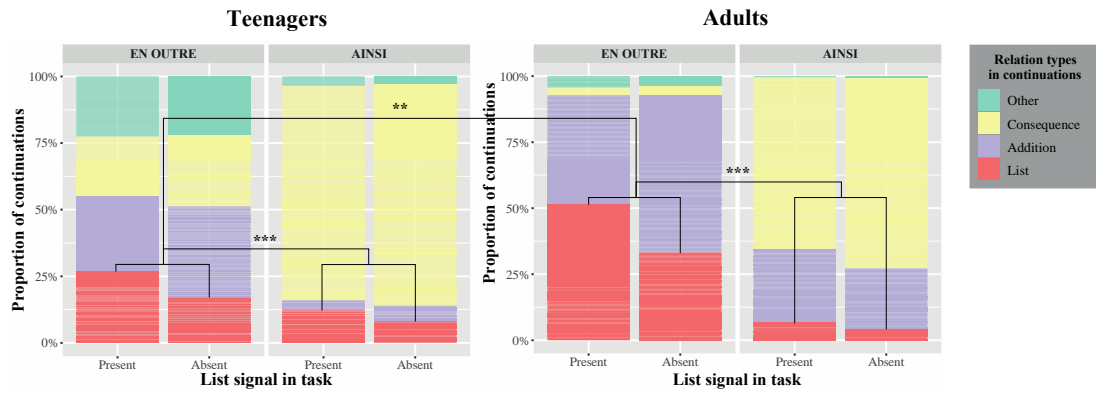


Figure 5. Proportions of different types of relations in the continuation sentences in Experiment 3.

	Estimate	SE	z	p
All participants				
(Intercept)	-7.23	1.33	-5.43	<.001
<i>En outre</i>	6.31	1.35	4.66	<.001
List signal	1.45	0.91	1.59	0.112
Teenagers	2.40	1.24	1.93	0.054
<i>En outre</i> *List signal	-0.44	0.97	-0.45	0.655
<i>En outre</i> *Teenagers	-3.46	1.27	-2.73	0.006
List signal*Teenagers	-0.73	0.92	-0.80	0.427
<i>En outre</i> *List signal*Teenagers	0.39	0.97	0.40	0.691
Teenagers				
(Intercept)	-4.45	0.67	-6.61	<.001
<i>En outre</i>	2.50	0.71	3.51	<.001
List signal	0.70	0.38	1.85	0.064
<i>En outre</i> *List signal	-0.05	0.49	-0.10	0.923
Adults				
(Intercept)	-10.43	2.46	-4.24	<.001
<i>En outre</i>	9.37	2.50	3.75	<.001
List signal	1.84	1.15	1.60	0.109
<i>En outre</i> *List signal	-0.67	1.27	-0.53	0.597

Table 6. Model's estimates for the best fitting model in Experiment 3.

Note. In the model for all participants, conditional $R^2\Delta=.66$, marginal $R^2\Delta=.29$; for teenagers, conditional $R^2\Delta=.50$, marginal $R^2\Delta=.13$; for adults, conditional $R^2\Delta=.35$, marginal $R^2\Delta=.17$.

7.4.2 Additional comparative analysis between Experiment 1 and Experiment 3 for the connective *en outre*

The final model for the analysis, comparing the production of list continuations after the task items without a connective (from Experiment 1) and after the items with the additive connective *en outre* (from Experiment 3), included List Signal (absent versus present), Connective (no connective versus *en outre*), and Group (adults versus teenagers) as fixed factors (both main and interaction effects), and Item and Participant as random intercepts (see Table 7 and Figure 6). This analysis showed that both groups of participants overall produced more list continuations after the items including the adjectives of quantity than after the items without them. Moreover, teenagers were on average less responsive to the presence of list signals than adults across both experiments.

The separate analysis within the group of teenagers showed that teenagers produced significantly more list continuations after the sentences with list signals than after the sentences without list signals when the connective *en outre* was absent in the task (log odds ratio=1.16, SE=0.27, $p < .0001$). In addition, the presence of the non-connective signals and the additive connective *en outre* significantly decreased the production of lists in comparison to the sentences that included only the non-connective signals (log odds ratio=-0.69, SE=0.29, $p=0.016$). In contrast, the analysis within the group of adults demonstrated that adults wrote significantly more list continuations after the sentences with list signals than after the sentences without list signals both when the connective *en outre* was present (log odds ratio=0.85, SE=0.43, $p=0.046$) and absent (log odds ratio=1.91, SE=0.38, $p < .0001$). However, the proportion of lists in the adult productions did not significantly change between the sentences with the connective *en outre* and those without any connective, both when adjectives of quantity were present (log odds ratio=-0.21, SE=0.49, $p=0.662$) and absent (log odds ratio=0.73, SE=0.39, $p=0.061$) in the task items.

