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EMPIRICAL STUDY

Individual Variations in the Mastery of Discourse Connectives from Teenage Years to Adulthood

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Abstract: Many connectives, such as *therefore* and *however*, are used very frequently in the written modality. Their acquisition thus represents an important milestone in developing written language competences. In this article, we assess the development of competence with such connectives by native French speakers in a sentence-level insertion task ($N = 307$, aged 12 to 64) and a text-level insertion task ($N = 172$, aged 13 to 71). Our results indicate that, despite a general progression in the level of competence with age, the academic level of participants is a strong predictor of competence within each age group, even during adulthood. In addition, from the age of 12, competence is related to the frequency of connectives in naturalistic data, with frequent connectives systematically mastered better than less frequent ones. Finally, in all age groups, the use and understanding of connectives is more challenging when sentences to complete are embedded within a richer context than when presented alone.

Keywords L1 acquisition; connectives; discourse; experimental study; French

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Introduction

Connectives play a crucial role in the processing and understanding of discourse. These linguistic items signal underlying coherence relations between different elements of discourse (Knott & Dale, 1994; Sanders, Spoorem, & Noordman, 1992) and thus have an impact on the interpretation of these relations. Previous research has shown that connectives contribute to the processing and understanding of discourse (e.g., Sanders & Noordman, 2000; Traxler, Sanford, Aked, & Moxey, 1997). Such processing and understanding can be facilitated, hindered, or not affected at all, depending on individual differences between speakers, the nature of the task, and the type of coherence relations encoded by connectives (e.g., Cain & Nash, 2011; Canestrelli, Mak, & Sanders, 2013; Degand & Sanders, 2002; Kleijn, Pander Maat, & Sanders, 2019; Köhne & Demberg, 2013; Millis, Graesser, & Haberlandt, 1993; Murray, 1995; Van Silfhout, Evers-Vermeul, & Sanders, 2014, 2015).

Whereas the early acquisition of connectives has been the subject of numerous studies (e.g., Cain & Nash, 2011; Florit, Cain, & Levorato, 2017; Pyykkönen & Järvikivi, 2012), the acquisition of connectives that are less common in spoken language and mostly bound to the written modality, such as *however* and *therefore* in English, has, to the best of our knowledge, rarely been investigated (though for exceptions see Crosson & Lesaux, 2013; Nippold, Schwartz, & Undlin, 1992; Zufferey & Gygax, 2020a, 2020b). Yet mastering these connectives represents an essential step in achieving effective written communication. In written communication, a greater diversity of connectives is typically used, with more precise functions compared to the spoken modality (Biber, 2006; Crible & Cuenca, 2017). Not surprisingly, their mastery is considered to be part of core academic language skills (Barr, Uccelli, Phillips, & Galloway, 2019; Snow & Uccelli, 2009). For these reasons, determining how the mastery of connectives bound to the written modality develops from teenage years to adulthood is important. An equally important issue is to assess whether this mastery is related to individual differences, for example, in academic background.

Background Literature

The acquisition of discourse connectives is a long and complex process that starts between the ages of 2 and 3 (e.g., Bloom, Lahey, Hood, Lifter, & Fiess, 1980; Evers-Vermeul & Sanders, 2009; Zufferey, 2010) and continues into the adult years (e.g., Zufferey & Gygax, 2020a). A large body of studies across different languages has analyzed various aspects of the acquisition of connectives during childhood (e.g., for English: Cain & Nash, 2011; Crosson,

Lesaux, & Martinello, 2008; Irwin & Pulver, 1984; McClure & Geva, 1983; for Finnish: Pyykkönen & Järvikivi, 2012; for Italian: Florit, Cain, & Levorato, 2017; for German: Volodina & Weinert, 2020; for Turkish: Oğuz & Özge, 2020), converging to conclude that even connectives used frequently in speech such as *because* and *after* are not fully acquired until the end of the primary school years. For instance, Cain and Nash (2011) showed that, in a within-sentence cloze task, 10-year-olds performed less well than adults for temporal connectives (*before*, *after*), causal connectives (*so*, *because*), and adversative connectives (*but*, *although*). In a comprehension test targeting temporal relations, Irwin and Pulver (1984) showed that even 8th-grade students (between the ages of 13 and 14) had difficulties in comprehending causal relations when the consequence (introduced in the main clause) preceded the cause (introduced in the subordinate clause by the connective *because*).

To the best of our knowledge, although the studies presented so far have been informative regarding children's and teenagers' mastery of connectives from the written modality, only a few studies have directly assessed how the ability to use and understand such connectives develops from childhood to early adulthood. Nippold, Schwartz, and Undlin (1992), for instance, assessed the competence of a group of English-speaking children, teenagers, and young adults aged 12 to 23. The authors tested connectives that tend to be used in more formal, mostly written contexts (e.g., *moreover*, *contrastively*, *nevertheless*) and found an important developmental effect between the age groups, whereby the older participants, aged 19 to 23, gave more accurate answers than the younger ones, aged 12 to 15. This study was one of the first to provide data on the mastery of connectives from the written modality during the teenage years, but the authors only tested a homogeneous population in terms of academic background, presumably with a similar degree of exposure to print. We argue, however, that individual variations between teenagers within the same age group may already exist, because teenagers at lower academic levels also have less exposure to print, which has been found to be relevant in explaining individual differences among adults (Zufferey & Gygax, 2020a). Nippold et al. (1992) also did not systematically assess the effect of the frequency of connectives in written corpora by comparing connectives with various frequencies, yet Zufferey and Gygax (2020a) found that frequency was an important variable accounting for differences between adults. These variables, namely connective frequency, academic level, and exposure to print, are included in our experiments.

In our experiments we also examine the use of different materials in order to gain a more comprehensive picture of the processes at stake. Others

(e.g., van Silfhout et al., 2015) have also examined such a variable by using naturalistic texts, mostly to avoid possible biases that may occur when isolating sentence processing, as in several previous studies (e.g., Cain & Nash, 2011; McClure & Geva, 1983). In their study on teenagers aged 12 to 15, van Silfhout et al. (2015) tested participants with different academic levels (pre-university or pre-vocational) using online and offline tasks that presented texts with and without connectives. The authors found that the presence of connectives facilitated the processing of coherence relations and contributed to better comprehension within whole paragraphs. Importantly, reading proficiency (as measured by van Silfhout et al., 2015) was a more accurate predictor of connective processing competence than academic level. On average, students with higher reading proficiency processed the texts more quickly and obtained higher scores on the comprehension task. However, this study raises several questions. For example, it did not include a control group of adults, and the adultlike level of processing and comprehension of coherence relations for this task was not known. More specifically, it would be important to determine whether reading proficiency is also a strong predictor among adults.

Furthermore, van Silfhout et al. (2015) did not assess the effects of some intrinsic characteristics of connectives, such as the type of coherence relation they encode and their frequency in corpus data. In their study on teenagers aged 13 to 16, Kleijn et al. (2019) found not only that connectives conveying different types of relations facilitated comprehension at a local level (coherence between sentences), but that the level of comprehension also depended on the coherence relation conveyed by the connective. For instance, the presence of causal and contrastive connectives (e.g., *as a result*, *but*) increased text comprehension, whereas this was not the case for temporal connectives (e.g., *afterwards*). More surprisingly, the presence of additive connectives (e.g., *and*) inhibited the comprehension of participants. The authors also pointed out that, although the academic level and reading proficiency of teenagers overall were related to the successful completion of the comprehension task, there was no significant interaction between type of coherence relations or coherence marking and reader characteristics. However, it may also be that students were more familiar with the connectives conveying a certain type of relation compared to the others. The effect of familiarity, or frequency, could be intertwined with the effect of coherence type. Additionally, similarly to van Silfhout et al., Kleijn et al. did not extend their study into adulthood, thus leaving out an important comparison.

In contrast, Zufferey and Gygax (2020b) examined a slightly older sample of French speakers, which included teenagers aged 16 and university students

aged 22, in a sentence-level insertion task. The authors tested only connectives that are normally used in the written modality (i.e., *aussi* "therefore," *en outre* "in addition," *en effet* "for ["because," "the reason for which,"]," *toutefois* "however") and did not include connectives that are more familiar to speakers and used abundantly in the oral modality (e.g., *mais* "but," *et* "and," *après* "after"). By limiting their investigation to only one modality, they could accurately assess the effects of both connective frequency and relation type on the ability to use connectives in a constrained production task. The results indicated that the complexity of the coherence relation did not play an important role in performance with these connectives; frequency turned out to be a better predictor of successful completion of the task. In addition, this study showed that teenagers from different academic backgrounds (pre-university high school vs. professional school) had different levels of proficiency with the more frequent connectives. Speakers who attended pre-university high school, which prepares them to enter university and, hence, has a more advanced curriculum in French, mastered frequent connectives better than students attending a professional school, which prepares them to go directly to work and involves less linguistic training. Moreover, the study revealed that even pre-university high school teenagers at the age of 16 do not possess an adult-like mastery of written connectives compared to university students. However, whereas teenagers came from two academic levels, adults included only university students studying French and had a particularly high proficiency level (as measured by the connective task). It is therefore possible that adults with more heterogeneous backgrounds would also show different levels of competences with connectives, which may be closer to those of high school students. Finally, the results of this study could be affected by the modalities of the sentence-level insertion task, which limits the use of connectives to short sentence pairs. As mentioned earlier, supplementing such a task with another task involving more naturalistic texts may provide us with better insights into the variables influencing the processing and understanding of connectives by teenagers and adults.

The Present Study

Tracing the Development in Competence With Connectives From Teenage Years to Adulthood

Our first hypothesis is that our experiments will show a general progress in the mastery of connectives from secondary school students (12–15 years old; M_{age} = 14.5) to high school students (15–18 years old; M_{age} = 16.6) and then to

adults, because, with time, speakers simply have more experience with connectives and are more exposed to them regardless of their academic background.

