

research papers

Good-Enough Sentence Processing in Adolescents and Adults under No-Noise and Auditory-Linguistic-Noise Conditions

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Abstract. According to modern syntactic theories, sentence comprehension can rely not only on grammatically driven algorithmic parsing of grammatical structure but also on good-enough processing, according to which we establish relations between words based on their meanings and our world knowledge without building accurate syntactic relations. Therefore, a good-enough processing strategy may lead to forming incorrect syntactic representations. In a self-paced reading experiment, we investigated how Russian-speaking adolescents (13–17 years old) and adults (20–40 years old) used good-enough vs. algorithmic parsing when reading grammatically complex sentences in a no-noise condition and in the presence of auditory linguistic noise (babble of voices). We found that adolescents relied on good-enough processing less than adults did. At the same time, we found that noise had no effect on reading speed neither in adolescents nor in adults but it speeded up question response time in adolescents.

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Keywords: good-enough processing, algorithmic parsing, syntax, auditory noise, adolescents, reading, plausibility, early closure

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Introduction

Modern approaches to sentence processing assume that in addition to bottom-up grammatically-driven algorithmic parsing of linguistic input, comprehenders can rely on top-down semantically-driven good-enough processing (Ferreira, Bailey, & Ferraro, 2002). According to the good-enough processing account, comprehenders may build sentence representations that rely on the lexical meanings of words and on the comprehenders' world knowledge. Good-enough representations are built faster than algorithmic representations, while providing sufficient information about the sentence content (Karimi & Ferreira, 2016; Koornneef & Reuland, 2016). At the same time, good-enough representations, driven by top-down processes, are fragile, susceptible to interference, and sometimes imprecise or even incorrect (Ferreira et al., 2002; Christianson, 2016). For example, the studies of good-enough parsing showed that after reading garden-path sentences like *'While the man hunted the deer that was brown and graceful ran into the woods'* participants responded "yes" to the question *'Did the man hunt the deer?'* in 51.2% cases, although the sentence did not state that (Christianson, Hollingworth, Halliwell, & Ferreira, 2001).

Good-enough processing may depend on the comprehenders' age. Studies of good-enough and algorithmic parsing in children and adolescents demonstrated that seven-to-twelve-year-old children tend to show greater reliance on grammatical information (Engelhardt, 2014) and slower access to semantic information (Joseph et al., 2008) than adults. Meanwhile, 16-year-old adolescents, much like adults, concurrently make use of both syntactic information and word meanings when reading sentences (Traxler, 2002; Engelhardt, 2014). This can be explained in terms of parsing preferences being calibrated by language experience: children do not yet have the same language exposure as adults and might rely more on bottom-up than top-down information. Moreover, children and adolescents are still in the process of learning to use linguistic strategies, such as the strategy of contextual abstraction that helps to process figurative expressions when the speaker attempts to infer meaning from the larger linguistic context (Nippold, 2000). Possibly, the good-enough processing strategy is also acquired during adolescence.

Most studies have focused on sentence processing in silent laboratory conditions. However, sentence processing

in real life rarely occurs in silence; it is usually accompanied by industrial or linguistic noise (e.g., conversations, television, radio, etc.). In their overview, Stansfeld, Haines, and Brown (2000) showed that noise increased cognitive load and impaired language comprehension in both adults and children, but the impairment was more prominent in children. Gibson, Bergen, and Piantadosi (2013) demonstrated a decline in sentence comprehension in the presence of noise, as comprehenders relied on frequency and word meaning and tended to build more semantically probable inaccurate representations instead of less probable accurate representations. In this study, we aim to address sentence processing in no-noise and noisy conditions and to investigate whether auditory linguistic noise increases the difficulty of the task and impairs syntactic processing. We expect adults to be less susceptible to the distracting effect of noise due to the ability to consciously ignore irrelevant input. In turn, adolescents should be more influenced by noise, since cognitive control is still being developed at this age (Anderson, Anderson, Jacobs, & Smith, 2011).