To summarize, similarly to the Experiment 2, teenagers were more sensitive to the adjectives of quantity in the task items that were not followed by a connective, while adults were sensitive to the non-connective signals in both conditions, independently of the connective *en outre*. Moreover, the presence of the connective *en outre* together with the non-connective signals significantly reduced the proportion of list productions by teenagers, but did not affect the proportion of lists produced by adult speakers.

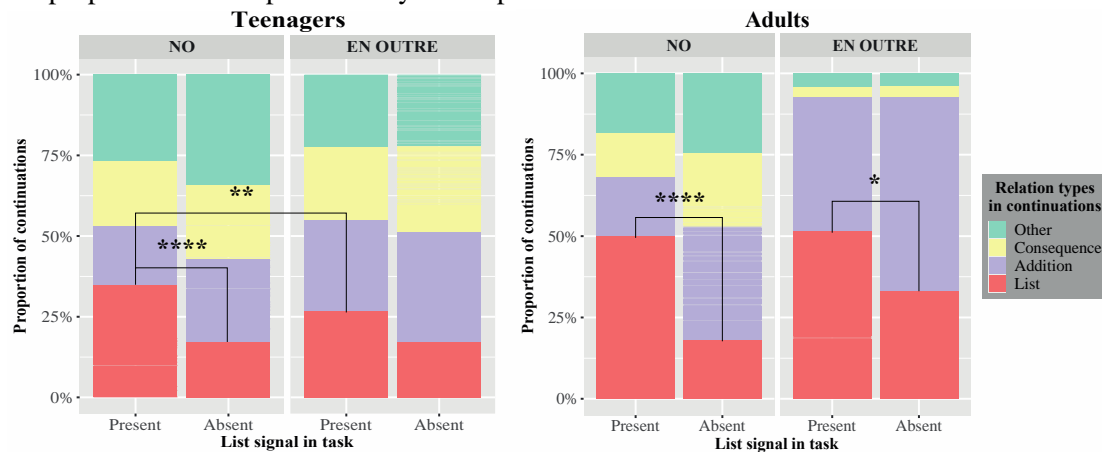


Figure 6. Proportions of different types of relations in the continuation after the task items without a connective (from Experiment 1) and after those with the connective *en outre* (from Experiment 3) across teenagers and adults.

	Estimate	SE	z	p
All participants				
(Intercept)	-1.86	0.33	-5.57	<.001
List signal	1.89	0.30	6.30	<.001
<i>En outre</i>	0.78	0.42	1.86	0.063
Teenagers	-0.21	0.34	-0.62	0.535
List signal* <i>En outre</i>	-1.00	0.31	-3.18	0.001
List signal*Teenagers	-0.73	0.22	-3.24	0.001
<i>En outre</i> *Teenagers	-0.85	0.50	-1.69	0.091
List signal* <i>En outre</i> *Teenagers	0.35	0.37	0.95	0.342
Teenagers				
(Intercept)	-2.09	0.26	-8.18	<.001
List signal	1.16	0.27	4.35	<.001
<i>En outre</i>	-0.01	0.30	-0.02	0.983
List signal* <i>En outre</i>	-0.69	0.25	-2.79	0.005
Adults				
(Intercept)	-1.93	0.34	-5.61	<.001
List signal	1.97	0.40	4.97	<.001
<i>En outre</i>	0.73	0.39	1.88	0.061
List signal* <i>En outre</i>	-0.94	0.40	-2.33	0.020

Table 7. Model's estimates for the best fitting model in the additional analysis, comparing the production of list continuations after the task items without a connective (from Experiment 1) and after those with the connective *en outre* (from Experiment 3).

Note. In the model for all participants, conditional $R^2\Delta=.66$, marginal $R^2\Delta=.29$; for teenagers, conditional $R^2\Delta=.28$, marginal $R^2\Delta=.03$; for adults, conditional $R^2\Delta=.41$, marginal $R^2\Delta=.10$.