Evaluating the Role of Frequency Versus Cognitive Complexity in Performance With Connectives

The age from which the frequency of connectives in the input becomes more important than the type of coherence relation they encode (given the cognitive complexity of some of those relations) has not been firmly established. However, some studies have shown that general frequency effects (i.e., not specific to connectives) do, in fact, *decrease* with age (e.g., Tiffin-Richards & Schroeder, 2015). To address this issue, we expanded the connective insertion task from Zufferey and Gygax (2020b) to a larger group of teenagers (starting from the age of 12) and assessed the use of the same four connectives that are generally bound to the written modality as were used in their experiment, namely *aussi* "therefore," *en outre* "in addition," *en effet* "for," and *toutefois* "however."

Whereas the connectives *en outre* and *toutefois* are monofunctional, *aussi* and *en effet* are polyfunctional and can convey the relations of addition (equivalent to *also* in English) and confirmation (equivalent to *indeed* in English), respectively. Because in our experiments the use of all connectives is tested in the sentence-initial position, we verified what the dominant function of each of the two mentioned connectives is in this position according to the data from written corpora. For *en effet* it is causality, which represents approximatively 80% of uses in corpus data (Zufferey & Gygax, 2020a). The connective *aussi* used sentence-initially can only encode a consequence relation similar to that conveyed by "therefore" (Roze, Danlos, & Muller, 2012).

We chose these four connectives for our experiments because they are well suited to testing the influence of frequency and of the cognitive complexity of coherence relations on the mastery of connectives. These connectives have different frequencies in written corpora, with *en effet* and *toutefois* being more frequent (211 and 185 occurrences per million words, respectively) than *aussi* and *en outre* (107 and 73 occurrences per million words, respectively; Zufferey & Gygax, 2020a). At the same time, all four connectives are generally bound to writing and less frequent than those commonly used in oral language (e.g., *mais* "but": 3,924 occurrences per million words; Zufferey & Gygax, 2020a).

The chosen connectives also encode different coherence relations varying in their degree of cognitive complexity. According to the cognitive coherence relation model (Sanders et al., 1992), the four relations that we examine here can be ordered in terms of complexity from the simplest type, additive (*en*

outre), followed by consequence (*aussi*), causal (*en effet*), and finally concessive (*toutefois*), the most complex type. Thus, two of the connectives are simpler in terms of coherence complexity and infrequent in corpora (*en outre* and *aussi*), and the other two encode more complex relations but have a higher frequency (*en effet* and *toutefois*). The cognitive coherence relation model decomposes coherence into four primitives, namely, *polarity* (positive vs. negative), *basic operation* (additive vs. causal), *source of coherence* (objective vs. subjective), and *order of the segments* (basic vs. non-basic). Inside each primitive, one dimension is deemed to be cognitively easier than the other, and relations that represent a combination of easier dimensions seem to be acquired before those that include more complex dimensions (Evers-Vermeul & Sanders, 2009, 2011).

Thus, our second hypothesis, based on the cognitive coherence relation model, is that, with time, the importance of cognitive complexity gradually decreases, given that children eventually acquire different relation types. Consequently, for teenagers, we would argue that frequency gradually becomes a better predictor for the mastery of written connectives, as suggested by the work of Nippold et al. (1992) and Zufferey and Gygax (2020a, 2020b).

Examining Relations Between the Mastery of Connectives and Individual Variation in Written Language Competence

We assessed the relation between the mastery of connectives and individual variation in written language competence within three age groups: secondary school students ($M_{age} = 14.5$), high school students ($M_{age} = 16.6$), and adults. Our third hypothesis was that participants who are more exposed to print and have a better grammatical awareness, within each age group, will also have a better ability to use connectives from the written modality appropriately. In order to determine the role of exposure to print, we assessed whether there was a correlation between the level of competence with connectives and a French version of the Author Recognition Test (ART-F; Stanovich & West, 1989; Zufferey & Gygax, 2020a), used to assess the degree of participants' exposure to print.

The second measure of individual linguistic variation with which we correlated the level of performance with connectives was a measure of written grammatical competence. Zufferey and Gygax (2020a) showed that for adults, the comprehension of written connectives was associated with their degree of general grammatical awareness. Similarly, Volodina and Weinert (2020) found that receptive grammatical competence was already a good predictor of comprehension of connectives for primary school children. We expect that teenagers

with a higher degree of grammatical awareness, in general, and of awareness concerning grammar typical for the written modality, in particular, may also better master connectives that are mostly used in this modality.

Assessing the Role of Academic Background in French as a Variable That Influences Competence With Connectives

Our fourth hypothesis was that, within each age group, academic level may be an important predictor of variation in the mastery of connectives, because it reflects a wide range of language skills. As outlined by Barr et al. (2019) and Snow and Uccelli (2009), performance with more advanced academic language differs from that with colloquial language on various levels, including greater diversity and precision in the lexicon, more complex grammar, and the users' greater explicit awareness of discourse structure. Moreover, Welie, Schoonen, Kuiken, and van den Bergh (2017) found that greater metacognitive awareness of text structure and of reading and writing strategies facilitates the processing and use of connectives. Therefore we suggest that the higher the level of academic training of a speaker, the more developed are their academic language proficiency, metacognitive awareness, and, thus, competence with connectives (Oğuz & Özge, 2020; Zufferey & Gygax, 2020b).

Studying the Role of the Experimental Context in Performance With Connectives

Finally, we systematically assessed the role of the experimental context in the accomplishment of the connective insertion task. We compared the performance of teenagers and adults across two types of cloze tests. The first one targets the use of connectives between two sentences, and the second one assesses their use in the broader context of texts, which may represent a more ecologically valid way to assess performance with connectives. If the results of previous studies were partially biased by the nonrealistic experimental nature of the tests (e.g., Nippold et al., 1992; Zufferey & Gygax, 2020b), we would expect that the scores for the text-level cloze test will be higher than those for the task limited to pairs of sentences. Conversely, if the results do not vary between the two cloze tests, it means that the reasons that account for the difficulty or ease with connectives are more profound than the nature of the context in which they are used.

Experiment 1: Sentence-Level Cloze Test

Our materials, including the language background questionnaire (Tskhovrebova, Zufferey, & Gygax, 2021a), cloze test (Tskhovrebova, Zufferey, &

Gygax, 2021b), grammaticality test (Tskhovrebova, Zufferey, & Gygax, 2021c), and author recognition test (Tskhovrebova, Zufferey, & Gygax, 2021d) are available on IRIS (iris-database.org) as well as the OSF site (https://osf.io/znhtp/). Our data (Tskhovrebova, Zufferey, & Gygax, 2021e), alongside the R code (Tskhovrebova, Zufferey, & Gygax, 2021f), are also publicly available on IRIS and OSF.

Method

Participants

A group of 191 school students aged 12 to 22 years old participated in Experiment 1. (Although some school students were over 18 years old, we refer to this group as teenagers in order to distinguish them from the two groups of adults who were not school students.) All the participants were native French speakers according to their French professors. The experiment was carried out among students of two school levels: secondary school and high school. Each level included different types of classes. The secondary school group contained classes of Level 1 and Level 2, where Level 1 is for students with a lower performance in French, and Level 2 is for students with higher grades. According to the Swiss education system, the separation between two levels is made on the basis of the annual mean grade that a student obtains in the discipline. The high school group was composed of three types of class that we will label as Levels A, B, and C. Students from Level A are those who chose a specialization in business and who can proceed directly to work in the commercial sector after their studies or, if they wish, can continue their studies in a professional school of management. Participants from Level B obtain the General Culture Certificate at the end of their studies, which gives them access to professional schools in the sectors of health, social work, sports, and so on. Finally, studies in Level C allow students to enter university. All the mentioned levels have different entry requirements, increasing from Level A to Level C. The youngest participants are from Levels 1 and 2, the eldest are the pupils from Level A, and in the middle are the participants from Levels B and C (see Table S1.1 in Appendix S1 of the Supporting Information online for age distribution among all the mentioned groups).

Two groups of adults also performed the test. The first comprised native French-speaking adults recruited on the Prolific© platform (Prolific, Oxford, UK, www.prolific.co). We included this group in order to assess the extent of individual variations among adults. The second group comprised native French-speaking university students studying French. We included this

second group in order to measure one of the highest degrees of proficiency with the connectives.

Materials and Procedures

Sentence-Level Cloze Test

The material for the sentence-level cloze test (Sentence-CT) was the same as that used by Zufferey and Gygax (2020b) and included 40 items. Each item represented a pair of two sentences separated with a blank, which the participants had to fill in with an appropriate connective, making a choice between *aussi* "therefore," *en effet* "for," *en outre* "in addition," and *toutefois* "however." Ten items were included for each coherence relation, namely consequence, cause, addition, and concession. All the items were conceived in such a way that there was only one possible correct interpretation in this particular discourse context. All the sequences of sentences were checked for ambiguity by the authors. An example item for each type of relation is given below (1–4). The full materials for this task can be accessed at https://osf.io/yxj8q/, IRIS, and in Appendix S2 of the Supporting Information online.

1. Consequence (correct answer *aussi*)

   Pascal n'avait pas pris ses clés. _____ il dû attendre son collègue pour rentrer dans son bureau.

   "Pascal didn't take his keys. _____ he had to wait for his colleague to enter the office."

2. Cause (correct answer *en effet*)
   Marc ne fut pas content de ses résultats. _____ il n'avait eu que des mauvaises notes aux examens.

   "Marc wasn't happy about his results. _____ he received only bad marks for the exams."

3. Addition (correct answer *en outre*)
   Georges avait une grande culture musicale. _____ il était passionné de photographie.

   "Georges had a great knowledge of music. _____ he was passionate about photography."

4. Concession (correct answer *toutefois*)
   Le maître n'avait pas terminé de présenter son cours. _____ il libéra ses élèves à l'heure prévue.

   "The teacher hadn't finished presenting his lesson. _____ he let the students go at the scheduled time."

