What is it that lingers? Garden-path (mis)interpretations in younger and older adults

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Previous research has shown that comprehenders do not always conduct a full (re)analysis of temporarily ambiguous “garden-path” sentences. The present study used a sentence–picture matching task to investigate what kind of representations are formed when full reanalysis is not performed: Do comprehenders “blend” two incompatible representations as a result of shallow syntactic processing or do they erroneously maintain the initial incorrect parsing without incorporating new information, and does this vary with age? Twenty-five younger and 15 older adults performed a multiple-choice sentence–picture matching task with stimuli including early-closure garden-path sentences. The results suggest that the type of erroneous representation is affected by linguistic variables, such as sentence structure, verb type, and semantic plausibility, as well as by age. Older adults’ response patterns indicate an increased reliance on inferencing based on lexical and semantic cues, with a lower bar for accepting an initial parse and with a weaker drive to reanalyse a syntactic representation. Among younger adults, there was a tendency to blend two representations into a single interpretation, even if this was not licensed by the syntax.

Keywords: Language comprehension; Good-enough language processing; Syntactic parsing; Language processing in ageing.

Garden-path sentences are temporarily ambiguous sentences that are structured in such a way that a comprehender’s initial parsing of the sentence is likely to be incorrect and to need reanalysis. An example of a garden-path sentence is “While the man hunted the deer ran into the woods”, where the noun phrase “the deer” is likely to be first interpreted as the direct object of the verb “hunted” in the subordinate clause, whereas it is in fact the subject of the verb “ran” in the main clause. Garden-path sentences allow for the investigation of the interplay between syntactic (algorithmic) processing, pragmatics/semantics, and prosody (in auditory presentation) in resolving temporary ambiguity and building a mental representation of the sentence meaning.

Reanalysis of garden-path sentences is not always completed fully—that is, a part of the initial misanalysis can persist. In the experiments by Christianson, Hollingworth, Halliwell, and Ferreira (2001), healthy young speakers had to read garden-path sentences word by word and answer yes/no comprehension questions such as “Did the man hunt the deer?”. The authors argue...
that lack of syntactic reanalysis led to a high rate of “Yes” responses to questions that tested the interpretation of the critical noun phrase both as the object of the subordinate clause (“Did the man hunt the deer?”) and as the subject of the main clause (“Did the deer run into the woods?”). Syntactically, “a deer” cannot be simultaneously assigned these two roles in a parse. Therefore, answering “Yes” to questions probing both the subject and the object roles for the noun phrase “the deer” may be caused by a syntactically unlicensed incomplete parse relying on the likelihood of combinations of individual word meanings rather than on an algorithmic syntactic analysis of the sentence (i.e., the structure is “good enough”). Alternatively, the paradoxical response pattern may reflect a “blend” of the reanalysed syntactic parse and the initial syntactically incorrect parse that has not been fully replaced (i.e., the reanalysis processes themselves are “good enough”), as suggested by Slattery, Sturt, Christianson, Yoshida, and Ferreira (2013).

However, using binary yes/no questions such as “Did the man hunt the deer?” (Christianson et al., 2001; Christianson, Williams, Zacks, & Ferreira, 2006; Kemper, Crow, & Kemtes, 2004) can only address a specific part of the interpretation that is directly targeted by the question at one time. The task does not provide direct evidence for a “blended” interpretation where “the deer” is present simultaneously in the representations of two clauses. Answering “Yes” to both “Did the man hunt the deer” and “Did the deer run into the woods?” does not necessarily mean that “the deer” as the object of the subordinate clause and as the subject of the main clause are combined in one single representation. Instead, they can be parts of two competing representations or, importantly, a result of a strategic repair triggered by confrontation with a comprehension question (participants might be biased to answer “yes” to any question that contains the same lexical items as those in the sentence stimulus). Eye-tracking studies focusing on eye movements during the ambiguous region of the sentence have been used to demonstrate the formation of the initial “garden-path” misinterpretation as well (Sturt, 2007), but these also lack direct evidence of what representation is ultimately formed. So, it has been proved that the initial syntactically unlicensed misinterpretation may linger, but it is not clear with what sentence interpretation the comprehender is ultimately left.

Only a limited body of research is available on the type of (mis)representations of garden-path sentences that are ultimately endorsed by comprehenders. Patson, Darowski, Moon, and Ferreira (2009) used a paraphrasing task and found that paraphrases of garden-path sentences corresponded to a “partially reanalysed” interpretation (referred to as “blended” in the present paper) in which the critical noun phrase was simultaneously present as the object of the subordinate clause and as the subject of the main clause. Christianson (2008) used a text-change paradigm and found that the likelihood of participants noticing deletions and additions of the pronoun “it” in certain syntactic contexts was also consistent with “incomplete reanalysis”—that is, “blended” representations.

The present study expands upon this line of research, using a sentence–picture matching (SPM) task with multiple response options corresponding to different possible (mis)representations of the sentence. Similar to comprehension questions, SPM is an offline task that only shows the sentence representation that is formed at the decision time; however, SPM can test the overall sentence representation (rather than only a part of it at a time, as is the case with comprehension questions) and also provide additional information on the type of this representation. This can be either a syntactically correct parse formed as a result of successful syntactic reanalysis, or one of several possible types of misinterpretation. We hypothesize that two common misrepresentation possibilities are (a) a “garden-path” representation where the initial misanalysis persists without adding new information to it (for a sentence “While the man hunted the deer ran into the woods”, this would be a representation where “the deer” is the object of “hunted” but not the subject of “ran”) or (b) a “blended” representation where the initial misanalysis is actually “blended” with new incoming information (“the deer” is both the object of “hunted” and the subject of “ran”), either as a result of a syntactically
In their intransitive use, the action of the verb is syntactic use intransitive versus transitive: even when used without an explicit object. (OPT) verbs imply the presence of an object between the two verb types is that optionally transitive structure, the action of the verb is directed toward an object, rather than to an implied object. In “Anna bathes the baby” (transitive structure), the object of the RAT verb “to bathe” is “the baby”, whereas in “Anna bathes” (intransitive structure), the action is reflexive—that is, Anna is bathing herself. In garden-path sentences, intransitive parsing of OPT verbs can still be compatible with their transitive interpretation—for example, if a sentence is parsed as “[While the man hunted], [the deer ran into the woods]”, it would still not be contradictory to assume that the man was hunting the deer. On the other hand, for causative (CAU) and RAT verbs the intransitive and transitive interpretation are not compatible—for example, if a sentence is parsed as “[While Anna bathed], [the baby played with a toy]”, it would be wrong to assume that Anna is bathing the baby (for extensive discussion of semantic and structural differences between OPT and RAT verbs, see Christianson et al., 2001, 2006). Thus, showing that “blended” representations are formed for RAT verbs, as well as for OPT verbs, is a powerful means to ascertain that such representations cannot be accounted for by postsyntactic pragmatic inferencing (or “general reasoning”, in the words of Christianson et al., 2001).