7.4.3 Additional comparative analysis between Experiment 1 and Experiment 3 for the connective *ainsi*

The final model for the analysis, comparing the production of list continuations after the task items without a connective (from Experiment 1) and after the items with the additive connective *ainsi* (from Experiment 3), included List Signal (absent versus present), Connective (no connective versus *ainsi*), and Group (adults versus teenagers) as fixed factors (both main and interaction effects), and Item and Participant as random intercepts (see Table 8 and Figure 7). This analysis shows that the presence of the non-connective signals significantly increased the production of lists for all the participants. However, overall, the presence of the consequence connective *ainsi* almost completely prevented participants from writing list continuations. The two separate within-group analyses confirmed general trends revealed in the analysis for all participants. The only difference was that when the consequence connective *ainsi* was present in the task sentences, adult speakers were not sensitive to the non-connective list signals (log odds ratio=1.09, SE=0.81, $p=0.176$). In contrast, teenagers responded to the presence of the

adjectives of quantity and produced slightly more lists even in the presence of the consequence connective *ainsi* (log odds ratio=0.78, SE=0.40, $p=0.049$).

We noticed however that not all participants who produced list continuations after the connective *ainsi* interpreted it as a consequence connective. Out of 115 continuations, *ainsi* was treated as a connective of consequence in only 11 of them. In the other 104 continuations, participants started their sentence with *que* and, this way, used it as an additive conjunction *ainsi que* ‘as well as’. In other words, some participants changed the connective intended in the task. As a result, it is complicated to interpret the effects of *ainsi* as a connective of consequence on list inference generation.

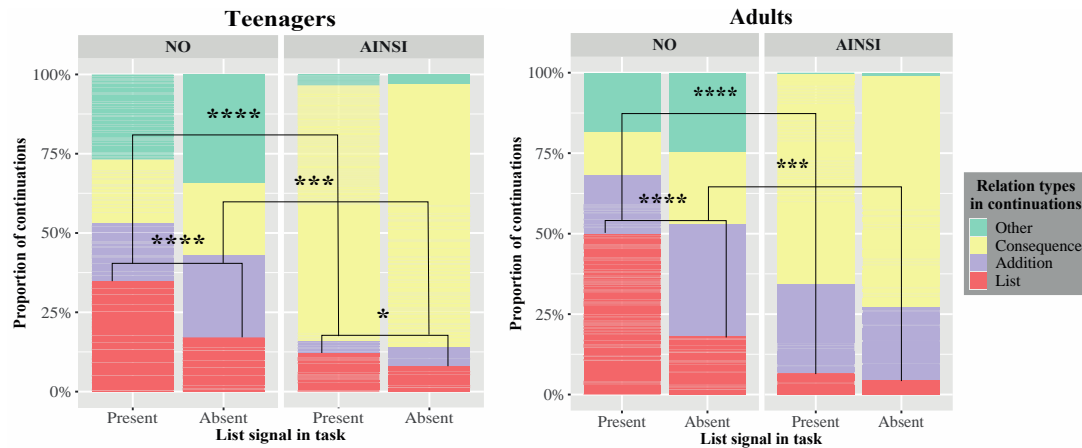


Figure 7. Proportions of different types of relations in the continuation after the task items without a connective (from Experiment 1) and after those with the connective *ainsi* (from Experiment 3) across teenagers and adults.

	Estimate	SE	z	p
All participants				
(Intercept)	-1.93	0.45	-4.28	<.001
List signal	1.96	0.32	6.11	<.001
<i>Ainsi</i>	-3.50	0.90	-3.91	<.001
Teenagers	-0.31	0.49	-0.64	0.525
List signal* <i>Ainsi</i>	-0.84	0.74	-1.13	0.261
List signal*Teenagers	-0.74	0.23	-3.18	0.001
<i>Ainsi</i> *Teenagers	2.09	0.98	2.14	0.032
List signal* <i>Ainsi</i> *Teenagers	0.37	0.80	0.47	0.641
Teenagers				
(Intercept)	-2.23	0.32	-6.90	<.001
List signal	1.20	0.28	4.26	<.001
<i>Ainsi</i>	-1.49	0.47	-3.16	0.002
List signal* <i>Ainsi</i>	-0.42	0.33	-1.26	0.209
Adults				
(Intercept)	-2.09	0.48	-4.37	<.001
List signal	2.12	0.39	5.37	<.001
<i>Ainsi</i>	-3.31	0.95	-3.48	<.001
List signal* <i>Ainsi</i>	-1.02	0.76	-1.34	0.180

Table 8 Model's estimates for the best fitting model in the additional analysis, comparing the production of list continuations after the task items without a connective (from Experiment 1) and after those with the connective *ainsi* (from Experiment 3).

Note. In the model for all participants, conditional $R^2\Delta=.48$, marginal $R^2\Delta=.17$; for teenagers, conditional $R^2\Delta=.43$, marginal $R^2\Delta=.09$; for adults, conditional $R^2\Delta=.62$, marginal $R^2\Delta=.32$.