Due to COVID-19 health security measures, the experiment was carried out in class (with pen and paper) for some of the students ($n = 131$), and others performed it online via a weblink.

Author Recognition Test for French-Speaking Adults

The material for the Author Recognition Test for French-Speaking Adults (ART-F) was also developed by Zufferey and Gygax (2020a). The test was designed to represent a French equivalent of the English ART (Stanovich & West, 1989). The task contained a list of 40 real names of authors and 40 fake ones (see https://osf.io/yxj8q/ for the full task). The participants had to tick a box for all the names that they recognized as author names. They were told that some names were fake and that they should select only the ones that they knew, as one point would be removed per incorrect answer. Thus, for each correct author, participants obtained 1 point, and for each false one, −1. The general score was calculated with the formula *correct items score* + *incorrect items score*. The maximum possible score is 40 and the minimum possible score is −40. In addition to the task itself, participants performed a subjective evaluation of their degree of exposure to print (i.e., *How regularly do you read?*), on an 11-point scale ranging from 0 (*never*) to 10 (*every day*).

Written Grammatical Competence

For measuring written grammatical competence, we used the same material as in the study by Zufferey and Gygax (2020a). It included 40 sentences, 20 of which were grammatically correct and 20 incorrect. The participants had to judge the correctness of the sentences on an 11-point scale ranging from 0 (*I am sure that it is incorrect*) to 10 (*I am sure that it is correct*). (Note, this is slightly different to the continuous scale slider used by Zufferey & Gygax, 2020a.) To calculate a general grammatical competence score per participant, we applied the formula correct score + (10 – incorrect score), following the procedure from the study by Zufferey and Gygax (2020a). The correct score was calculated as the mean of all answers on the correct sentences and the incorrect score was calculated as the mean of all responses on the incorrect sentences. The maximum possible score was 20 and the minimum possible

score was −20. The incorrect sentences contained an error typical of the written modality, such as: omission of written agreements that are silent in the oral modality; incorrect or missing agreements assigned to a part of speech in a way that reflects a lack of grammatical parsing or a mis-parsing; misuse and omission of diacritical marks that determine grammatical precision. The full materials, including the precise instructions and the rating scale, can be accessed at https://osf.io/vdmbf/.

Results

Connectives in the Sentence-Level Cloze Test

We analyzed participants' responses in terms of correctness (i.e., right or wrong) by fitting a mixed-effects logistic regression model on the binary variable. The analysis was conducted using the R software (RStudio Team, 2015), and models were tested with the glmer function of the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). Models were compared with the anova() function, which calculates the chi-square value of the log-likelihood ratio in order to evaluate the difference between models, following Baayen's (2008) procedure. Similarly to previous studies on the same issue (e.g., Zufferey and Gygax, 2020b), models were compared using a forward-testing approach. Fixed effects were included one at a time (main and interaction effects), and each resulting model was compared to a model that did not include the added effect. When comparing models, we also evaluated the contribution of random slopes to the models by using log-likelihood tests when it was justified by the design (as suggested by Barr, Levy, Scheepers, & Tily, 2013). To obtain *p* values for our final model, we used the summary() function from the lmerTest package (Kuznetsova, Bruun, Brockhoff, & Christensen, 2014). Following the procedure set out by Schreiber-Gregory (2018), we verified that the assumptions of logistic regressions were met (i.e., appropriate outcome structure, absence of multicollinearity, linearity of independent variables and log odds, and an appropriate sample size). The assumption of observation independence was not met, because our experiment had a repeated measures design (in that the same participants completed multiple test items, and the same test items were taken by multiple participants). However, we accounted for it by adding the random effects as intercepts for both items and participants in our mixed-effects models.

First, we built a model assessing the results of all participants. Our model fit continued to improve after adding group (secondary school, high school, and adults) and connective (*en effet* "for," *toutefois* "however," *en outre* "in

addition," and *aussi* "therefore")—both main and interaction effects—as fixed effects. It further improved after including connective as a random slope by participant, accommodating for the fact that the connectives may unequally impact different participants (see Table S1.2 in Appendix S1 of the Supporting Information online for comparison of the estimates of model fit across all participants). Because adding other random slopes did not have a further positive effect on the model, our final model included group and connective as fixed effects, item and participant as random intercepts, and connective as random slope by participant.[1] We did not add the task mode (online vs. offline) into the general model because it coincided with group in the case of adults. We applied treatment contrasts for the unordered connective and group. The "cause" relation (i.e., *en effet*) was set as the reference level for comparing the scores associated to the different connectives, since *en effet* constitutes the most frequently used connective in written French. For group, we chose "adults" as the reference level, because this group was assumed to include speakers with the highest level of competence (see Table 1). The statistical significance level was set at alpha .05.

As is apparent in Figure 1, across all groups, participants performed significantly better with the more frequent connectives *en effet* "for," $M = .83$, 95% CI [.78, .89], and *toutefois* "however," $M = .87$, 95% CI [.83, .92], compared to the less frequent connectives *en outre* "in addition," $M = .39$, 95% CI [.30, .47], and *aussi* "therefore," $M = .41$, 95% CI [.31, .51], with the estimates' difference between cause (set as reference level) and addition being 6.83, and between cause and consequence 5.58. These findings replicate the results obtained by Zufferey and Gygax (2020a, 2020b) for adults and high school participants. Moreover, participants from secondary school and high school scored significantly lower than adults across all connectives, which was reflected by the difference in estimates with the intercept of 6.72 for secondary school and 5.69 for high school. These estimates also show that there was a developmental trend between the two school levels, with a 1.03 increase in estimates from secondary to high school.

In addition, we performed a pairwise comparison between groups and connectives using the lsmeans() function of the emmeans package in R (Lenth, 2020). First, this comparison confirmed that adults significantly outperformed teenagers across all connectives (see Table S1.3 in Appendix S1 of the Supporting Information online for the estimates). Second, it also revealed that there was an important developmental effect for the connectives *en effet* and *toutefois* between secondary school, $M_{\text{en effet}} = .67$, 95% CI [.60, .73], $M_{\text{toutefois}} = .74$, 95% CI [.67, .80], and high school, $M_{\text{en effet}} = .81$, 95% CI [.76, .87], $M_{\text{toutefois}}$

Table 1 Model estimates for the best-fitting model within all the tested groups of participants in Experiment 1

Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*	Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*
		All participants						**High school**			
(Intercept)	3.83	[3.32, 4.33]	0.26	14.77	<.001	(Intercept)	2.13	[1.63, 2.63]	0.26	8.32	<.001
GROUP						TYPE OF CLASS					
High school	−1.86	[−2.38, −1.35]	0.26	−7.10	<.001	Level B	−0.85	[−1.63, −0.07]	0.40	−2.14	.033
Secondary school	−2.89	[−3.47, −2.32]	0.29	−9.93	<.001	Level A	0.13	[−0.56, 0.83]	0.35	0.38	.704
		CONNECTIVE						CONNECTIVE			
Toutefois	0.12	[−0.54, 0.78]	0.34	0.36	.722	Toutefois	0.56	[−0.10, 1.22]	0.34	1.65	.099
En outre	−3.00	[−3.61, −2.39]	0.31	−9.68	< .001	En outre	−3.39	[−4.03, −2.75]	0.33	−10.38	<.001
Aussi	−1.75	[−2.45, −1.05]	0.36	−4.88	<.001	Aussi	−3.43	[−4.17, −2.68]	0.38	−9.01	<.001
GROUP × CONNECTIVE						TYPE OF CLASS × CONNECTIVE					
High school × Toutefois	0.56	[−0.05, 1.17]	0.31	1.80	.071	Level B × Toutefois	0.37	[−0.54, 1.28]	0.46	0.80	.426
Secondary school × Toutefois	0.36	[−0.30, 1.01]	0.33	1.07	.284	Level A × Toutefois	0.15	[−0.68, 0.99]	0.43	0.36	.717
High school × En outre	−0.68	[−1.30, −0.05]	0.32	−2.12	.034	Level B × En outre	0.07	[−0.96, 1.10]	0.53	0.13	.898
Secondary school × En outre	0.73	[0.03, 1.43]	0.36	2.05	.040	Level A × En outre	−0.95	[−1.85, −0.05]	0.46	−2.07	.039

(*Continued*)

Table 1 (Continued)

Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*	Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*
High school × Aussi	−2.43	[−3.23, −1.62]	0.41	−5.91	<.001	Level B × Aussi	−0.82	[−2.14, 0.50]	0.67	−1.22	.223
Secondary school × Aussi	−1.02	[−1.91, −0.14]	0.45	−2.27	.023	Level A × Aussi	−2.37	[−3.54, −1.21]	0.60	−3.99	<.001
		Secondary school						**All adults**			
(Intercept)	1.36	[0.90, 1.83]	0.24	5.71	<.001	(Intercept)	4.31	[3.37, 5.24]	0.48	9.02	<.001
TYPE OF CLASS						GROUP					
Level 1	−1.05	[−1.65, −0.45]	0.31	−3.44	.001	Other adults	−0.69	[−1.56, 0.17]	0.44	−1.57	.116
CONNECTIVE						CONNECTIVE					
Toutefois	0.53	[−0.06, 1.12]	0.30	1.77	.077	Toutefois	0.43	[−0.80, 1.67]	0.63	0.69	.491
En outre	−2.29	[−2.93, −1.65]	0.33	−7.00	<.001	En outre	−2.24	[−3.32, −1.16]	0.55	−4.08	<.001
Aussi	−2.51	[−3.16, −1.85]	0.33	−7.50	<.001	Aussi	−0.62	[−1.89, 0.65]	0.65	−0.96	.336
TYPE OF CLASS × CONNECTIVE						GROUP × CONNECTIVE					
Level 1 × Toutefois	−0.05	[−0.74, 0.64]	0.35	−0.14	.887	Other adults × Toutefois	−0.73	[−1.80, 0.33]	0.54	−1.35	.178
Level 1 × En outre	0.29	[−0.55, 1.12]	0.43	0.67	.503	Other adults × En outre	−1.73	[−2.75, −0.71]	0.52	−3.33	<.001
Level 1× Aussi	0.04	[−0.82, 0.91]	0.44	0.09	.924	Other adults × Aussi	−2.36	[−3.64, −1.08]	0.65	−3.61	< .001

Note. In the model for all participants, conditional $R^2\Delta = .65$ and marginal $R^2\Delta = .39$; for secondary school, conditional $R^2\Delta = .46$ and marginal $R^2\Delta = .26$; for high school, conditional $R^2\Delta = .65$ and marginal $R^2\Delta = .44$; for all adults, conditional $R^2\Delta = .51$ and marginal $R^2\Delta = .21$.