Overall, semantic persistence effects are greater, and the reanalysis of garden-path sentences seems to present a greater challenge when the linguistic parameters allow the comprehender to adhere to the initial misanalysis for a longer time. However, Sturt (2007) demonstrates in an eye-tracking study that processing is slowed down at the ambiguous point in the sentence even in easier processing conditions, such as in sentences where the erroneous garden-path interpretation is semantically implausible, suggesting that comprehenders initiate the erroneous parsing even in the presence of strong lexical cues. Similarly, self-paced-listening experiments by DeDe (2010) suggest that postverbal ambiguous noun phrases in these sentence types are initially always interpreted as direct objects, even in the presence of strong prosodic and semantic cues to the contrary. The present study examines whether any of the linguistic factors mentioned here might affect not only the success of garden-path reanalysis but also the type of the erroneous representations that are formed.

Linguistic factors contributing to the garden-path sentence interpretation may also be weighted differently across populations. For example, speakers with aphasia (language impairment after brain damage) may rely more on semantic and pragmatic cues due to deficient syntactic processing.
mechanisms (Caramazza & Zurif, 1976). Differences in processing strategies may exist within neurologically healthy speakers as well, for example due to age. Healthy aging has been repeatedly shown to affect language processing along with other cognitive domains. These changes are not necessarily evident in normal “everyday” processing conditions (Glisky, 2007), but they can be revealed by slower reaction times and increased error rates in experimental settings that place increased demands on linguistic processing, for example by using complex syntactic structures (Kemper, 1986, 1992; Obler, Fein, Nicholas, & Albert, 1991) or an increased rate of incoming speech (Wingfield, 1996; Wingfield, Tun, Koh, & Rosen, 1999). Some frameworks try to account for age-related changes in language processing by a generalized low-level processing decline, such as a general decline in perception (Pichora-Fuller, 2003) or a general reduction in processing speed (Salthouse, 1996). Other frameworks suggest higher order mechanisms, such as reduced working memory capacity (Anders, Fozard, & Lillyquist, 1972; Caplan & Waters, 1999, 2002) or a decline in inhibitory control (Hamm & Hasher, 1992; Hasher, Zacks, & May, 1999). However, some age-related changes might be positive, such as a continuing growth in world knowledge (Schaie, 1994), and these may increase the efficiency of relying on “common sense” inferencing in natural day-to-day language use (Christianson et al., 2006).

Several previous studies have investigated garden-path processing in healthy ageing. Kjelgaard, Titone, and Wingfield (1999) tested younger and older adults on the completion of syntactically ambiguous sentence beginnings such as “Although the two friends pushed the car . . .” and found no differences in sentence completion preferences in younger versus older adults: Both groups preferred late-closure interpretations and demonstrated similar effects of sentence prosody. In a reading experiment with yes/no comprehension questions, however, Christianson et al. (2006) found that the effect of verb type on garden-path sentence processing differed between older and younger adults: Older adults were more likely to endorse the transitive interpretation of garden-path sentences for OPT verbs than the younger group, suggesting that older adults tend to overly on heuristics-like “good-enough” processing, rather than on the mechanisms of full syntactic processing (at least, in lab conditions under time pressure). Also, older comprehenders tended to fail to endorse the reflexive interpretation of RAT verbs, which the authors attribute to reduced working memory resources in this age group. In line with this, the older participants’ ability to successfully reanalyse the garden-path structure and thus discard the initial incorrect interpretation was strongly correlated with their reading span, indicating a role for working memory in syntactic (re)analysis. Kemper et al. (2004), who probed garden-path reading and comprehension in an eye-tracking experiment, also concluded that reduced working memory capacity is the underlying reason that makes older adults rely on heuristics rather than on the algorithmic syntactic reanalysis of the sentence structure. Their stimuli were ambiguous with regard to relative clause attachment (e.g., “The experienced soldiers warned about the dangers before the midnight raid”/“The experienced soldiers warned about the dangers conducted the midnight raid”), and they found that eye movement and response patterns of older adults were similar to those of younger participants with a low working memory span.

Still, previous research on garden-path processing in older adults had the same limitations as most previous research with the younger population—that is, it did not directly probe the full ultimate representations of garden-path sentences. The present study aims to investigate the effect of age on garden-path processing not only with respect to online processing costs or the ultimate success of recovery from garden-paths, which requires inhibition of the initial misinterpretation, but primarily with respect to the type of incorrect representation that is formed in the case of unsuccessful recovery. Relative to younger adults, will older adults show a greater tendency to blend the licensed with the unlicensed interpretation, or will they hold on to the initial (unlicensed) interpretation more strongly? The former might occur if
older adults are building their meaning representation primarily based on the plausibility of propositional content and a greater reliance on heuristics over syntactic mechanisms. The latter result would be expected if older adults’ comprehension patterns reflect not only a reduced inhibition of the initial garden-path interpretation, but also a greater tendency to simply stop parsing after a good-enough interpretation is available. One additional way in which the present study expands on previous research is that the sentences were presented auditorily rather than visually. Although self-paced reading has many advantages (such as eliminating confounding by prosody), it is also of interest to investigate garden-path processing in a more naturalistic auditory presentation.

EXPERIMENTAL STUDY

Method

Participants
Twenty-five younger adults (21 females; mean age = 22.7 years, range = 18–32 years; mean number of years of formal education = 14.7 years, range = 10–21) and 15 older adults (12 females; mean age = 66.0 years, range = 60–75 years; mean number of years of formal education = 17.2 years, range = 12–22) participated in the experiment. The younger adults were recruited through advertisements at the University of South Carolina. The older adults were recruited from the community through advertisements and local senior organizations. All participants were native speakers of English with normal or corrected-to-normal hearing and vision, no history of psychiatric or neurological disorders, and no history of speech or language problems. All participants except for two in the younger group were right-handed. All participants were compensated for their time.