7.4.4 Comparative analysis between Experiment 2 and Experiment 3

In order to see whether connectives with different frequencies had a different impact on the generation of list inference, we performed an analysis, contrasting the results from Experiment 2, which included more frequent connectives, and from Experiment 3, which assessed less frequent connectives. However, given the issue in the interpretation of results after the connective *ainsi*, we excluded all the results for both connectives of consequence (*ainsi* and *donc*) from this analysis and focused only on the two connectives of additive relations (*en plus* and *en outre*).

The statistical procedure remained the same as in previous analyses. We also made three separate models for different groups of participants (for teenagers, adults, and all participants together) and reported the details of model selection for teenagers and adults in the Online Appendix (see Table S9). Similar to previous analyses, the measures of exposure to print did not predict the variation in the sensitivity to list signals. Finally, treatment contrasts

were applied to the factor of Connective, where *en plus* was set as a reference level for comparison in all three models.

The final model for all participants included List Signal, Connective, and Group as fixed factors (both main and interaction effects), and Item and Participant as random intercepts (see Table 9). Comparing the results from all participants revealed that teenagers produced significantly fewer list continuations than adults after the prompt including the connective *en outre*. However, all other interactions were not statistically significant. The separate within-group analyses demonstrated that connective frequency played a role only for the group of teenagers, as they produced significantly fewer list continuations after the less frequent connective *en outre* than after the more frequent *en plus*, both when list signals were absent (log odds ratio=1.30, SE=0.28, $z=4.67$, $p<.0001$) or present (log odds ratio=1.13, SE=0.27, $z=4.16$, $p<.0001$) in the task. As for the group of adults, the frequency of connectives did not affect the proportion of list continuations.

	Estimate	SE	<i>z</i>	<i>p</i>
All participants				
(Intercept)	-0.82	0.32	-2.56	0.011
List signal	0.88	0.31	2.85	0.004
<i>En outre</i>	-0.09	0.41	-0.21	0.830
Teenagers	0.19	0.33	0.57	0.569
List signal* <i>En outre</i>	0.11	0.32	0.34	0.735
List signal*Teenagers	-0.41	0.26	-1.56	0.119
<i>En outre</i> *Teenagers	-1.24	0.49	-2.53	0.011
List signal* <i>En outre</i> *Teenagers	0.06	0.39	0.16	0.870

Table 9. Model's estimates of the best fitting models the analysis, comparing the task with the more frequent connective *en plus* 'in addition' (from Experiment 2) and the task with less frequent connective *en outre* 'in addition' (from Experiment 3).

Note. In the model for all participants, conditional $R^2\Delta = .30$, marginal $R^2\Delta = .07$.

7.4.5 Discussion

The results of the Experiment 3 were similar to those from the Experiment 2. It was shown that the presence of the consequence connective *ainsi*, similar to the more frequent consequence connective *donc*, almost completely overrode the inference from the non-connective signals of the list relation in both groups of participants. As for the additive connective *en outre*, the effects again were not the same for the two age groups. Teenagers were sensitive to the adjectives of quantity only in the task items that were not followed by the additive connective *en outre*, while adults remained sensitive to the non-connective signals, independently of the additive connective. In general, the presence of *en outre* significantly decreased the production of list continuations in teenagers in comparison to the sentences not followed by any connective and to those followed by the more frequent additive connective *en plus*. However, this finding should be interpreted with caution, as it is based on a comparison between two separate experiments.

To sum up, the findings from Experiments 2 and 3 demonstrated that the combination of list signals with additive connectives did not significantly increase the production of list continuations, but rather decreased (*en outre*) or left unchanged (*en plus*). Given that these connectives signal a more generic additive relation, they can be used to express the relation of list, but are not limited to it. As a result, when a connective expressing a more generic additive relation is used together with a non-connective signal of a more specific list relation, it does not significantly improve the inference for a more specific list signal. This effect may stem from

the fact that the inference of a more generic additive relation, coming from a more salient and monofunctional signal such as connective, competes with the inference of the list relation, coming from a less prominent and non-monofunctional non-connective signal. We make in the next section an additional analysis aiming to assess whether participants were more sensitive to the additive connectives and produced significantly more additive continuations in the conditions that included additive connectives *en plus* and *en outre*.

8 Analysis of additive continuations after the sentences with additive connectives *en plus* and *en outre*

8.1 Comparative analysis between Experiment 1 and Experiment 2 for the connective *en plus*

In order to examine whether more additive continuations were produced after the items including the additive connective *en plus*, we created a statistical model, comparing the proportion of additive continuations after the sentences without any connective (from Experiment 1) and those followed by the connective *en plus* (from Experiment 2). The results of both age groups were analyzed together, as we did not need to include the measures of exposure to print in the analysis. The details on model selections can be found in the Online Appendix also for this analysis.