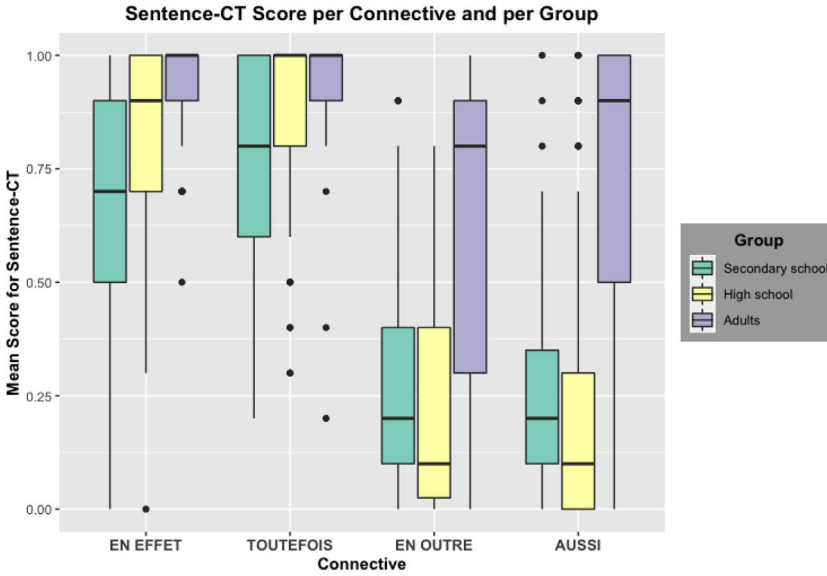

Figure 1 Mean proportions of correct connective production by three groups of participants across connectives in Experiment 1, with boxplots representing 50% interquartile range. [Color figure can be viewed at wileyonlinelibrary.com]

= .88, 95% CI [.84, .92], with an increase by 1.03 and 1.23 estimates, respectively. Finally, we did not observe a significant effect for the connectives *en outre* and *aussi* between secondary school, $M_{\text{en outre}} = .27$, 95% CI [.21, .33], $M_{\text{aussi}} = .23$, 95% CI [.17, .29], and high school, $M_{\text{en outre}} = .23$, 95% CI [.17, .28], $M_{\text{aussi}} = .21$, 95% CI [.14, .28], although participants from a lower level scored slightly higher for these two connectives.

Analyses per Group

After performing this global analysis, we decided to explore the results within each age group and created three separate statistical models following the same procedure. Because there were unordered variables, we also used treatment contrasts. As described above, "cause" (i.e., *en effet*) was set as the reference level for comparing connectives across all models. Models for secondary and high school participants included the fixed effect type of class, with Levels 1 and 2 for the secondary school students and Levels A, B, and C for the high school students. "Level 2" was chosen as the reference level for comparing classes within secondary school, and "Level C" was set as the reference for high school. Finally, the model for adults had a fixed effect group (university

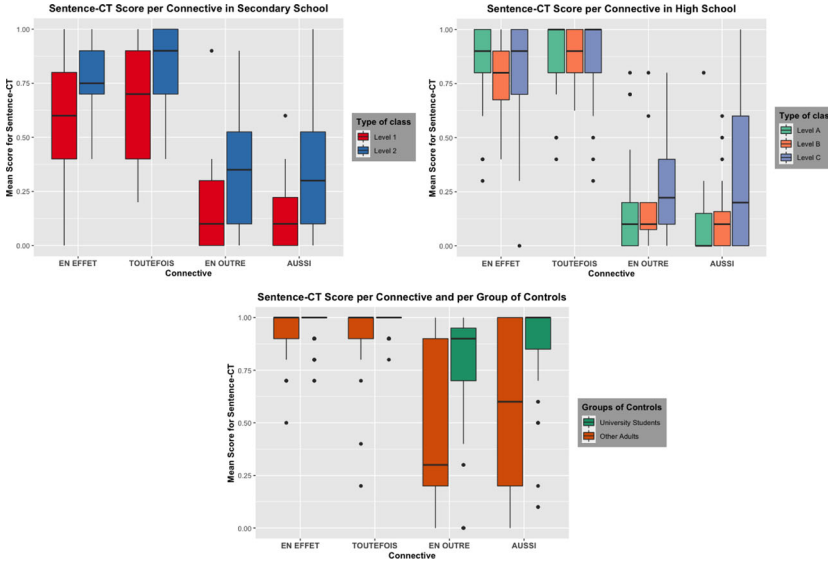

Figure 2 Mean proportions of correct connective production in Experiment 1 across participants from secondary school (upper left panel), participants from high school (upper right panel), and adults (lower panel), with boxplots representing 50% interquartile range. [Color figure can be viewed at wileyonlinelibrary.com]

students and other adults), where "university students" were a reference for comparing the two groups of adults.

Secondary School

In the final model designed for the secondary school group, the model included type of class and connective as fixed effects, item and participant as random intercepts, and connective as random slope by participant (see Table S1.2 in Appendix S1 of the Supporting Information online). After we tried to add other random slopes, the model did not converge. Among the participants from secondary school, students from the Level 1 class performed the task fully in class, whereas those from Level 2 completed it online. Because the variables of academic level and the mode (online vs. offline) of the task coincide, we did not include the task mode in the final model. Figure 2 demonstrates that teenagers from secondary school on average have higher scores for the more frequent connectives *en effet* "for," $M = .67$, 95% CI [.60, .73], and *toutefois* "however," $M = .74$, 95% CI [.67, .80], than for the less frequent *en outre* "in addition," $M = .27$, 95% CI [.21, .33], and *aussi* "therefore," $M = .23$, 95% CI

[.17, .29], as was also found for the whole population. According to the final model estimates (Table 1), the results for addition (i.e., *en outre*) and consequence (i.e., *aussi*) are indeed significantly lower than those for cause (i.e., *en effet*). In addition, the final model estimates as well as the output of the post hoc pairwise comparison (see Table S1.3 in Appendix S1 of the Supporting Information online) indicate that students from Level 1 obtained significantly lower scores across all connectives.

High School

The final model for high school participants included type of class and connective as fixed effects, item and participant as random intercepts, and connective as random slope by participant (see Table S1.2 in Appendix S1 of the Supporting Information online). The model did not improve when we added the task mode into it. It also did not converge when we added other random slopes. Figure 2 shows that, on average, high school students also scored better with the more frequent connectives *en effet*, $M = .81$, 95% CI [.76, .87], and *toutefois*, $M = .88$, 95% CI [.84, .92], than with the less frequent *en outre*, $M = .23$, 95% CI [.17, .28], and *aussi*, $M = .21$, 95% CI [.14, .28]. Similarly to the findings for the secondary school group, the estimates of our final model (Table 1) demonstrated that the results for addition and consequence were indeed significantly lower than those for cause. In addition, according to the pairwise analysis among three classes, Level B on average performed significantly less well than Level C for the connectives *en effet*, *en outre*, and *aussi* (see Table S1.3 in Appendix S1 of the Supporting Information online). Finally, it seems that the class of Level A scored significantly lower than the reference class of Level C for the connectives *en outre* and *aussi*.

Adults

The final model for the adult participants included group and connective as fixed effects, item and participant as random intercept, and connective as random slope by participant (see Table S1.2 in Appendix S1 of the Supporting Information online). When we added other random slopes to the model, it stopped converging. As shown in Figure 2 and Table 1, the controls also performed better with *en effet*, $M = .95$, 95% CI [.93, .97], and *toutefois*, $M = .95$, 95% CI [.92, .98], than with *en outre*, $M = .63$, 95% CI [.54, .72], and *aussi*, $M = .73$, 95% CI [.64, .81]. Finally, we found a significant difference between the results for the group of adults with various backgrounds and those for university students, the former scoring significantly lower for the connectives

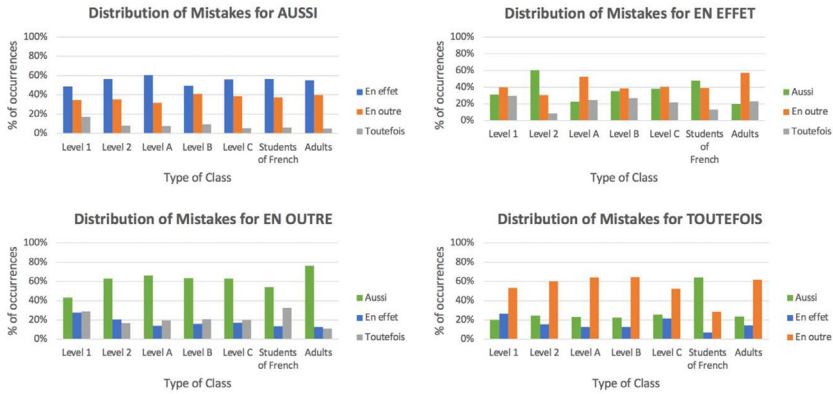

Figure 3 The percentage of errors across all tested groups and connectives in Experiment 1. [Color figure can be viewed at wileyonlinelibrary.com]

toutefois, *en outre*, and *aussi* (see Table S1.3 in Appendix S1 of the Supporting Information online).