Previous studies that investigated good-enough processing used passive constructions (Ferreira, 2003), locally ambiguous garden-path sentences (Karimi & Ferreira, 2016), or sentences with scope ambiguity induced by quantifiers (Dwivedi, 2013). In the Russian language, an unambiguous construction (that is, a sentence with a participial clause) allows us to pit algorithmic against good-enough processing. Participial clauses in Russian are relatively widespread, "syntactically empowered" by case alignment, and represent a sufficiently complex grammatical structure for the syntactic parser to be actively engaged (Malyutina, Laurinavichyute, Terekhina, & Lapin, 2018).

To sum up, we investigated how adolescents and adult participants relied on algorithmic and good-enough processing of Russian sentences. We hypothesized that adolescents should rely on good-enough parsing less than adults do because the use of this strategy should increase with age due to the growth of language exposure and world knowledge as well as mastering of strategies. Moreover, we studied how sentences are processed in no-noise laboratory conditions and in noisy conditions and whether noise would affect adolescents and adults differently. Finally, we introduced a novel construction for the study of good-enough processing — syntactically unambiguous sentences with a participial clause. Overall, our study aimed

to shed light on how language is processed in real-life conditions and how this changes across the lifespan.

Method

Participants

Forty-seven adolescents (32 female; age range 13–17 years, $M_{age}=15$ years) and 55 adults (27 female; age range 20–38 years, $M_{age}=26$ years) participated in the experiment. All participants were native speakers of Russian, with normal or corrected to normal vision and hearing, and no history of neurological, psychiatric or speech disorders. None of the participants had studied linguistics. All adult participants and the parents of the adolescents gave written informed consent in accordance with the Declaration of Helsinki.

Stimuli

The experiment used 56 stimuli and 112 fillers divided into two sets that were counterbalanced between the experimental sessions — with and without noise. Each set included 84 sentences: 28 stimuli sentences and 56 fillers. The stimuli were Russian sentences with a participial clause attached to one of two nouns in the genitive noun phrase, as shown in Table 1. In such a structure, the participle can syntactically depend on either of the two nouns in the noun phrase. The relevant syntactic dependencies are denoted by inflection. The experiment had a 2×2 design, manipulating the attachment site (early / late closure) and the semantic match between the participial clause and the noun (plausible / implausible). Each

sentence was followed by a two-alternative comprehension question.

In sentences (1) and (3), participles were semantically related to and syntactically depended on the same noun in the noun phrase (plausible sentences). Conversely, in sentences (2) and (4), participles were semantically related to a noun that they did not depend on syntactically (implausible sentences). If participants chose a semantically appropriate but syntactically incorrect answer in sentences (2) and (4), it would mean that they were relying on the good-enough processing strategy. Therefore, a larger proportion of incorrect answers in sentences (2) and (4) compared to (1) and (3) would show greater reliance on good-enough rather than algorithmic processing. Alternations between (1, 2) and (3, 4) would allow us to distinguish between early and late closure syntactic preferences (see Chernova, 2016; Sekerina, 2003).

The grammatical gender of the nouns in the sentence was counterbalanced within the stimuli set: in one half of the stimuli sentences, both nouns in the genitive noun phrase were masculine while in the other half they were feminine. Semantic plausibility of participles was assessed in the online norming study prior to the experiment. Only those participles that were rated as highly plausible with one of the two nouns and implausible with the other noun were selected for further stimuli construction. The two stimuli sets were matched on sentence length in words and syllables, length in syllables of the critical nouns, gender of the critical nouns, and case of the first critical noun.

There were three types of fillers: plausible sentences with either early or late closure (structurally similar to the stimuli) but with comprehension questions that did not