Results show that both groups of participants indeed produced significantly more additive continuations after the sentences containing the additive connective *en plus* than after the sentences without any connective (see Table 10 for the model's estimates and Figure 8). The sensitivity to the frequent additive connective *en plus* was not significantly different between the two age groups. Moreover, in the sentences without any connective, participants produced more additive continuations when the adjectives of quantity were absent (log odds ratio=0.73, SE=0.25, $p=0.003$). In the sentences including the additive connective, the presence of adjectives of quantity did not affect the proportion of additive continuations (log odds ratio=0.47, SE=0.28, $p=0.086$). Finally, when both types of signals were absent in the task sentences, adults on average wrote more additive continuations than teenagers (log odds ratio= 0.48, SE=0.21, $p=0.022$).

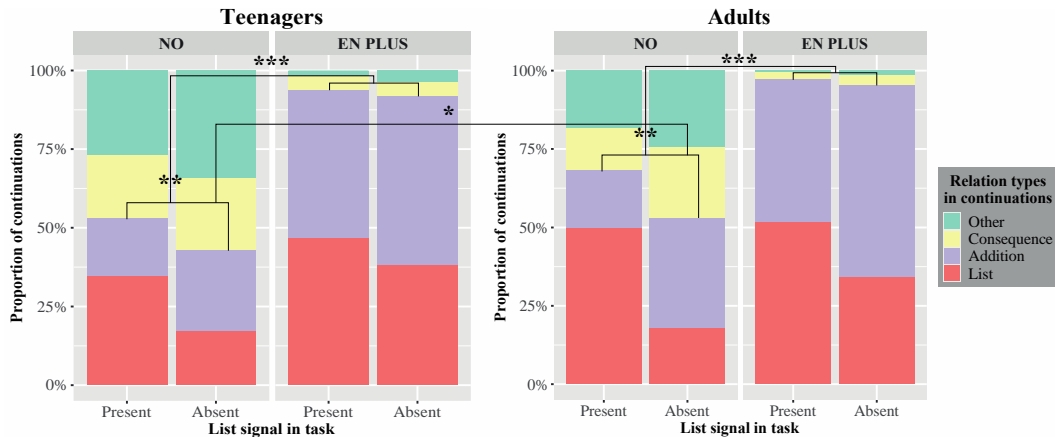


Figure 8. Proportions of different types of relations in the continuation after the task items without a connective (from Experiment 1) and after those with the connective *en plus* (from Experiment 2) across teenagers and adults.

	Estimate	SE	z	p
(Intercept)	-0.82	0.30	-2.70	0.007
List signal	-1.00	0.31	-3.18	0.001
<i>En plus</i>	1.34	0.38	3.55	<0.001
Teenagers	-0.57	0.29	-1.98	0.048
List signal* <i>En plus</i>	0.27	0.34	0.79	0.427
List signal*Teenagers	0.52	0.22	2.35	0.019
<i>En plus</i> *Teenagers	0.18	0.42	0.42	0.672
List signal* <i>En plus</i> *Teenagers	-0.07	0.34	-0.20	0.838

Table 10. Model's estimates of the best fitting model in the analysis, comparing additive continuations after the task items without a connective (from Experiment 1) and after those with the connective *en plus* (from Experiment 2).
Note. Conditional $R^2\Delta = .31$, marginal $R^2\Delta = .10$.

8.2 Comparative analysis between Experiment 1 and Experiment 3 for the connective *en outre*

In order to examine whether more additive continuations were produced after the items including the additive connective *en outre*, we created a statistical model, comparing the proportion of additive continuations after the sentences without any connective (from Experiment 1) and those followed by the connective *en outre* (from Experiment 3).

Results show that there were also significantly more additive continuations after the sentences containing the additive connectives *en outre* than after the sentences without connectives (see Table 11 for the model's estimates and Figure 9). However, adults were more sensitive to the less frequent additive connective *en outre*, as they produced significantly more additive sentences than teenagers after the task items including this connective (log odds ratio=1.03, SE=0.26, $p<0.001$). Finally, as in the analysis for the connective *en plus*, after the items without any connective, participants produced more additive continuations when the adjectives of quantity were absent (log odds ratio= 0.76, SE=0.26, $p=0.004$). In contrast, after the sentences including the additive connective *en outre*, the presence of adjectives of quantity did not affect the proportion of additive continuations (log odds ratio=0.53, SE=0.29, $p=0.073$).