Distribution of Errors

In order to ensure that the results were not due to some systematic errors because one or the other connective was consistently being chosen in error, we also explored the distributions of errors per connective and per type of group (Figure 3). We noticed that, both for teenagers and for adults, the most frequent error for *en outre* "in addition" was *aussi* "therefore," and for *aussi* it was *en effet* "for." There was no systematic pattern of error for *toutefois* "however" or for *en effet*.

Measures of Written Language Proficiency and Associations With Use of Connectives

Generally (and as expected), across proficiency measures, participants from high school performed better than those from secondary school (Table S1.4 in Appendix S1 of the Supporting Information online). Interestingly, Level 2 students outperformed Level 1 students across all the language proficiency measures despite the fact that both classes are from the same age group (Table S1.1 in Appendix S1 of the Supporting Information online). Among the classes from high school, Level C students obtained the highest scores for all three tasks, except for the grammatical competence measure, and Level B had the lowest means in all tasks. Neither group of teenagers reached the scores

from the adults in any of the tasks, even though the adults with varied backgrounds scored lower than the university students across all measures. To measure the reliability of the ART-F and the written grammatical competence test, we calculated Cronbach's alphas, following the procedure of Stanovich and West (1989) for the former and that of Zufferey and Gygax (2020b) for the latter. The overall reliability of both measures was similar to that reported in the initial studies, and high for the ART-F (.90, 95% CI [.89, .92]), and medium-high for the grammatical task (.68, 95% CI [.61, .73]). When considering the reliability scores of the ART-F and the written grammatical competence test separately for teenagers (.64, 95% CI [.56, .70] and .66, 95% CI [.56, .74], respectively) and for adults (.88, 95% CI [.85, .90] and .71, 95% CI [.63, .77], respectively), we noticed that both measures had higher reliability in the case of adults.

Each of the proficiency measures was correlated against the Sentence-CT, separately for teenagers and adults. Within all teenagers (as a whole), Spearman's correlations between the scores of the Sentence-CT (the main connective task) and the three measures of language competence slightly varied, from the strongest ones for subjective exposure to print, rho = .33, 95% CI [.19, .45], $p < .001$, and the ART-F, rho = .29, 95% CI [.15, .42], $p < .001$, to the weakest one for written grammatical competence, rho = .21, 95% CI [.07, .35], $p = .003$. However, these correlations were still quite weak, as their rho coefficients ranged from .2 to .3 (Goehring, 1981). In contrast, correlations within the group of adults (as a whole) were stronger between the Sentence-CT and the three measures of linguistic competence (for the ART-F, rho = .51, 95% CI [.36, .64], $p < .001$; for subjective exposure to print, rho = .42, 95% CI [.25, .56], $p < .001$; for written grammatical competence, rho = .48, 95% CI [.32, .61], $p < .001$).

Discussion

The results of Experiment 1 showed that, across all groups, teenagers performed better with more frequent connectives (*en effet* "for" and *toutefois* "however") than with less frequent ones (*en outre* "in addition" and *aussi* "therefore"). These findings are in line with the performance of the adult groups as well as with the results of previous studies on children, adults, and high school teenagers (e.g., Nippold et al., 1992; Zufferey & Gygax, 2020a, 2020b). Therefore, our result supports the frequency hypothesis for connectives used in written modality.

Another important finding concerns the difference in performance between secondary and high school students. This developmental difference was

especially pronounced for more frequent connectives in general and for the connective *en effet* in particular. The analysis of results within each school level also suggested that students with a more advanced curriculum (Level 2 for secondary school and Level C for high school) scored better at least for the infrequent connectives, independently of their age. In fact, among high school students, Level A obtained the lowest scores for the low frequency connectives *en outre* and *aussi*, despite their being older than other high school students. In addition, Level 2 and Level C also outperformed all other classes from the same school type (i.e., age range) across all tasks of linguistic competence.

These findings demonstrate that academic background is indeed a strong predictor for students' ability to use connectives. Besides, this predictor stays valid not only during teenage years, but also for adults, as was shown by the results for our two adult groups. University students studying French scored significantly higher than adults from different backgrounds for the connectives *toutefois*, *en outre*, and *aussi*, although the difference between the two groups was significantly greater for the less frequent connectives *aussi* and *en outre*.

The distribution of errors seems to suggest some interesting mechanisms. First, regarding the connective *aussi*, its frequent replacement by *en effet* in consequence relations seems to indicate that participants were not aware of its causal meaning. This interpretation is reinforced by the fact that they tended to erroneously use *aussi* instead of *en outre* in additive relations. Taken together, these mistakes indicate that participants only associated the more frequent additive meaning with *aussi*, even though it never functions with this meaning in the sentence-initial position. This result therefore suggests that polyfunctional connectives represent an area of difficulty, even for native speakers. Interestingly, when participants used an erroneous connective in concessive relations, it was by using the additive connective *en outre*. This misuse seems to suggest that our participants have not yet encoded a specific value for this connective, as negative relations are rarely confused with positive ones. This problem is a further indication that infrequent connectives are not mastered by a portion of native speakers.

Finally, the correlations between the connectives task and the measures of exposure to print were positive, which suggests that there is a link between the competence with written connectives and the degree of exposure to print. However, the fact that these correlations were stronger for adults than for teenagers means that either (a) teenagers may be less impacted by how much they read, and there might even be a floor effect, as suggested by the low scores on the measure of exposure to print (see Table S1.4 in Appendix S1 of the Supporting

Information online), or (b) the measures of exposure to print that we used were not optimal for younger populations.

However, as mentioned earlier, our results may be constrained to artificial sentence-pair processing only. In Experiment 2, we address this by conducting an experiment similar to Experiment 1, but with more naturalistic texts.

Experiment 2: Text-Level Cloze Test

Participants

A group of 85 teenagers from 13 to 19 years old, the same as those who took part in Experiment 1, also took part in Experiment 2. Some participants came from secondary school (Levels 1 and 2) and others from high school (Level C). In addition, two adult groups participated: 40 university students specializing in French and 47 adults recruited on the Prolific© platform (Prolific, Oxford, UK, www.prolific.co). All the participants were native French speakers. A more detailed view of the distribution of participants between different groups is reported in Table S1.5 (see Appendix S1 of the Supporting Information online).

Materials and Procedures

Text-Level Cloze Test

The materials for the text level cloze test (Text-CT) consisted of eight short texts (approximately 250 words each) with blanks that participants had to fill in with an appropriate connective. All the omitted connectives were in the sentence-initial position, similarly to Experiment 1. Participants had to choose between the same four connectives as in the Sentence-CT (i.e., *aussi*, *en effet*, *en outre*, and *toutefois*). The texts were real texts taken from websites presenting news and various cultural and historical phenomena for teenagers (https://dimoitou.ouest-france.fr; https://www.1jour1actu.com) and adapted to the purposes of the study. The texts covered a wide range of topics, such as new technologies in archaeology, Black Friday and the environment, and urbanization. In their final versions, each text included four paragraphs with one missing connective per paragraph. In total, each connective had to be used once in every text. However, students were not prevented by the software from using the same word twice. All the paragraphs were controlled for alternative interpretations so that only the intended one was possible. The participants first saw the whole text with the four blanks and had to read it. Afterwards, they saw, one by one, separate paragraphs of the same text and had to fill in each blank with an appropriate connective. They could not go back to the previous paragraph.

All the participants did this task online via a weblink. To access the task, see https://osf.io/p35u6/ and Appendix S3 of the Supporting Information online.

The Author Recognition Test for French-Speaking Adults and Written Grammatical Competence

The two measures of language competence were the same as in Experiment 1: the ART-F and written grammatical competence.

Results

Connectives in the Text-Level Cloze Test

We analyzed the results using the same procedure as in Experiment 1, fitting mixed-effect logistic regression models on the binary variable and checking the assumptions of logistic regressions. We started by performing a global analysis across all groups, and applied the same treatment contrasts for the variables connective and group as in Experiment 1.

Our model fit continued to improve after we added group (secondary school; high school; and adults, combining both groups) as a fixed effect, then the main and interaction effects of connective (cause vs. concession vs. addition vs. consequence), and finally connective as a random slope by participant. Because adding other random slopes did not improve the model, the final model included group and connective as fixed effects, item and participant as random intercept, and connective as random slope by participant (see Table S1.6 in Appendix S1 of the Supporting Information online for the estimates of the model fit). As in Experiment 1, we set the "cause" relation (i.e., *en effet*) as the reference level for comparing connectives and the group of adults as the reference level for comparing three age groups. As an Experiment 1, we selected an alpha level of .05 as the level of significance for the statistical tests.