Materials
The experiment used sentences consisting of a proposed (adverbial adjunct) subordinate clause and a main clause (e.g., "While the man hunted the deer ran into the woods"). The following linguistic characteristics were manipulated: verb type, transitivity of the sentence structure, semantic plausibility of the incorrect interpretation, and clause order.

Verb type. Fifty English verbs participating in transitivity alternations were used in the experiment (see Levin, 1993): Thirty were optionally transitive (henceforth, OPT) verbs that show unspecified object alternation, 10 were reflexive absolute transitive (RAT) verbs, showing the reflexive object alternation, and 10 were verbs that show the causative/inchoative alternation (CAU). To the best of our knowledge, CAU verbs have not been used in research of garden-path processing before. Similar to RAT verbs, CAU verbs have a different meaning when their syntactic use is intransitive versus transitive: In their intransitive use, the action of the verb is directed toward its subject, rather than to an implied object. For example, in "Anna trips the boy" (transitive structure), the direct object of the CAU verb "to trip" is "the boy", so that Anna's action causes the boy to trip, whereas in "Anna trips" (intransitive structure), it is Anna herself who falls over. It should be noted that syntactic differences do exist between CAU and RAT verbs: For RAT verbs, but not for CAU verbs, it is possible to add an explicit reflexive pronoun to the sentence without changing its meaning or acceptability (e.g., "Anna dressed" = "Anna dressed herself"; "Anna tripped" ≠ "Anna tripped herself"). However, since CAU and RAT verbs have the same characteristics with regard to licensed intransitive versus transitive interpretations, and both differ from OPT verbs in this respect, we combined them into a single group, which enabled us to increase the number of stimuli. OPT and CAU/RAT verb groups were matched on length in a number of syllables and on the Brown corpus lemma frequency (Francis & Kucera, 1982) obtained from the MRC Psycholinguistic Database (Coltheart, 1981).

Each verb appeared in a sentence template modified to form 10 experimental sentence conditions (Table 1) by manipulating transitive/intransitive sentence structure, semantic plausibility of the incorrect interpretation, and clause order.
Clause order and transitivity of the sentence structure. Clause order could be either the subordinate clause preceding the main clause (Conditions 1, 3, 5, 7, 9 in Table 1) or the main clause preceding the subordinate clause (Conditions 2, 4, 6, 8, 10). The sentence structure type could be either intransitive (Conditions 1–6) or transitive (Conditions 7–10). Thus, the combination of intransitive structure and the subordinate–main clause order created garden-path sentences (Conditions 1, 3, 5). Sentences were matched on length in the number of words within intransitive structures—that is, within Conditions 1–6 (mean = 10.1, SD = 1.37, range 7–13), as well as within transitive structures—that is, Conditions 7–10 (mean = 11.3, SD = 0.92, range 9–13). Due to the presence of an object in transitive structures, these were significantly longer than intransitive structures, \( t(498) = 23.56, p < .001 \).

Plausibility. For garden-path sentences, the plausibility manipulation referred to the degree of semantic plausibility of the initial incorrect “garden-path” parsing of the sentence—that is, of the parse in which the critical noun phrase was interpreted as the direct object of the subordinate clause. Local plausibility refers to the match between a verb and its direct object (e.g., the verb phrase “to hunt a deer” is locally plausible, whereas the verb phrase “to hunt a plane” is locally implausible). Global plausibility is a measure of whether the described situation makes sense as a whole and is possible to imagine happening in the real world (e.g., the incorrect parsing of the sentence “While the man hunted the deer ran into the woods” is globally plausible, whereas the incorrect parsing of the sentence “While the man hunted the pheasant the plane flew over the woods” is globally implausible). Garden-path sentences could be plausible (Condition 1: it is plausible that a man would hunt a deer), locally implausible—that is, the object is not a good match for the verb (Condition 3: it is not plausible that a man would hunt a plane); and globally implausible—that is, the object is a good match for the verb but it does not make sense for it to be both the verb object and the subject of the main clause (Condition 5: it is plausible that a man would hunt a deer while it is pacing in the zoo). Intransitive non-garden-path sentences (Conditions 2, 4, 6) were created by changing the

<table>
<thead>
<tr>
<th>Type</th>
<th>Sentence</th>
<th>Structure</th>
<th>Plausibility</th>
<th>Clause order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>While the man hunted the deer ran into the woods.</td>
<td>Intransitive</td>
<td>Plausible</td>
<td>Subordinate–main</td>
</tr>
<tr>
<td>2</td>
<td>The deer ran into the woods while the man hunted.</td>
<td>Intransitive</td>
<td>Plausible</td>
<td>Main–subordinate</td>
</tr>
<tr>
<td>3</td>
<td>While the man hunted the plane flew over the woods.</td>
<td>Intransitive</td>
<td>Locally implausible</td>
<td>Subordinate–main</td>
</tr>
<tr>
<td>4</td>
<td>The plane flew over the woods while the man hunted.</td>
<td>Intransitive</td>
<td>Locally implausible</td>
<td>Main–subordinate</td>
</tr>
<tr>
<td>5</td>
<td>While the man hunted the deer paced in the zoo.</td>
<td>Intransitive</td>
<td>Globally implausible</td>
<td>Subordinate–main</td>
</tr>
<tr>
<td>6</td>
<td>The deer paced in the zoo while the man hunted.</td>
<td>Intransitive</td>
<td>Globally implausible</td>
<td>Main–subordinate</td>
</tr>
<tr>
<td>7</td>
<td>While the man hunted the pheasant the plane flew over the woods.</td>
<td>Transitive</td>
<td>Plausible</td>
<td>Subordinate–main</td>
</tr>
<tr>
<td>8</td>
<td>The plane flew over the woods while the man hunted the pheasant.</td>
<td>Transitive</td>
<td>Plausible</td>
<td>Main–subordinate</td>
</tr>
<tr>
<td>9</td>
<td>While the man hunted the plane the pheasant flew over the woods.</td>
<td>Transitive</td>
<td>(Locally) implausible</td>
<td>Subordinate–main</td>
</tr>
<tr>
<td>10</td>
<td>The pheasant flew over the woods while the man hunted the plane.</td>
<td>Transitive</td>
<td>(Locally) implausible</td>
<td>Main–subordinate</td>
</tr>
</tbody>
</table>
clause order in the corresponding garden-path sentences. Thus, for these conditions, plausibility referred to the plausibility of inferring that the noun is the object of the verb.