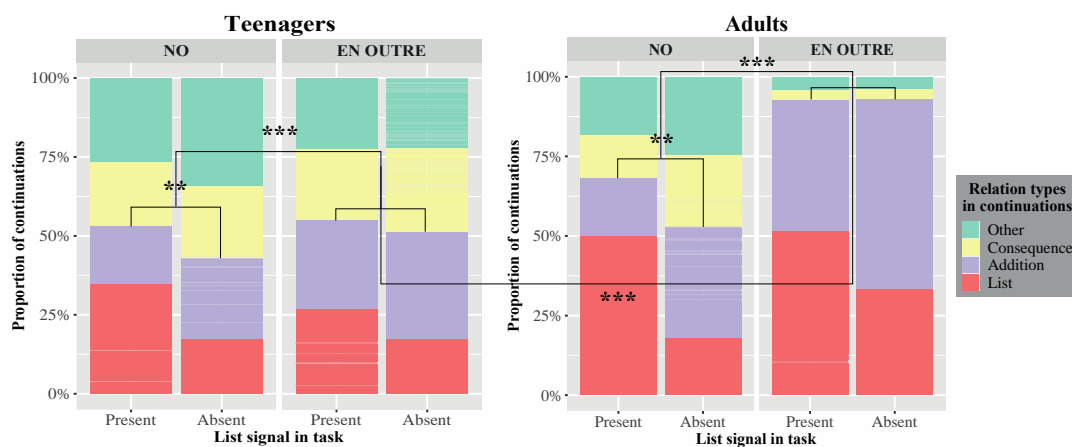


Figure 9. Proportions of different types of relations in the continuation after the task items without a connective (from Experiment 1) and after those with the connective *en outre* (from Experiment 3) across teenagers and adults.

	Estimate	SE	z	p
(Intercept)	-0.79	0.28	-2.81	0.005
List signal	-1.01	0.30	-3.37	<0.001
<i>En outre</i>	1.18	0.34	3.47	<0.001
Teenagers	-0.56	0.27	-2.10	0.036
List signal* <i>En outre</i>	0.16	0.31	0.53	0.597
List signal*Teenagers	0.51	0.22	2.34	0.019
<i>En outre</i> *Teenagers	-0.79	0.40	-1.99	0.047
List signal* <i>En outre</i> *Teenagers	0.13	0.36	0.37	0.709

Table 11. Model's estimates of the best fitting model in the analysis, comparing additive continuations after the task items without a connective (from Experiment 1) and after those with the connective *en outre* (from Experiment 3). *Note.* Conditional $R^2\Delta = .25$, marginal $R^2\Delta = .05$.

9 General discussion

In the current set of experiments, we examined whether native French-speaking teenagers were sensitive to signals of the list relation, expressed by the adjectives of quantity *plusieurs* ‘several’ and *différents* ‘various’ (Experiments 1, 2, 3). We also assessed whether this sensitivity was modulated by the presence of another signal of coherence relation, namely connectives of additive and consequence relations, varying in frequency (Experiments 2, 3). Finally, we systematically contrasted the results obtained by teenagers with those of a control group of adults, and assessed whether their performance in the main task was modulated by their linguistic competence, as measured by the author recognition test.

9.1 Sensitivity to non-connective signals of list relation

Both groups of participants were sensitive to list signals, as they produced more continuations expressing a list relation when one of the adjectives of quantity was present in the first sentence of the task that did not include connectives (see the main analysis of Experiment 1). However, teenagers' receptiveness to alternative list signals was still inferior to that of adults. This finding might indicate that sensitivity to alternative signals develops with age and the increasing linguistic experience that is normally associated to it. It is possible that teenagers are less sensitive to alternative signals than adults because they have not yet mastered non-sentence-initial usage of coherence markers. Indeed, when teenagers used connectives in their own productions, they preferred to use them in sentence-initial position and only rarely used them in other positions. In contrast, adults produced connectives in different syntactic positions and even did so more frequently in non-sentence initial positions.

In addition, the fact that linguistic experience and level of linguistic proficiency develop with age is reflected in the types of continuations produced by teenagers and adults. We observed that, across all experiments and conditions, teenagers produced more elliptic continuations that lacked subject or verb. Out of 5604 continuations written by teenagers, 670 (12 %) were elliptic; whereas only 38 (2%) of the 2509 completions created by adults had an ellipsis. Most ellipses were found in list continuations across both age groups (503 (75%) in teenagers and 36 (95%) in adults). Note that some participants analyzed *ainsi* not as a connective of consequence, but as an additive connective *ainsi que*, by adding *que* in their continuation sentence (see example 21). Since all such instances were elliptic, this accounted for most elliptic sentences produced by adults and an important part of ellipses produced by teenagers (see Table 12). However, even when no connective was present in the prompt, the

proportion of elliptic sentences written by teenagers was still greater than that of adults (54% vs. 25%).