As in the Sentence-CT, across all groups, participants attained higher scores for the more frequent connectives *en effet* "for," $M = .68$, 95% CI [.62, .74], and *toutefois* "however," $M = .69$, 95% CI [.62, .76], and significantly lower scores for the less frequent connectives *aussi* "therefore," $M = .41$, 95% CI [.33, .49], and *en outre* "in addition," $M = .37$, 95% CI [.30, .44], with an estimated difference of 3.64 between cause (*en effet*) and addition, and 3.11 between cause and consequence (see Figure 4 and Table 2). In addition, we can observe a general developmental effect between the three groups. The secondary school group has an estimate of -1.79 ± 0.23 *SE*, the high school group -1.14 ± 0.23 *SE*, and the combined adult groups 1.75 ± 0.27 *SE*. Finally, we performed a post hoc pairwise comparison (see Table S1.7 in Appendix S1 of the Supporting Information online). The comparison

Table 2 Model estimates for the best-fitting model within all the tested groups of participants in Experiment 2

Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*	Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*
	All participants						**High school**				
(Intercept)	1.75	[1.22, 2.28]	0.27	6.45	< .001	(Intercept)	0.63	[0.04, 1.23]	0.30	2.08	.038
GROUP						CONNECTIVE					
High school	−1.14	[−1.59, −0.69]	0.23	−4.95	< .001	Toutefois	−0.13	[−0.85, 0.60]	0.37	−0.34	.733
Secondary school	−1.79	[−2.24, −1.34]	0.23	−7.79	< .001	En outre	−1.94	[−2.79, −1.09]	0.43	−4.47	< .001
CONNECTIVE						Aussi	−2.16	[−3.14, −1.18]	0.50	−4.33	< .001
Toutefois	0.66	[−0.09, 1.40]	0.38	1.73	.084						
En outre	−1.89	[−2.61, −1.17]	0.37	−5.11	< .001						
Aussi	−1.36	[−2.11, −0.60]	0.39	−3.51	< .001						
GROUP × CONNECTIVE											
High school × Toutefois	−0.73	[−1.30, −0.17]	0.29	−2.54	.011						

(*Continued*)

Table 2 (Continued)

Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*	Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*
Secondary school × Toutefois	−0.80	[−1.38, −0.23]	0.29	−2.74	.006						
High school × En outre	−0.02	[−0.61, 0.56]	0.30	−0.07	.943						
Secondary school × En outre	0.75	[0.18, 1.33]	0.29	2.57	.010						
High school × Aussi	−0.66	[−1.36, 0.05]	0.36	−1.82	.068						
Secondary school × Aussi	0.04	[−0.65, 0.73]	0.35	0.11	.911						
	Secondary school						**All adults**				
(Intercept)	0.48	[−0.07, 1.03]	0.28	1.70	.088	(Intercept)	2.30	[1.53, 3.07]	0.39	5.87	< .001
TYPE OF CLASS						GROUP					
Level 1	−0.77	[−1.34, −0.19]	0.29	−2.61	.009	Other adults	−0.75	[−1.33, −0.17]	0.30	−2.52	.012
CONNECTIVE						CONNECTIVE					
Toutefois	0.52	[−0.30, 1.35]	0.42	1.25	.212	Toutefois	0.55	[−0.53, 1.63]	0.55	1.00	.318
En outre	−2.15	[−2.98, −1.32]	0.42	−5.07	< .001	En outre	−2.01	[−3.00, −1.03]	0.50	−4.00	< .001
Aussi	−1.48	[−2.27, −0.68]	0.41	−3.62	< .001	Aussi	−1.17	[−2.23, −0.11]	0.54	−2.16	.030

(*Continued*)

Table 2 (Continued)

Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*	Parameter	Estimate	95% Wald CI	*SE*	*z*	*p*
TYPE OF CLASS × CONNECTIVE						GROUP × CONNECTIVE					
Level 1 × Toutefois	−0.95	[−1.83, −0.08]	0.45	−2.14	.033	Other adults × Toutefois	0.13	[−0.65, 0.90]	0.39	0.32	.748
Level 1 × En outre	1.63	[0.78, 2.49]	0.44	3.75	< .001	Other adults × En outre	−0.06	[−0.68, 0.56]	0.32	−0.18	.860
Level 1 × Aussi	0.50	[−0.34, 1.34]	0.43	1.17	.240	Other adults × Aussi	−0.54	[−1.34, 0.26]	0.41	−1.32	.186

Note. In the model for all participants, conditional $R^2\Delta = .45$ and marginal $R^2\Delta = .21$; for secondary school, conditional $R^2\Delta = .21$ and marginal $R^2\Delta = .09$; for high school, conditional $R^2\Delta = .41$ and marginal $R^2\Delta = .14$; for all adults, conditional $R^2\Delta = .45$ and marginal $R^2\Delta = .16$.

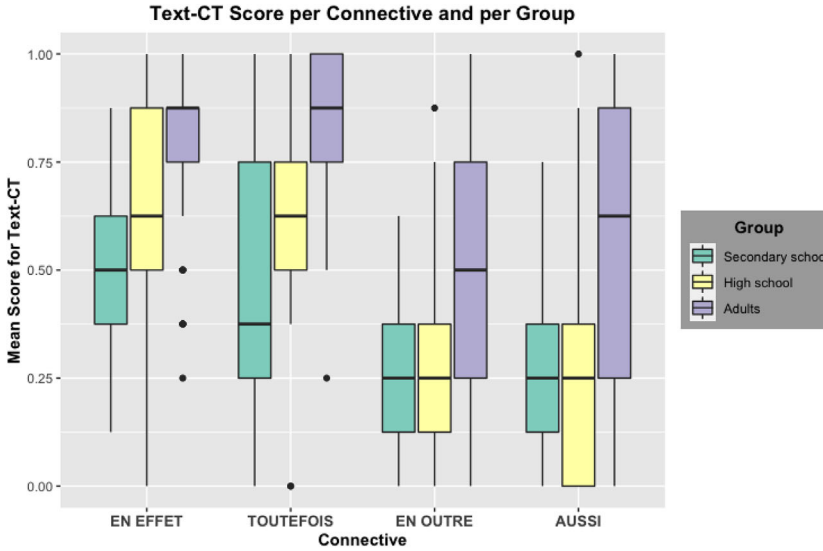

Figure 4 Mean proportions of correct connective production across all participants in Experiment 2, with boxplots representing 50% interquartile range. [Color figure can be viewed at wileyonlinelibrary.com]

demonstrated that between teenagers and adults there was a significant difference in scores across all connectives, meaning that even the most advanced teenagers still did not reach the performance of adults even for frequent connectives. In addition, we observed a significant developmental effect between the secondary and high school types for the connectives *en effet* and *toutefois*, with an estimated increase by 0.65 and 0.72, respectively.

Analyses per Group

Secondary School

After this global analysis, we decided to analyze the results within each group of participants. We began with the classes of secondary school. Our final model included type of class (Level 1 and Level 2) and connective as fixed effects, item and participant as random intercept, and connective as random slope by participant (see Table S1.6 in Appendix S1 of the Supporting Information online for the final model). As can be seen in Figure 5, classes of Level 1 scored on average significantly lower than those of Level 2 (with an estimate of -0.77 ± 0.29 *SE*), and all classes performed worse with *en outre* "in addition," $M = .27$, 95% CI [.23, .31], and *aussi* "therefore," $M = .25$, 95% CI [.21, .30],

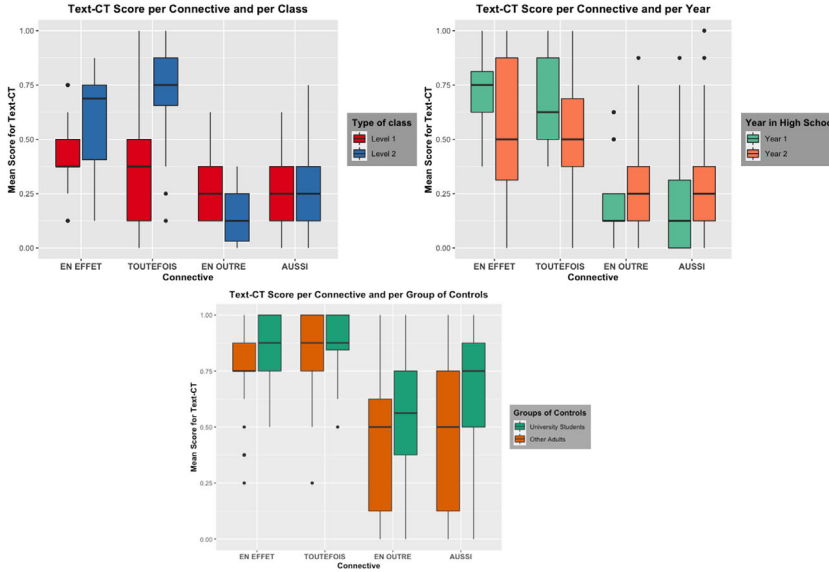

Figure 5 Mean proportions of correct connective production across participants from secondary school (upper left panel), participants from high school (upper right panel), and adults (lower panel) in Experiment 2, with boxplots representing 50% interquartile range. [Color figure can be viewed at wileyonlinelibrary.com]

than with *en effet* "for," $M = .49$, 95% CI [.44, .54], and *toutefois* "however," $M = .47$, 95% CI [.39, .54]. Moreover, the pairwise comparison revealed a significant difference between the two classes, showing that Level 2 scored significantly higher than Level 1 for the connectives *en effet*, $M_{\text{Level2}} = .61$, 95% CI [.55, .67], versus $M_{\text{Level1}} = .44$, 95% CI [.39, .48], and *toutefois*, $M_{\text{Level2}} = .69$, 95% CI [.62, .75], versus $M_{\text{Level1}} = .39$, 95% CI [.30, .43], and slightly lower for *en outre*, $M_{\text{Level2}} = .17$, 95% CI [.13, .21], versus $M_{\text{Level1}} = .32$, 95% CI [.28, .36] (see Table S1.7 in Appendix S1 of the Supporting Information online).

High School

In order to analyze the results from high school students, we used a model including connective as a fixed effect, item and participant as random intercepts, and connective as random slope by participant (see Table S1.6 in Appendix S1 of the Supporting Information online for the final model). Even though the participants from High school included classes from years 1 and 2, adding this variable as a fixed effect to the model did not improve it (see Table S1.6 in

Appendix S1), suggesting that the performance with connectives within the same academic level (Level C) does not necessarily depend on the age of participants (see Table S1.5 in Appendix S1 for the distribution of age among participants). Furthermore, as shown in Figure 5 and Table S1.7 in Appendix S1, high schoolers also scored significantly higher with the more frequent connectives *en effet*, $M = .62$, 95% CI [.55, .68], and *toutefois*, $M = .60$, 95% CI [.53, .66], than with *en outre*, $M = .26$, 95% CI [.20, .31], and *aussi*, $M = .26$, 95% CI [.19, .33].