In sentences with transitive structure (i.e., Conditions 7–10, none of which are “garden-paths”) plausibility referred to the goodness of match between a verb and its actual object in the sentence. In these conditions, plausibility could only take on a plausible or a locally implausible value (e.g., in Conditions 7 and 8 it is plausible that a man would hunt a pheasant; in Conditions 9 and 10 it is locally implausible that a man would hunt a plane).

Plausibility ratings were obtained in two preliminary surveys of native speakers of English without any history of neurological/psychiatric disorders or speech/language problems. In the local plausibility survey, participants rated the goodness of match of the verb and its object (e.g., “to hunt a deer”, “to hunt a plane”) on a scale from 1 to 7, with one being an implausible combination and 7 being a plausible combination. The survey was conducted online in multiple sessions, and each item was rated by 25 to 34 participants (20 females; mean age = 30.5 years, SD = 14.3, range 19–69). To be included into the locally plausible condition, verb–noun combinations had to obtain an average score greater than 4.3 (mean = 6.51, SD = 0.67). To be included into the locally implausible condition, situations had to obtain an average score less than 3.7 (mean = 2.12, SD = 0.71).

Plausible and implausible objects within sentence templates were matched on imageability, familiarity, length in syllables (ranging one to three syllables in length), and the Brown corpus lemma frequency (Francis & Kucera, 1982) obtained from the MRC Psycholinguistic Database (Coltheart, 1981; see Table 2).

Experimental lists. In a Latin square design, five experimental lists were created by including two versions of each sentence template into each list. To ensure that the participants were not exposed to two versions of the sentence that were very similar (e.g., Conditions 1 and 2), pairings of conditions were created that were maximally dissimilar and therefore could be assigned to the same experimental list (these were as follows: 1–10, 2–7, 3–8, 4–5, 6–9). Each experimental list contained 100 sentences overall (10 items in each of the 10 experimental conditions). The order of presentation was randomized and was different for each participant.

Table 2. Lexical characteristics of plausible and implausible objects

<table>
<thead>
<tr>
<th>Object/verb type</th>
<th>Imageability</th>
<th>Familiarity</th>
<th>Length in syllables</th>
<th>Lemma frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plausible objects, RAT/CAU verbs</td>
<td>602.29 (38.27)</td>
<td>562.93 (47.14)</td>
<td>1.56 (0.62)</td>
<td>45.38 (71.66)</td>
</tr>
<tr>
<td>Implausible objects, RAT/CAU verbs</td>
<td>581.67 (55.86)</td>
<td>543.33 (53.39)</td>
<td>1.61 (0.85)</td>
<td>45.56 (54.13)</td>
</tr>
<tr>
<td>Plausible objects, OPT verbs</td>
<td>581.93 (59.02)</td>
<td>550.81 (52.11)</td>
<td>1.66 (0.72)</td>
<td>52.46 (74.48)</td>
</tr>
<tr>
<td>Implausible objects, OPT verbs</td>
<td>587.42 (39.11)</td>
<td>556.85 (60.61)</td>
<td>1.53 (0.67)</td>
<td>38.64 (50.64)</td>
</tr>
</tbody>
</table>

Note: Means, with standard deviations in parentheses. OPT = optionally transitive; CAU = causative; RAT = reflexive absolute transitive.
Auditory stimuli. Sentences were recorded by a young female native speaker of American English who was instructed to produce them with “neutral” intonation—that is, without a strongly marked boundary between the clauses but still not with a completely flat intonation. The recordings were then normalized to −0.1 dB and de-noised using Audacity software (Audacity Team, 2013).

To test post hoc whether there were prosodic differences between conditions, we adopted the approach of DeDe (2010) and used Praat software (Boersma, 2001) to measure the duration and pitch change in critical segments of the sentence: first noun phrase (While the man hunted the deer ran into the woods), first verb (While the man hunted the deer ran into the woods), second noun phrase (While the man hunted the deer ran into the woods), third noun phrase (in transitive-structure sentences only; While the man hunted the deer the pheasant ran into the woods), and second verb (While the man hunted the deer ran into the woods). The analysis was conducted over conditions with subordinate–main clause order only (Conditions 1, 3, 5, 7, 9), in which prosody may have potentially played an important role in the perception of clause closure. For each sentence segment, we conducted two repeated measures 5 × 2 (2 × 2 for third noun phrase) analyses of variance (ANOVAs) with subsequent pairwise comparisons to test whether duration and pitch change differed between sentence conditions and verb types, using Bonferroni correction for multiple comparisons (α = .005). The only significant finding was the effect of experimental condition on the duration of the first noun phrase, F(4, 192) = 4.48, p = .002, driven by the first noun phrase being significantly longer in Conditions 1 and 5 than in Condition 9 (by 19 and 15 ms, respectively, on average). Additionally, the stimuli did not differ on pauses between the first verb and the second noun phrase: There were no measurable pauses in any individual stimuli.

Picture types. For each sentence, three pictures were created for the multiple-choice sentence–picture matching task (see Figure 1). Examples of picture types offered for each sentence condition are provided in Appendix A. For intransitive structure sentences (Conditions 1–6), one picture (“correct” type) corresponded to the correct syntactic parsing of the sentence where the noun was only interpreted as the subject of the main clause, whereas the target of the action in the subordinate clause was different (for OPT verbs, it was some entity that was not mentioned in the sentence; for CAU/RAT verbs, it coincided with the subject). The “blended” picture corresponded to an “in-between” interpretation where the critical noun phrase was interpreted as both the object of the subordinate clause and the subject of the main clause. Though technically not licensed by the syntax, this interpretation was not necessarily incorrect for OPT verbs. For CAU/RAT verbs, however, the blended interpretation was inherently incorrect. The “garden-path” picture corresponded to the initial erroneous (garden-pathed) parsing where the noun was only interpreted as the object of the subordinate clause, whereas the subject of the main clause was some new entity not mentioned in the sentence. This interpretation was incorrect for both OPT and CAU/RAT verbs.