(21) Task sentences:

L'enfant a surpris ses parents. Il voulait comprendre pourquoi le ciel était bleu.
Ainsi, ...

'The child surprised his parents. He wanted to understand why the sky was blue.
Therefore, ...'

Continuation:

que pourquoi la neige est-t-elle blanche.
'as well as why the snow is white.'

	No connective	<i>Ainsi</i>	<i>Donc</i>	<i>En outre</i>	<i>En plus</i>	Total N
Teenagers	271 (.54)	86 (.17)	0	11 (.02)	135 (.27)	503
Adults	9 (.25)	21 (.58)	0	0	6 (.17)	36

Table 12. Raw number (and proportion) of elliptic sentences in list continuations across all three experiments and all age groups.

This finding may of course indicate that teenagers took the task less seriously and paid less attention to it. However, it may also mean that they have not yet mastered all the particularities of written language, which precisely tends to avoid ellipses (see, e.g., Menzel, 2016). Another indication of the fact that teenagers may not master the written modality is the usage of connective *et* 'and' in sentence-initial position produced in their own sentences. Whereas in oral speech it is perfectly normal to use this connective in the beginning of the sentence, in written language it is not stylistically appropriate, as coordinating conjunctions are not possible in sentence-initial position according to reference grammars (see, e.g., Riegel, Pellat & Rioul, 2021).

9.2 Sensitivity to list signals combined with connectives

When the task combined both non-connective signals and connectives, we found different effects in the production of list continuation sentences. First of all, the difference between the proportion of list continuations after the sentences including and not including the list signal was not the same within three experiments. After the cue sentences with connectives *en plus* and *en outre*, teenagers and adults produced more list continuations when a list signal was present than when it was absent. However, the observed effects were significant only for the group of adults, suggesting that teenagers are probably even less sensitive to the non-connective list signals when a more salient signal like connective is also present in the sentence (see comparisons reported in 6.4.2 and 7.4.2).

The presence of list signals together with the connectives of consequence *donc* and *ainsi* did not have any effect on the generation of list inference. Indeed, after the task passages followed by the connectives of consequence, the list relation was almost completely absent in the continuation sentences produced by both teenage and adult participants (see comparisons between the items with consequence connectives and those without connectives reported in 6.4.3 and 7.4.3). Presumably, this means that connectives signaling the relation of consequence create a much stronger mental inference of this relation than do the non-connective list signals for the relation of list. However, the results for *ainsi* should be considered with caution, as in a significant number of cases, it was interpreted as a different type of signal (*ainsi que*), used for marking addition.

Secondly, we observed that in the condition without list signal, there were significantly more list continuations after *en plus* in comparison to the task without connectives in all age groups (see comparisons between the items with the additive connective *en plus* and those without connectives reported in 6.4.2). In other words, this means that even the additive connective *en plus* alone can generate inference of the list relation. However, when both *en plus*

and the list signal were present in the cue sentence, it did not significantly reinforce the inference of a list relation. As demonstrated in the analysis of additive continuations (see 8.1), *en plus* can generate not only an inference of the list relation, but also that of an additive relation. Therefore, when both types of signals are present in the sentence, the additional additive function of the connective may compete with the inference of the list relation from the non-connective signal. Alternatively, and in line with findings of Crible and Demberg (2021), this effect may be due to a stronger inference power of connectives as a type of coherence signal compared to list signals within the related segments.

In the condition without list signal, after the more infrequent additive connective *en outre*, the proportion of list continuations produced by teenagers was the same as in the task without connectives; while when combined with the list signals, there were even fewer list continuations in comparison to the same condition in the task without connectives (see comparisons between the items with additive connective *en outre* and those without connectives reported in 7.4.2). As for adults, although they produced slightly more list sentences after the connective *en outre*, their proportion was not significantly higher than in the task without connectives in both conditions (with and without list signal). As far as the comparison of connectives with different frequencies was concerned, teenagers produced significantly more list continuations after the more frequent additive connective *en plus* than after the infrequent connective *en outre*. In contrast, there was no such difference between the effects of the two additive connectives for adults (see 7.4.4 for the comparative analysis between items with the less frequent additive connective and the more frequent one).