Adults

As in Experiment 1, we built a separate statistical model to analyze the results of adults. The final model for adults included group (university students and other adults) and connective as fixed effects, item and participant as random intercepts, and connective as random slope by participant (see Table S1.6 in Appendix S1 of the Supporting Information online for the final model). As we can see in Figure 5 and Table 2, both groups of adults also performed better with *en effet*, $M = .80$, 95% CI [.76, .85], and *toutefois*, $M = .85$, 95% CI [.81, .89], than with *aussi*, $M = .56$, 95% CI [.48, .65], and *en outre*, $M = .47$, 95% CI [.41, .54], although their scores were higher than those of teenagers. The mean scores per connective presented here are the averaged means of both adult groups combined together. Furthermore, the performance of the group of adults with various backgrounds was on average lower than that of the university students. However, the difference between university students and other adults was significant only for three of the connectives *en effet*, $M_{\text{Uni}} = .85$, 95% CI [.82, .89], versus $M_{\text{Other}} = .76$, 95% CI [.71, .81]; *aussi*, $M_{\text{Uni}} = .68$, 95% CI [.60, .75], versus $M_{\text{Other}} = .47$, 95% CI [.39, .55]; and *en outre*, $M_{\text{Uni}} = .55$, 95% CI [.49, .62], versus $M_{\text{Other}} = 0.41$, 95% CI [.34, .47] (see Table S1.7 in Appendix S1 of the Supporting Information online for the estimates of the pairwise comparison).

Distribution of Errors

We also examined the distributions of errors per connective and per group (Figure 6). In this task, no specific pattern was revealed with connectives *en effet* "for," *en outre* "in addition," or *toutefois* "however" in teenagers. In contrast, we noticed that the most frequent mistake for *aussi* "therefore" was *en effet* (similarly to the findings from the Sentence-CT). Among the adult groups, we did not see any trend for mistakes with connectives *aussi*, *en effet*, or *toutefois*, whereas for *en outre*, the most common mistake was *aussi* (as observed in the Sentence-CT).

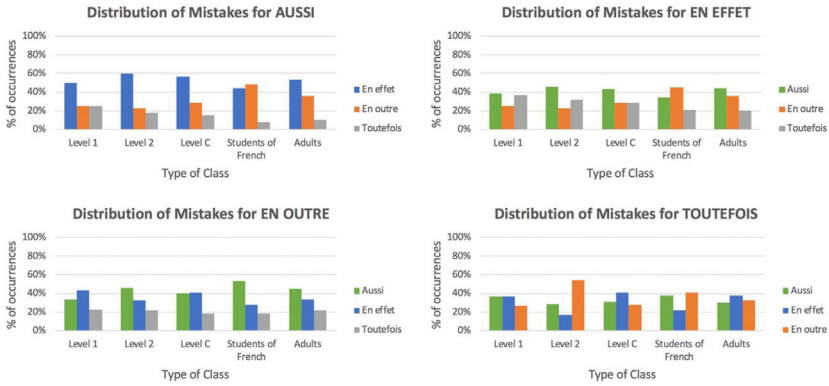

Figure 6 The percentage of errors across all tested groups and connectives in Experiment 2. [Color figure can be viewed at wileyonlinelibrary.com]

Measures of Written Language Proficiency and Associations With Use of Connectives

The scores across all language measures increased between secondary and high school (see Table S1.8 in Appendix S1 of the Supporting Information online). As in Experiment 1, participants from Level 2 performed better than those from Level 1 across all tasks. However, even the most advanced teenager group (Level C) did not manage to reach the same scores as adults. Similarly to Experiment 1, the reliability of the ART-F and the task on written grammatical competence, measured by calculating Cronbach's alpha, was higher for adults (.90, 95% CI [.86, .92], and .70, 95% CI [.57, .77], respectively) than for teenagers (.67, 95% CI [.59, .73], and .50, 95% CI [.30, .62], respectively). The general Cronbach's alpha for the ART-F across all groups was .92, 95% CI [.90, .94], and that for written grammatical competence was .62, 95% CI [.52, .69].

The Spearman's correlation values between Text-CT (the main connective task) and other measures of written linguistic competence were also positive, but still below .5 for teenagers (rho = .27, 95% CI [.06, .47], $p = .013$, for the ART-F; rho = .36, 95% CI [.15, .54], $p = .001$, for subjective exposure to print; rho = .17, 95% CI [−.05, .38], $p = .123$, for grammatical competence). The correlations between the same measures for the combined adult groups were different. Whereas the correlation between the Text-CT and subjective exposure to print was comparable to that across teenagers (rho = .34, 95% CI [.14, .52], $p = .001$), the correlations between the Text-CT and the other measures were much stronger (rho = .68, 95% CI [.54, .78], for the ART-F,

and rho = .52, 95% CI [.35, .66], for grammatical competence, with $p < .001$ for both).

Discussion

As in Experiment 1, across all groups of participants, the more frequent connectives *en effet* and *toutefois* led to higher scores than the less frequent *en outre* and *aussi*. Moreover, there was a developmental trend for the frequent connectives from secondary school students to adults. However, there was no visible progress with the infrequent connectives between secondary and high school students.

A more detailed analysis within each age group also revealed interesting findings. When we examined the students from secondary school who were of the same age but differed in their academic background, we found important differences in competence with connectives. Indeed, students from a more advanced level (Level 2) scored significantly higher for frequent connectives than those from Level 1. In striking contrast, when we compared students from high school who were from different age groups but had the same academic background (Level C), we found no difference in performance. This seems to suggest that academic level is a stronger predictor of performance relative to age. The fact that Level 1 students slightly outscored the group from Level 2 for the connective *en outre* should be investigated further. We believe that this result needs to be confirmed on a larger group of participants from both types of classes in order to draw further conclusions. We suggest that such a difference in the scores of the Level 2 class indicates that *en outre* is particularly difficult to use in a text for all school students, even more advanced ones. We should, however, take into account that the average performance with the two less frequent connectives was below chance level for all teenagers, which may partially explain the reversed distribution of scores for *en outre* between the two levels of secondary school.

Interestingly, the difference of academic background persists among adults. Whereas the results for the connective *toutefois* are very similar across the two groups of adults, those for *en effet*, *en outre*, and *aussi* differ between university students of French and adults with various backgrounds. This result again suggests that age is probably not the most important influence on competence with connectives. Instead, the mastery of connectives depends on the level of written language competence.

For this text level task, it was more difficult to see a trend in the production of errors by teenagers, because the range of incorrect answers varied widely. The fact that teenagers chose *en effet* instead of *aussi* may reflect the fact that

they correctly identified a causal link between the segments but incorrectly used a causal instead of a consequence connective because they failed to attribute a consequence meaning to *aussi*. Generally, having more context seems to have increased uncertainty about the intended coherence relation compared to Experiment 1, as it is not clear from the pattern of errors which relations participants inferred when they misused a connective.

Finally, performance on the measures of written linguistic competence increased with academic level and were more strongly correlated with the scores for the Text-CT across the groups of adults than the groups of teenagers. This could be due to their having to insert connectives in natural texts, a task more closely resembling the constraints of normal reading. However, the fact that these correlations were stronger for adult groups than for teenagers suggests again that either (a) teenagers may be less impacted by how much they read (there might even be a floor effect), or (b) the measures of exposure to print that we used were not optimal for younger populations.

General Discussion

Frequency Versus Cognitive Complexity

Across two constrained production tasks, we assessed the ability of teenagers and adults to appropriately use four different French connectives in the written modality. To the best of our knowledge, this is the first study to assess the ability to use connectives that includes such a large age range, extending from early teenage years to adulthood. Within each age group, proficiency with connectives was compared between groups with various levels of academic competence, enabling us to examine the roles of age and academic competence together. We also compared the ability to use connectives across two types of cloze tests: one with a minimal two-sentence context and the other with a larger and more naturalistic textual context. Taken together, these two tasks provided converging evidence regarding the role of academic level and connective frequency. Significant differences were found between groups with different levels of academic achievement in both tasks and in all age groups. Additionally, in both tasks, connectives with a lower frequency in corpus data (*en outre* "in addition" and *aussi* "therefore") were mastered less well than connectives with a higher frequency (*en effet* "for" and *toutefois* "however"), even though these latter connectives encode more complex coherence relations. Furthermore, the teenagers' performance with the less frequent connectives was on average below chance level.

These findings provide further confirmation that, once speakers have acquired the basic meaning and function of connectives, their frequency becomes

a better predictor of their difficulty compared to the degree of cognitive complexity of the coherence relation they encode. This is true at least in offline tasks such as those utilized in this study. It is possible that, when investigating older speakers, offline experiments cannot really capture the effect of coherence complexity on competence with connectives. Indeed, previous studies on adults, which reported a greater difficulty in the processing of subjective compared to objective causal relations (e.g., Traxler et al., 1997) and of negative compared to positive ones (e.g., Morera, León, Escudero, & de Vega, 2017), used online measures (i.e., measures of reading patterns such as eye movements and reading speed). Future research will need to assess whether teenagers and adults process the tested coherence relations differently when they are conveyed by written connectives compared to when they are conveyed by oral connectives. This will be an important contribution to the online reading literature, which has not yet made such a comparison.

The Role of Context

Important differences also emerged between the sentence-level cloze test (Experiment 1) and the text-level cloze test (Experiment 2). First, the scores for the group of adults decreased across all connectives in the text-level cloze test, and this was also the case for the scores for more frequent connectives for teenagers. This might indicate that processing coherence relations in a text is cognitively more demanding than within a more reduced linguistic context. This is also reflected in the different patterns of error distribution between the two tasks. The text-level cloze test resulted in a much more heterogeneous pattern of errors. A larger text may require greater cognitive capacity and may thus inhibit understanding of coherence relations and the use of connectives to convey them. Failure to understand one coherence relation may further challenge the understanding of other relations in a text, creating a cumulative effect. This contrasts with the sentence-level cloze test, where all the items are independent from each other.

We do not observe a big difference in scores between the two tasks among teenagers for the less frequent connectives, probably because their results with these connectives are already quite low in the linguistically reduced context of sentence pairs and are not further impacted by the greater complexity of more naturalistic texts. We should, however, be careful in the interpretation of these findings. Whereas adults did both tasks on the Internet, the majority of teenagers completed the sentence-level cloze test at school with pen and paper.