For transitive (non-garden-path) structure sentences (Conditions 7–10), the “correct” picture was the only correct response for both verb types and corresponded to the correct interpretation. The “blended” picture corresponded to the reversed interpretation where the two nouns—the object of the subordinate clause and the subject of the main clause—had changed places (thereby turning the plausible sentence into implausible and vice versa). The “garden-path” picture corresponded to interpreting both nouns as objects of the verb and inferring that something that was not mentioned in the sentence was the subject of the main clause. This type mainly served for the purposes of symmetry to intransitive-sentence picture types, being similar to the “garden-path” picture for those sentence conditions.

All pictures were black-and-white line drawings (see Figure 1 for an example). All picture types within one sentence template included the same entities: Even when they were not a part of the action in a particular interpretation type, they were still included as part of the background. Therefore, the pictures within one sentence type
Figure 1. (a) Example of layout of the screen: Response options for an optionally transitive (OPT) verb "to hunt", Sentence Conditions 1–2 ("While the man hunted the deer ran into the woods"/"The deer ran into the woods while the man hunted"); top left: "correct" response; top right: "garden-path" response; bottom: "blended" response. (b) Example of layout of the screen: Response options for a reflexive absolute transitive (RAT) verb "to brush", Sentence Conditions 3–4 ("While Karen brushed the letter lay on the cushion"/"The letter lay on the cushion while Karen brushed"); top left: "blended" response; top right: "garden-path" response; bottom: "correct" response.
were matched for the number and content of depicted entities (with the exception of “argument combining representation” pictures for transitive structure sentences that contained one additional entity). Pictures were modified by the artist until both researchers (S.M. and D.B.d.O) agreed on their adequacy for representing the target sentence context.

**Procedure**

Prior to the experiment, participants were given oral and written instructions. They were informed that they would listen to sentences presented through headphones and see three pictures on the screen that would appear with the start of each sentence. They were instructed to listen to each sentence until the end and to click on the picture that corresponded to the sentence, choosing “the best match” if they were unsure of the correct response. Participants were seated in front of a computer screen, put on headphones, completed a short practice session that did not include any experimental items, and then started the experiment. The pictures were presented against a light-grey background, with sentence onset simultaneous to picture onset. The mouse cursor only appeared on the screen after the end of each sentence to avoid premature responses and was located at the centre of the screen at an equal distance from all three pictures (Figure 1). Response types were balanced for their position on the screen. Participants had 7 s to make a response after the end of each sentence presentation. Between the sentences, a fixation cross was presented at the centre of the screen for a duration of 1.5 s. Stimulus presentation as well as the recording of responses and reaction times was controlled by E-Prime software. In the middle of the experiment, participants had a short break. The entire experiment lasted approximately 20 min.

**Data analysis and hypotheses**

All statistical analyses were performed in SPSS software, Version 22. Analysis was performed on the reaction times, percentage of “correct” responses (reflecting accurate syntactic reanalysis in garden-path sentences and accurate analysis in all other sentence conditions), and the types of responses not reflecting syntactic reanalysis (i.e., choice of the “blended” or “garden-path” pictures). Response type percentages were empirical logit transformed before analysis (Haldane, 1956).

**Reaction times and percentage of “correct” responses.**

The aims of the analyses of reaction times and the percentage of “correct” responses (i.e., responses reflecting full syntactic reanalysis) were two-fold. The first aim was to examine how reaction times and accuracy are affected by the manipulated linguistic factors. We hypothesized that slower reaction times and lower accuracy might be yielded by OPT verbs, which are leaving more possibility for postsyntactic inferencing; by subordinate–main clause order and intransitive sentence structure, which in combination constitute the garden-path sentences; and by semantically plausible misinterpretations (i.e., the plausible condition within Sentence Types 1–6 and the implausible condition within Sentence Types 7–10). The second aim was to investigate the effects of age on sentence processing—namely, whether age would have an overall detrimental effect, as reflected by reaction times, accuracy, or both, as well as whether there would be any interactions between age and linguistic variables. If older adults are more detrimentally affected by factors contributing to linguistic complexity, such as intransitive sentence structure and subordinate–main clause order, this might suggest that they are less able or prone to use the syntactic decoding mechanisms required to overcome the initial misinterpretation. If they are less sensitive to the verb type manipulation than younger participants, this may indicate a reduced reliance on lexical syntactic information to achieve a fully licensed parse. By contrast, if they are more sensitive to verb type, this indicates that they make greater use of lexical syntactic information, possibly compensating for reduced online structural syntactic processing. If older adults are more prone to semantic plausibility effects, this might suggest that they overrely on heuristic mechanisms, such as inferencing based on semantic and lexical cues.

For both reaction times and the empirical logit transformed percentage of “correct” responses,
repeated measures ANOVAs were used. Since plausibility manipulation was different within intransitive and transitive structure sentences, and because the sentences in these two groups of conditions differed significantly in their length, we did the analysis in two stages. First, we performed a repeated measures ANOVA with the transitivity of the structure as a within-subject factor and age as a between-subject factor. Then, we performed two separate repeated measures ANOVAs for transitive and intransitive structure sentences with age as a between-subjects factor and verb type, clause order, and plausibility as within-subject factors. We conducted both analyses aggregating the data by subject (F₁) and aggregating the data by item (F₂).

Response types. Response type distributions were analysed in garden-path sentences (i.e., Conditions 1, 3, 5) only, since these are the sentence types where error types are most readily interpretable. “Correct” responses represent a successful full syntactic reanalysis without any “traces” of the initial garden-path parsing. “Garden-path” responses represent the persistence of the initial erroneous “garden-path” interpretation without adding new information to it. “Blended” responses represent a “blend” representation reflecting incomplete syntactic processing where the initial misanalysis is “combined” with new incoming information (either a result of shallow analysis that represents the “garden-path” noun in two incompatible syntactic roles, or a result of less than perfect reanalysis mechanisms that cause interference between the initial “garden-path” parsing and a later reanalysed interpretation). However, we should note that in the case of OPT verbs, “blended” responses can also reflect postsyntactic inferencing mechanisms (or “general reasoning”, cf. Christianson et al., 2001), rather than incomplete syntactic processing. Namely, a participant might syntactically parse a sentence as “[While the man hunted], [the deer ran into the woods]” but then, after the syntactic processing stage, make an inference that the man was hunting a deer, based on the compatibility of the two propositions.