Taken together, these findings suggest that *en outre* does not facilitate the inference of the list relation and may even hinder this inference, especially in the case of young speakers. Indeed, teenagers may be less familiar with the less frequent connective *en outre* compared to adults. Hence, it is more difficult for them to infer a more specific list relation. This finding as well as the fact that teenagers produced some list continuations even in the presence of the consequence connective *ainsi* also suggest that the mastery of a specific connective may be an additional factor affecting the inference generation.

In addition, similar to the connective *en plus*, a more generic additive meaning triggered by *en outre* may override the more specific list meaning, as suggested by the analysis of additive continuations (see 8.2). Nevertheless, the fact that an important number of list relations was produced even in the presence of more salient, stronger, and prototypical signals of coherence such as the additive connectives *en plus* and *en outre*, shows that non-connective list signals are an important source for inferring a list relation. These signals start to be perceived and to affect discourse inferences as early as at the age of 12 and their impact increases with age. It is however important to point out that the presented comparisons should be considered with caution, as they are made between experiments.

In contrast to Scholman et al. (2020), we did not find an effect of the author recognition test on the sensitivity to non-connective list signals both for teenagers and adults. Although the French versions of the ART were strong predictors for the use of connectives in other studies (Tskhovrebova, Zufferey & Tribushinina, 2022; Zufferey & Gygax, 2020b), it probably requires further validation in French. As a matter of fact, the French version of this test included 80 items, while the English ART, used by Scholman et al. (2020), consisted of 130 items, which might have rendered this version a more sensitive measure. Moreover, the performance of both groups of participants was not very high on the measures of exposure to print (teenagers: $M=6.44$, $SD=6.08$, observed range: -11 to 28, possible range: -40 to 40; adults: $M=8.89$, $SD=5.43$, observed range: -1 to 23, possible range: -40 to 40). This may have created a floor effect that did not allow us to track individual variation. Finally, the lack of effect of ART scores in the present experiments may also suggest that exposure to print does not necessarily reflect individual differences in the ability to infer an intended coherence relation. It is possible that this ability constitutes a specific type of linguistic competence that should be assessed with a more sensitive measure.

9.3 Limitations and future directions

The present set of experiments had several limitations that should be taken into account in follow-up research. It is important to point out that we examined the effect of non-connective and connective signals on production data and can only speculate about the comprehension level of the coherence relations included in our study. In other words, the continuation task provided evidence only about one type of coherence relation that a participant chose to write down, while all other relations that might have been inferred as well remain unknown. This suggests that participants might have been more sensitive to alternative list signals, but the task did not always reveal this sensitivity. Moreover, one of the most important limitations is related to the design of the experiments, as they involved between-participant design. As a result, the comparisons made between experiments 1, 2, and 3 should be interpreted with caution. Future research should therefore address the issue of the design and focus on comprehension measures in order to complement our findings.

As for the interpretations of the results on the interaction between adjectives of quantity and additive connectives, it should be noticed that since the relation of list is a subtype of the relation of addition, we cannot exclude that in some continuations both relations simply co-existed, without necessarily competing with each other. Furthermore, the analysis of the connective insertions in the participants' productions have hinted that, perhaps, temporal connectives, such as *ensuite* and *puis*, may be even better suited for marking list relations and should be analyzed in future studies.

Finally, an important contribution to future research would be to unveil other types of non-connective signals that can generate coherence inferences when used alone or together with connectives, and to continue the examination of other linguistic competences that may better explain individual variation in speakers' sensitivity to non-connective signaling.

10 Conclusion

Taken together, the results of the current series of experiments suggest that expressions of quantity are an important source for the inference of the list relation as early as in teenage years, even though the sensitivity to these non-connective signals still develops into adulthood. The fact that the combination of a non-connective signal with the connective *en plus* did not significantly increase the inference of a list relation in both age groups indicates that a more generic additive relation, signaled by this connective, may compete with a more specific relation of list. Furthermore, it seems that the inference of the list relation in teenagers is inhibited by a less frequent additive connective *en outre*, and is almost completely hindered by both types of consequence connectives. Ultimately, the degree of exposure to print, as measured by the ART on our data, does not predict the individual differences in the sensitivity to the adjectives of quantity as signals of the list relation. More globally, the presented set of experiments shows that the examination of how different types of coherence signals combine with each other opens many new avenues of enquiry for future research. This type of research sheds light onto the linguistic devices that can reinforce or inhibit the generation of a certain coherence relation, and thus, allows to understand the functioning of this relation better.

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Disclosure statement

The authors report there are no competing interests to declare.

Data availability statement

The data that support the findings of this study are openly available in OSF repository at https://osf.io/ca7hm/?view_only=b59ac0969a3045f5978074f7015b6291.

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