Still, the fact that a more natural experimental environment hinders the use of written connectives is in itself revealing, as one might have expected

that a richer context could increase the ability to infer the intended coherence relation. Yet, even though the correct relation may have been inferred, it did not lead to the use of an appropriate connective. This leads to the conclusion that participants are genuinely unsure about the meaning of some connectives in the written modality.

This result was not observed in previous studies, where the context in texts either facilitated the performance with connectives or did not influence it at all (Scholman & Demberg, 2017; Yung, Demberg, & Scholman, 2019). This discrepancy can in the first instance be explained by our text-level cloze task being rather different from those used in the studies mentioned. In those studies, arguments that had to be connected were marked by a black color and the sentences providing additional context were gray. The order of these contextual elements and arguments was also always the same. In consequence, participants knew which sentences were supposed to be linked by a connective and which were there just to provide context. This was not the case in our experiment 2, hence making the task more challenging.

Some may argue that the nature of the texts themselves (their content or genre) could have affected performance. This is rather unlikely, as we presented short expository texts specifically conceived for teenagers and written in an accessible way. As for genre, van Silfhout et al. (2015) showed that its effect was rather limited when teenagers aged 12 to 15 dealt with explicit or implicit marking of coherence relations in expository and narrative texts.

It could finally be argued that lower performance in the Text-CT in comparison to the Sentence-CT might stem from individual differences between participants in the two experiments. However, whereas the adults differed between the two tasks, the teenagers did not (that is, as they were the same participants, they had the same individual characteristics). This is confirmed by the scores for the ART-F, our measure of individual variation in exposure to print, which are comparable between the two experiments for both teenagers and adults.

Individual Variation

Another important aspect of our results is that we found a difference in performance not only between connectives with different frequencies in corpus data, but also between different groups of participants. Predictably and in line with the studies by Nippold et al. (1992) and Zufferey and Gygax (2020b), we observed a developmental trend between teenagers and adults across all connectives. However, when we compared the results within different age groups, we also discovered that age was not the most meaningful predictor of competence. Whereas the high school students outperformed students from

secondary school for frequent connectives, the results for infrequent connectives did not differ between the two age groups in either task. Moreover, among the secondary school students, teenagers with a lower academic level scored significantly lower compared to students with a higher academic level in the Sentence-CT. In the Text-CT, however, they differed only in the frequent connectives. That the difference between the groups of teenagers was found mostly for frequent connectives is compatible with the explanation in terms of exposure to print. Indeed, students with a higher academic level, who read more as part of their curricula, have had enough exposure to frequent connectives to master them better, but not yet for infrequent ones. A different pattern is found within the adult groups. Whereas all of them have been exposed to connectives frequently enough to master the frequent ones, differences between them, as a function of academic background, are still found for the infrequent connectives.

We should, however, consider the findings with caution, given that adults with various academic backgrounds were recruited via a crowdsourcing platform. There is evidence that the results provided by such sources may be less reliable due to a lack of motivation (e.g., Scholman & Demberg, 2017) or lower attentiveness (e.g., Schwab & Liu, 2020) of participants. This criticism could, however, also apply to the group of university students who completed the task via a weblink and for whom we had the same degree of control as for the participants from Prolific. Hence, the results provided by the two groups of adults can be considered comparable despite these challenges.

The difference between the two groups of adults leads us to question precisely which linguistic skills made the university students of French more successful than the mixed group of adults in the task on connectives. We suggest that it may be related to their explicit and more extensive training in metacognitive analysis of text structure, such as the analyses described by Welie et al. (2017). It is also possible that metacognitive awareness may explain the variation observed between teenagers belonging to different academic levels, as those at more advanced levels may have a more thorough grounding in all aspects of the French language.

Limitations and Future Directions

Other directions may need to be explored in future studies. First, the present study should be extended to a larger group of connectives varying in frequencies both in written (or formal) and oral (or nonformal) registers. Second, one may want to explore whether frequency, found to be an important variable in offline tasks (where readers can take their time and reread), also has an

impact on the ability to read sentences in online tasks (such as during reading by documenting eye movements or reaction times). Such tasks would provide important information on the processing of different types of connectives, given that current studies are still mostly performed with connectives frequently used in speech. Third, it would be interesting to contrast findings on the production of connectives, as in our experiments, with findings on their comprehension. Cloze tests may not necessarily be illustrative of comprehension processes. They rather assess a more targeted ability to match connectives with particular contexts. Although some have tried to address this issue (e.g., Nippold et al., 1992), true comprehension tasks (e.g., semantic judgments) have not been systematically contrasted with production tasks.

Moreover, it may be worthwhile to examine other measures of individual variation that could relate to the mastery of connectives by teenagers. Volodina and Weinert (2020) found, for instance, that parental socioeconomic status has a strong effect on the development of comprehension of connectives and receptive grammar skills in primary school children. It is possible that socioeconomic status is also a strong predictor of individual variation in the mastery of connectives by teenagers and may be associated with the academic level of young participants.

Finally, future work will need to explore in more detail precisely how and when adultlike ability is attained. The fact that the ability to use connectives continues to develop even among young adults is compatible with an explanation of competence in terms of exposure to print, as exposure to print continues to increase throughout the lifespan (see also Dabrowska, 2019 and Hulstijn, 2019 for discussion).

Conclusion

Our results generally corroborated the findings of Zufferey and Gygax (2020b) and extended them to a larger group of participants. We found that academic background was a strong predictor of competence with connectives that are generally bound to the written modality, both for teenagers from secondary to high school and for adults. Moreover, the level of academic competence, at least in part, was found to be related to the degree of exposure to print and the level of grammatical competence, as measured by the ART-F, subjective exposure to print, and written grammatical competence measures. Mean scores on these not only increased with age (from secondary school to adulthood), but also varied according to the academic level of participants, at least among adults and secondary school teenagers. Our correlations also supported the idea that language users with more exposure to print on average also had a

better awareness of grammar and a better mastery of connectives. These results are in line with previous findings—for adults—on the relation between individual variation in the ART-F and the mastery of connectives (Zufferey & Gygax, 2020a) and between individual variation in the ART-F and coherence relation inferences (Scholman, Demberg, & Sanders, 2020).

The lower correlations between the tasks in the teenage groups are probably due to the fact that the tasks used for language proficiency may not be sensitive enough to capture true variations in this age group. A good score on the ART-F requires extensive reading of literature outside of the school program. Teenagers who participated in our experiments are probably exposed to different book genres or possibly even different types of written materials. Similarly, the low scores obtained across the board on the grammatical task indicate that it was most likely too complex for teenagers. This created a floor effect, masking potentially more fine-grained individual differences within each academic level than those observed in the study by van Silfhout et al. (2015).

It is also noteworthy that even teenagers from the oldest age group (aged 17) did not yet reach an adultlike performance, not only in comparison to the French language university students (as in Zufferey & Gygax, 2020b) but also when compared to the group of adults from a general population. This indicates that the ability to use connectives continues to develop during early adulthood.

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Note

1 The measures of individual linguistic competence (the ART-F, written grammatical competence, and subjective exposure to print) did not systematically improve model fit across the experiments, most likely due to the fact that a large number of competence scores were low in some of the tested groups. To ensure consistency across the experiments, we therefore decided to only include age group and academic level as fixed effects, in both experiments.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1. Additional Tables.
Appendix S2. Sentence-Level Cloze Test.
Appendix S3. Text-Level Cloze Test.

Appendix: Accessible Summary (also publicly available at https://oasis-database.org)

Individual Differences in the Mastery of Connectives From Teenage Years to Adulthood

What This Research Was About and Why It Is Important

Connectives, such as *hence* or *in addition*, are linguistic elements that link ideas in written and oral texts. Since many connectives, such as *therefore* and *however*, are frequently used, their acquisition represents an important

milestone in developing written communication skills. How people become competent with these connectives from early teenage years to adulthood has rarely been studied. To address this issue, we assessed how native French-speakers aged 12 to 71 use connectives, paying particular attention to several factors that could potentially influence their competence. More specifically, we examined how the connectives' frequency (how often they are generally used in French), participants' academic background in French as well as the context of the task would affect how well connectives are used. Results suggest that, despite a general progression in competence with age, the academic level of participants is a strong predictor of competence, even during adulthood. In addition, starting from the age of 12, competence is related to the frequency of connectives, as frequent connectives are systematically mastered better than less frequent ones. Finally, in all age groups, the use and understanding of connectives is more challenging when sentences to complete are embedded within a richer context than when presented alone.

What the Researchers Did

- We examined the use of connectives among three age groups of native French-speakers: 69 secondary school students ($M_{age} = 14.5$), 125 high school students ($M_{age} = 16.6$), and 203 adults (over 18 years old).
- Within each age group, participants varied in their academic background in French.
- We studied four French connectives frequent in written texts (*aussi* [therefore], *en effet* [for, because of], *en outre* [in addition], and *toutefois* [however]).
- The tested connectives had different frequencies in written corpora.
- We conducted two experiments. The first assessed the usage of connectives to connect isolated pairs of sentences and the second examined their usage inside more extensive and naturalistic texts.

What the Researchers Found

- Academic background in French was found to be an important predictor of the competence with written connectives within each age group, even though there was a general progression in the level of competence with age.
- Frequent connectives were better mastered than nonfrequent ones by all participants.
- For all the participants, the use and understanding of connectives was more challenging when they had to insert them inside texts rather than when connecting isolated sentences.

Things to Consider

- Our findings suggest that individual variation in the mastery of connectives does not fade with age. In consequence, other measures of individual variation should be examined in future research.
- Since the type of the task (isolated sentences vs. texts) can influence performance with connectives, task-type should be taken into account when creating teaching activities.
- As this study was in the written modality, future research will need to assess whether teenagers and adults process the coherence relations differently when they are conveyed with connectives in the spoken modality in comparison to those in the written modality.

Materials, data, open access article: Materials and data are publicly available at IRIS (iris-database.org) and OSF (https://osf.io/).
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