The aims of this analysis were to examine what type of representation is more often chosen whenever full syntactic reanalysis is not performed (whether it is a “blended” representation or the initial “garden-path” representation), as well as how this is modified by the linguistic properties of the sentence and the age of the comprehender. A hypothesis with regard to the effect of linguistic manipulations was that the response types will be strongly affected by plausibility. That is, the proportion of “blended” representations will be larger in plausible sentences, where they reflect likely real-world situations, and smaller in globally implausible sentences, where interpreting the noun as the subject of the second clause reflects an unlikely real-world situation. With regard to the age, if the older group chooses more “blended” representations than the younger group, this likely reflects a decreased role of syntactic processing in older comprehenders, resulting in a noun being represented in two syntactically incompatible roles. However, if the older group shows an increase in initial “garden-path” representations, this might reflect a more general disruption in online processing and “keeping up” with the incoming sentence material—that is, a reluctance to add new material to an already established parse. Additionally, testing the interaction between verb type and age will allow us to examine whether older and younger comprehenders differ in how strongly they rely on inferencing. If older adults rely on inferencing more than younger adults, they are going to show a relatively greater increase in “blended” responses for OPT verbs than for CAU/RAT verbs, since “blended” responses for OPT verbs may result from postsyntactic inferencing that does not necessarily contradict the syntactic parse, as discussed above.

To address these aims, we used a generalized estimating equations (GEE) procedure in SPSS 22.0 to perform a repeated measures logistic regression with binomial distribution on the responses of participants that did not belong to the “correct” type. The dependent variable was the binary dummy-coded type of response (“blended” or “garden-path”); null responses were excluded from the analysis. The independent variables were age, verb type, and plausibility condition; the model included all two-way interactions.
Correlation analysis. Additionally, we performed a correlation analysis with the goal to explore how the prevalence of the two misrepresentation types (“blended” or “garden-path”) in individual participants may be associated with their speed or accuracy of garden-path sentence processing. We performed two-tailed Pearson correlations between participants' average reaction times in garden-path sentences (i.e., Conditions 1, 3, 5), their log-transformed proportion of “correct” responses out of total responses, and their log-transformed proportion of “garden-path” responses out of total incorrect responses. The correlation analysis was performed both aggregating across younger and older participants and for the younger and older group separately.

Results
Mean reaction time was 2608 ms ($SD = 681$ ms, range = 1412–3860 ms) for younger participants and 3252 ms ($SD = 589$ ms, range = 2210–4314 ms) for older participants. The accuracy was 92% on average for younger participants ($SD = 3$%, range = 80–96%) and 81% on average for older participants ($SD = 12$%, range = 49–93%). A summary of all results reported below is provided in Table 3.

Reaction times
The repeated measures ANOVA performed on reaction times with transitivity of the structure as a within-subject factor revealed a significant effect of transitivity of sentence structure [$F_1(1, 38) = 61.50$, $p < .001$; $F_2(1, 48) = 36.03$, $p < .001$], with intransitive structure sentences having slower responses (mean = 3037 ms, $SD = 765$ ms, across participants) than transitive structure sentences (mean = 2567 ms, $SD = 691$ ms, across participants), and age, [$F_1(1, 38) = 9.29$, $p = .004$; $F_2(1, 48) = 169.96$, $p < .001$], with older participants responding slower (mean = 3252 ms, $SD = 589$ ms, across participants) than younger participants (mean = 2608 ms, $SD = 681$ ms, across participants). No other factors or interactions were significant.

Within transitive structure sentences (see Figure 2a), a repeated measures ANOVA performed on reaction times revealed a significant effect of age [$F_1(1, 38) = 6.65$, $p = .014$; $F_2(1, 48) = 75.90$, $p < .001$], with older participants responding slower (mean = 2945 ms, $SD = 553$ ms, across participants) than younger participants (mean = 2341 ms, $SD = 674$ ms, across participants); verb type, $F_1(1, 38) = 12.03$, $p = .001$ ($F_2$ analysis nonsignificant), with OPT verbs having slower responses (mean = 2582 ms, $SD = 731$ ms, across participants) than CAU/RAT verbs (mean = 2389 ms, $SD = 743$ ms, across participants); and a trend towards an effect of plausibility [$F_1(1, 38) = 3.49$, $p = .069$; $F_2(1, 48) = 2.61$, $p = .113$], with implausible conditions having slower responses (mean = 2550 ms, $SD = 754$ ms, across participants) than plausible conditions (mean = 2421 ms, $SD = 748$ ms, across participants). The analysis also revealed a clause order by plausibility interaction that was significant in by-subject analysis, $F_1(1, 38) = 4.09$, $p = .050$, although not in by-item analysis, $F_2(1, 48) = 2.16$, $p = .148$, with the plausibility effect being present in the subordinate–main clause order (Cohen’s $d = 0.33$ in $F_1$ analysis) but not in the main–subordinate clause order (Cohen’s $d = 0.01$ in $F_1$ analysis). No other factors or interactions were significant.