Table 1. Stimuli Example

Plausible, early closure	(1) Лариса выслушала воспитательницу дочери, обучающую детей чтению и письму. Larisa listened to the tutor (Acc, fem) of the daughter (Gen, fem), *who teach-PART* (Acc, fem) children how to read and write.
Comprehension question	Кто обучал детей чтению и письму? — Воспитательница / Дочка Who was teaching children how to read and write? — The tutor / The daughter
Implausible, early closure	(2) Лариса выслушала воспитательницу дочери, капризничающую из-за погремушки. Larisa listened to the tutor (Acc, fem) of the daughter (Gen, fem), *who weep-PART* (Acc, fem) about the rattle.
Comprehension question	Кто капризничал из-за погремушки? — Воспитательница / Дочка Who was weepy about the rattle? — The tutor / The daughter
Plausible, late closure	(3) Лариса выслушала воспитательницу дочки , капризничающей из-за погремушки. Larisa listened to the tutor (Acc, fem) of the daughter (Gen, fem) , *who weep-PART* (Gen, fem) about the rattle.
Comprehension question	Кто капризничал из-за погремушки? — Воспитательница / Дочка Who was weepy about the rattle? — The tutor / The daughter
Implausible, late closure	(4) Лариса выслушала воспитательницу дочки , обучающей детей чтению и письму. Larisa listened to the tutor (Acc, fem) of the daughter (Gen, fem) , *who teach-PART* (Gen, fem) children how to read and write.
Comprehension question	Кто обучал детей чтению и письму? — Воспитательница / Дочка Who was teaching children how to read and write? — The tutor / The daughter

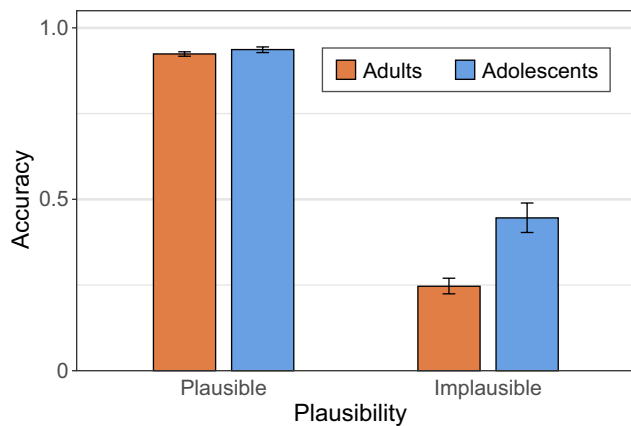


Figure 1. Mean accuracy in plausible and implausible conditions for adolescents and adults.

force participants to choose between the two nouns (for example, *The countess admired the guest's brother, who, played the flute excellently. What did the guest's brother play? The flute / The violin*), and sentences that were structurally different from the stimuli (for example, *The footballer scored two goals in a very important game, and his son was very proud of him. How many goals did the footballer score? Two / Three*). Auditory linguistic noise was a three-person babble of voices of Russian speakers, created by combining three radio recordings so that individual words were comprehensible.

Procedure

Stimuli were presented on a laptop using E-Prime software. Auditory noise was presented continuously during the entire experiment's duration on a player over headphones at the same volume level (40–45 dB) for all participants. Each participant was tested in two sessions: one session with auditory noise and the other session without noise. The order of sessions was pseudorandomized and there was a 15-minute break between sessions. During each session, participants performed a non-cumulative self-paced reading task in which sentences were presented word-by-word in the center of the screen and participants advanced to the next word by pressing the spacebar. After each sentence, they answered a comprehension question with two response options by pressing a button.

Analysis

We fitted three regression models: with question response accuracy, with log-transformed mean-per-word reading times, and with log-transformed question response times as dependent variables. The models were estimated with the *lme4* package (Bates, Maechler, Bolker, & Walker, 2015) and the results were plotted with *ggplot2* (Wickham, 2016).

The first model included six independent variables: the main effect of age (adolescents coded as 1, adults as -1), the main effect of noise (auditory noise session coded as 1, no-noise session as -1), the main effect of plausibility (implausible coded as 1, plausible as -1), and the main effect of closure (late closure coded as 1, early as -1), as well as plausibility by age and age by noise interactions. The second and the third models also included the three main effects (age, noise, plausibility) and two interactions (plausibility by age, age by noise).

All models also included by-subject and by-item random intercepts.

Results

We found that all participants were attentive to filler questions (85 % accuracy), so all the data were included in the analysis. The analysis showed higher accuracy in plausible than in implausible sentences (93 % vs 32%; $Est. = -1.51$, $SE = 0.05$, $z = 2.92$, $p = .003$) and higher accuracy in adolescents compared to adults (77 % vs 66%; $Est. = 0.27$, $SE = 0.09$, $z = -28.89$, $p < .001$). Crucially, adolescents were more accurate than adults in the implausible sentences ($Est. = 0.17$, $SE = 0.05$, $z = 3.33$, $p = .001$). Mean response accuracy for each age group in plausible and implausible sentences is presented in Figure 1. Our results also provide evidence that the participants processed sentences with early closure more accurately than sentences with late closure (75 % vs 67%; $Est. = -0.17$, $SE = 0.05$, $z = -3.74$, $p < .001$). Noise and the age by noise interaction were non-significant.