Within intransitive structure sentences (see Figure 2b), a repeated measures ANOVA performed on reaction times revealed a significant effect of age [$F_1(1, 38) = 6.45$, $p = .015$; $F_2(1, 48) = 132.42$, $p < .001$], with older participants responding slower (mean = 3456 ms, $SD = 657$ ms, across participants) than younger participants (mean = 2786 ms, $SD = 657$ ms, across participants); clause order [$F_1(1, 38) = 14.57$, $p < .001$; $F_2(1, 48) = 17.58$, $p < .001$], with subordinate–main clause order having slower responses (mean = 3147 ms, $SD = 827$ ms, across participants) than main–subordinate clause order (mean = 2928 ms, $SD = 766$ ms, across participants); plausibility [$F_1(2, 76) = 12.92$, $p < .001$; $F_2(2, 96) = 6.16$, $p = .003$], with plausible (mean = 3133 ms, $SD = 777$ ms, across participants) and globally implausible (mean = 3174 ms,
Table 3. Brief summary of results

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Significant/trending factors or interactions</th>
</tr>
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| Reaction times | * Age (older > younger)  
| Analysis with only the factors of transitivity and age | * Transitivity (intransitive > transitive)  
| Analysis within transitive-structure sentences | * Age (older > younger)  
| Analysis within intransitive-structure sentences | * Verb type (OPT > CAU/RAT)  
| Analysis within intransitive-structure sentences | * Verb type (OPT > CAU/RAT)  
| Analysis within intransitive-structure sentences | * Plausibility (implausible > plausible)  
| Analysis with only the factors of transitivity and age | * Clause Order × Plausibility interaction  
| Analysis within transitive-structure sentences | * Clause Order (main–subordinate > subordinate–main)  
| Analysis within intransitive-structure sentences | * Verb Type × Clause Order interaction  
| Analysis within intransitive-structure sentences | * Verb Type × Plausibility interaction  
| Analysis within intransitive-structure sentences | * Plausibility (plausible/globally implausible > locally implausible)  
| Accuracy | * Age (younger > older)  
| Analysis with only the factors of transitivity and age | * Transitivity (Transitive > Intransitive)  
| Analysis within transitive-structure sentences | * Age (younger > older)  
| Analysis within intransitive-structure sentences | * Clause Order (main–subordinate > subordinate–main)  
| Analysis with only the factors of transitivity and age | * Verb Type × Clause Order interaction  
| Analysis within transitive-structure sentences | * Plausibility (locally implausible > globally implausible > plausible)  
| Analysis within intransitive-structure sentences | * Verb Type (OPT > CAU/RAT)  
| Analysis with only the factors of transitivity and age | * Verb Type × Age interaction  
| Analysis within transitive-structure sentences | * Clause Order × Age interaction  
| Analysis within intransitive-structure sentences | * Plausibility (blended responses: plausible > locally implausible > globally implausible)  
| Analysis within intransitive-structure sentences | * Age (blended responses: younger > older)  
| Analysis within intransitive-structure sentences | * Verb Type × Plausibility interaction  
| Analysis within intransitive-structure sentences | * Slower processing speed associated with lower accuracy  
| Analysis with only the factors of transitivity and age | * Lower accuracy associated with a greater tendency to select “blended” responses  
| Analysis within transitive-structure sentences | * Verb Type × Plausibility interaction  
| Analysis within intransitive-structure sentences | * Lower accuracy associated with a greater tendency to select “blended” responses  

Note: OPT = optionally transitive; CAU = causative; RAT = reflexive absolute transitive. The symbol > denotes slower reaction times in the reaction times analysis and higher accuracy in the accuracy analysis.

*Effects that were significant in both by-item and by-subject analysis (p < .05). (*) Effects that either (a) were approaching significance in by-item and/or by-subject analysis (.05 < p < .1) or (b) were significant (p < .05) in one type of analysis (by-item/by-subject) but not the other one.

SD = 859 ms, across participants) sentences having slower responses than locally implausible sentences (mean = 2806 ms, SD = 787 ms, across participants), with no difference between the first two; and verb type \([F_1(1, 38) = 9.27, p = .004; F_2(1, 48) = 3.30, p = .076]\), with OPT verbs having slower responses (mean = 3095 ms, SD = 813 ms, across participants) than CAU/RAT verbs (mean = 2871 ms, SD = 839 ms, across participants). The analysis also revealed a significant verb type by clause order interaction \([F_1(1, 38) = 6.82, p = .013; F_2(1, 48) = 3.32, p = .075]\), the clause order effect being larger for CAU/RAT verbs (Cohen’s \(d = 0.48\) in \(F_1\) analysis) than for OPT verbs (Cohen’s \(d = 0.20\) in \(F_1\) analysis); and a trend towards an interaction between verb type and plausibility, \(F(2, 38) = 2.91, p = .061\), although not approaching significance in the \(F_2\) analysis, the plausibility effect being larger for OPT verbs (Cohen’s \(d = 0.36\) and 0.51 for locally implausible vs. plausible and globally implausible sentences, respectively, in \(F_1\) analysis) than for
Figure 2. (a). Reaction times (in ms) for sentences with transitive structure. Error bars represent standard errors of the mean. Numbers 7 to 10 denote sentence conditions; T = transitive structure; SM = subordinate–main clause order (bars are highlighted in darker grey colour); MS = main–subordinate clause order (bars are highlighted in lighter grey colour); P = plausible; L = locally implausible; OPT = optionally transitive; CAU = causative; RAT = reflexive absolute transitive. (b) Reaction times (in ms) for sentences with intransitive structure. Error bars represent standard errors of the mean. Numbers 1 to 6 denote sentence conditions; I = transitive structure; G = globally implausible.
CAU/RAT verbs (Cohen’s $d = 0.29$ and $0.19$ for locally implausible vs. plausible and globally implausible sentences, respectively, in $F_1$ analysis). No other factors or interactions were significant.

**Percentage of “correct” responses**

A repeated measures ANOVA performed over the empirical logit transformed percentage of “correct” responses—that is, responses reflecting a complete and correct syntactic (re)analysis—revealed a significant effect of transitivity of sentence structure [$F_2(1, 38) = 134.64, p < .001; F_2(1, 48) = 52.54, p < .001$], with transitive structure sentences eliciting more “correct” responses (mean = 91.0%, $SD = 8.7%$, across participants) than intransitive structure sentences (mean = 72.8%, $SD = 11.5%$, across participants), and of age [$F_1(1, 38) = 18.86, p < .001; F_2(1, 48) = 105.20, p < .001$], with younger adults making more “correct” responses (mean = 83.8%, $SD = 5.2%$, across participants) than older adults (mean = 73.6%, $SD = 12.1%$, across participants). No other factors or interactions were significant.