The analysis of reading times revealed that adolescents are slower than adults at reading sentences (765 ms vs 487 ms; $Est. = 0.226$, $SE = 0.012$, $t = 19.41$, $p < .001$). Interestingly, no significant change in reading speed in the noisy condition was observed, neither for adolescents nor for adults.

The analysis of question response times showed that all participants spent more time answering comprehension questions after implausible compared to plausible sentences ($Est. = 0.027$, $SE = 0.01$, $t = 2.79$, $p = .005$). Surprisingly, we found that in the noisy condition adolescents responded to questions faster than in the no-noise condition ($Est. = 0.041$, $SE = 0.018$, $t = 2.25$, $p = .02$), whereas adults showed no significant change in question response speed in noisy versus no-noise conditions ($p = .47$). Mean question response times for each age group in the no-noise and noisy conditions are shown in Figure 2.

Discussion

The purpose of the present study was to compare bottom-up algorithmic sentence parsing and top-down good-enough processing in adolescents and adults. Additionally, we looked at sentence processing in no-noise laboratory conditions versus noisy conditions in two groups of participants. We ran a within-subject self-paced reading experiment with auditory linguistic noise and in silence in two groups of participants: 13-to-17-year-old adolescents and 20-to-38-year-old adults. Participants read Russian sentences with a participial clause in which semantic and syntactic cues contradicted each other, and then they answered comprehension questions. Our main finding is that adolescents relied on good-enough processing less than adults did. We also found that noise had no effect on reading speed. However, in the presence of noise, adolescents answered comprehension question faster compared to the no-noise condition, whereas no such effect was observed in adults. Finally, we confirmed the preference for early as compared to late closure for Russian sentences (Chernova, 2016; Sekeřina, 2003; Fedorova & Yanovich 2006).

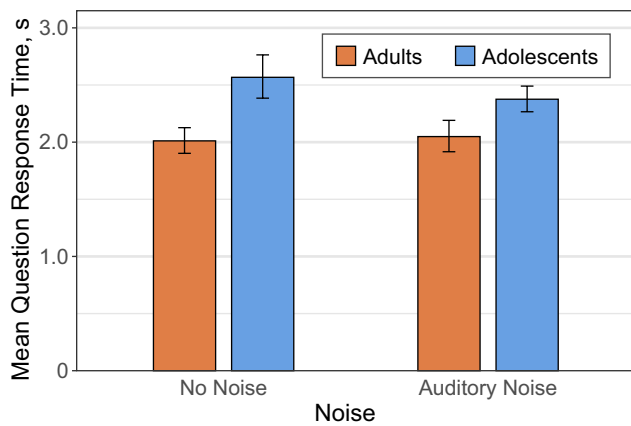


Figure 2. Mean question response times for adolescents and adults in the no-noise and auditory-linguistic-noise conditions.

We found that both adults and adolescents exhibited reliance on the good-enough processing strategy. In most cases, participants preferred a semantically appropriate but syntactically incorrect answer after implausible sentences. This means that they were guided more by word meanings (e.g., a good semantic match of *tutor* and *teach*, or *daughter* and *weep*) and world knowledge about the structure of events than by the syntactic relations between words. We also did not find any slowdown in the processing of implausible compared to plausible sentences. Importantly, our results indicated that adolescents were more attentive to grammatical information when reading implausible sentences and therefore made fewer errors in the implausible condition than adults did. This result confirms and expands the findings of Engelhardt (2014) and Joseph et al. (2008). Indeed, adolescents seem to be inclined to use algorithmic parsing and rely less on semantic cues. Possibly, adolescents are still learning to use linguistic strategies (Nippold, 2000; 2016) and their reliance on top-down semantic heuristics is not yet formed to the same extent that it is in adults.

Another possible explanation for why adolescents were more attentive to grammar than adults is the grammatical training that adolescents receive at school. Typically, during Russian classes, 13-to-17-year-old students are taught to pay attention to morphological markers and agreement errors. Meanwhile, adults do not have such training on a regular basis. Therefore, our findings can be explained by a metalinguistic phenomenon of increased attention to grammatical cues during reading in adolescents but not in adults. The current experimental design does not allow us to distinguish between strategy maturation and school training accounts for the smaller plausibility effect in adolescents compared to adults. An experiment with auditory presentation of stimuli could help to differentiate between these two possibilities.

Our results indicate that the participants relied on top-down semantically-driven good-enough processing. One can speculate about the nature of representations that are formed during good-enough processing. On the one hand, these could be fuzzy and underspecified representations guided by semantic rather than syntactic relations between words (Koornneef & Reuland, 2016). But on the other hand, the representations might be fully specified, as the participants might subconsciously correct ('normalize') morphological markers in implausible sentences and

build representations that they perceived as grammatically consistent with the true content of the sentences (Fillenbaum, 1971; 1974). In that case, adolescents might be less likely to perform this correction due to the experimenter's authority, which could prompt them to accept each stimulus as a correct linguistic input. Further research is needed to distinguish between these two types of good-enough representations.

The comparison of no-noise and noisy conditions showed that the participants' average reading speed and accuracy did not differ between the noise and no-noise conditions. At the same time, adolescents speeded up to respond to comprehension questions in the presence of auditory linguistic noise, whereas adults did not. Importantly, the adolescents' faster responding in the presence of noise was not accompanied by a decline in response accuracy. Overall, these results suggest that the noisy environment forced adolescents to be more attentive during reading and to come up with an answer to a comprehension question faster in order to finish the experiment as soon as possible. These findings do not support the hypothesis that noise complicates language processing for 13–17 year-olds as compared to adults (Anderson et al., 2011; Nippold, 2016). Cognitive control mechanisms in our adolescent participants were already sufficiently mature to deal with the level of noise used in the experiment.

Overall, our findings contribute to the understanding of which factors affect reliance on algorithmic versus good-enough sentence processing. However, our study has an important limitation. We used a non-cumulative self-paced reading task that differs from real-life reading processes because it did not allow the participants to regress to previous input in order to revise understanding. At the same time, for our research question, the self-paced reading task has been shown to be sufficiently sensitive to reveal syntactic effects that have been replicated in more naturalistic eye movement paradigms (Ferreira & Henderson, 1990; Just, Carpenter, & Woolley, 1982). For future studies, it seems reasonable to verify our findings in an eye-tracking experiment that would provide a more naturalistic reading setting.

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■ экспериментальные сообщения ■

Поверхностная обработка речи у подростков и взрослых при наличии или отсутствии речевого шума в слуховой модальности

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Аннотация. Современные теории понимания предложений различают синтаксически мотивированную алгоритмическую обработку и поверхностную обработку. Стратегия поверхностной обработки речи позволяет человеку опираться на лексико-семантические эвристики и языковой опыт и таким образом экономить усилия при восприятии речи. В отличие от алгоритмической обработки, такая стратегия может приводить к некорректной интерпретации предложения. Настоящее исследование выявляет, как подростки и взрослые используют стратегию поверхностной обработки и как шум голосов влияет на степень опоры на поверхностную обработку. В эксперименте с использованием методики чтения с саморегуляцией скорости приняли участие группа подростков 13–17 лет и группа молодых взрослых 20–40 лет. Испытуемые читали предложения, некоторые из которых провоцировали поверхностную интерпретацию, и отвечали на вопросы об их содержании; при этом половина эксперимента проходила в тишине, а половина — с предъявлением шума голосов. Результаты показали, что подростки в меньшей степени опираются на поверхностную обработку, чем взрослые. Кроме этого было обнаружено, что шум голосов не влияет на скорость чтения ни у подростков, ни у взрослых, однако провоцирует подростков отвечать на вопросы быстрее.

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Ключевые слова: поверхностная обработка речи, алгоритмическая обработка речи, синтаксис, шум голосов, подростки, чтение, раннее закрытие

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