Within transitive structure sentences (see Figure 3a), a repeated measures ANOVA performed on the percentage of “correct” responses revealed significant effects of age [$F_1(1, 38) = 24.61, p < .001; F_2(1, 48) = 154.75, p < .001$], with younger participants making more “correct” responses (mean = 94.5%, $SD = 3.6%$, across participants) than older participants (mean = 85.1%, $SD = 11.3%$, across participants); and clause order [$F_1(1, 38) = 12.47, p = .001; F_2(1, 48) = 7.59, p = .008$], with main–subordinate clause order eliciting more “correct” responses (mean = 92.5%, $SD = 8.5%$, across participants) than subordinate–main clause order (mean = 89.0%, $SD = 10.1%$, across participants). The analysis also revealed two significant interactions: age by plausibility [$F_1(1, 38) = 5.10, p = .030; F_2(1, 48) = 3.73, p = .060$]—namely, the facilitatory effect of plausibility only being present in the older group (Cohen’s $d = 0.75$ in $F_1$ analysis), with plausible sentences eliciting more “correct” responses than implausible sentences, with a smaller effect in the opposite direction in the younger group (Cohen’s $d = −0.23$ in $F_1$ analysis); and clause order by plausibility [$F_1(1, 38) = 8.68, p = .005; F_2(1, 48) = 7.63, p = .008$], the facilitatory effect of plausibility being present in the subordinate–main clause order (Cohen’s $d = 0.76$ in $F_1$ analysis), with a smaller effect in the opposite direction in the main–subordinate clause order (Cohen’s $d = −0.33$ in $F_2$ analysis). No other factors or interactions were significant.

Within intransitive structure sentences (see Figure 3b), a repeated measures ANOVA performed on the percentage of “correct” responses revealed significant effects of age [$F_1(1, 38) = 12.88, p = .001; F_2(1, 48) = 64.58, p < .001$], with younger participants making more “correct” responses (mean = 76.8%, $SD = 8.2%$, across participants) than older participants (mean = 66.1%, $SD = 13.3%$, across participants); clause order [$F_1(1, 38) = 9.50, p = .004; F_2(1, 48) = 10.47, p = .002$], with main–subordinate order eliciting more “correct” responses (mean = 75.3%, $SD = 8.9%$, across participants) than subordinate–main order (mean = 70.3%, $SD = 15.9%$, across participants); plausibility [$F_1(2, 76) = 49.43, p < .001; F_2(2, 96) = 16.67, p < .001$], with the following pattern of percentage “correct” responses: plausible (mean = 62.0%, $SD = 14.0%$, across participants) < globally implausible (mean = 73.9%, $SD = 15.0%$, across participants) < locally implausible (mean = 82.4%, $SD = 10.6%$, across participants), all pairwise comparisons significant at $p < .05$; and verb type [$F_1(1, 38) = 48.71, p = .001; F_2(1, 48) = 11.33, p = .002$], with OPT verbs eliciting more “correct” responses (mean = 81.9%, $SD = 15.6%$, across participants) than CAU/RAT verbs (mean = 66.2%, $SD = 10.9%$, across participants). The analysis also revealed trends towards interactions of verb type by age [$F_1(1, 38) = 3.16, p = .084; F_2(1, 48) = 7.85, p = .007$], with the verb type effect being greater in the younger group (Cohen’s $d = 1.95$ in $F_1$ analysis) than in the older group (Cohen’s $d = 0.97$ in $F_1$ analysis); and clause order by age [$F_1(1, 38) = 3.26, p = .079; F_2(1, 48) = 3.35, p = .073$], with the effect of clause order being greater in the younger group (Cohen’s $d = 0.52$ in $F_1$ analysis) than in the younger group (Cohen’s $d = 0.18$ in $F_1$ analysis). No other factors or interactions were significant.
Figure 3. (a) Accuracy (in % correct) for sentences with transitive structure. Error bars represent standard errors of the mean. Numbers 7 to 10 denote sentence conditions; T = transitive structure; SM = subordinate–main clause order (bars are highlighted in darker grey colour); MS = main–subordinate clause order (bars are highlighted in lighter grey colour); P = plausible; L = locally implausible; OPT = optionally transitive; CAU = causative; RAT = reflexive absolute transitive. (b) Accuracy (in % correct) for sentences with intransitive structure. Error bars represent standard errors of the mean. Numbers 1 to 6 denote sentence conditions; I = transitive structure; G = globally implausible.
Response types

The proportion of “blended” responses within each participant’s responses not belonging to the “correct” type constituted an average of 69.0% in the younger group (SD = 37.9%) and 61.5% in the older group (SD = 32.9%).

Distributions of “blended” and “garden-path” responses within garden-path sentences (i.e., Conditions 1, 3, 5) are shown in Figure 4.

The repeated measures logistic regression revealed that the type of incorrect response was significantly affected by plausibility, $\chi^2(2) = 30.38$, $p < .001$, with a greater number of “blended” responses for the plausible (mean = 84.1%, SD = 21.8%) than for the locally implausible (mean = 76.3%, SD = 26.0%), which was greater than that for the globally implausible (mean = 39.7%, SD = 38.1%) condition, and a verb type by plausibility interaction, $\chi^2(2) = 7.88$, $p = .019$, indicating that effects of plausibility on response type were modulated by verb type (see Figure 4). There was also a weak statistical trend towards an effect of age, $\chi^2(1) = 2.65$, $p = .103$, with a greater number of “blended” responses in...
the younger group (mean = 72.8%, SD = 22.5%) than in the older group (mean = 67.9%, SD = 14.7%). No other factors or interactions were significant, including the effect of verb type, where the mean proportion of “blended” responses was 56.8% (SD 32.9%) for OPT verbs and 42.1% (SD 42.4%) for CAU/RAT verbs.

Correlation analysis
The correlation analysis of garden-path sentences aggregating across younger and older participants revealed that slower processing speed was associated with lower accuracy (r = .480, p = .002; however, the correlation was not significant either in the younger or in the older group separately), and, at the level of a statistical trend, lower accuracy was also associated with a greater tendency to select “blended” responses (r = .297, p = .063; reaching statistical significance in the analysis of the younger group, r = .602, p = .001, but nonsignificant within the older group). No other correlations were significant.

Discussion
This study used a sentence–picture matching task to investigate the mechanisms of processing auditorily presented sentences (including temporarily ambiguous “garden-path” sentences) in healthy younger and older adults. The pictures represented different possibilities in generating a sentence representation: (a) successfully completing syntactic reanalysis; (b) “blending” the separate representations of two sentence parts into one (either directly violating syntactic licensing constraints, CAU/RAT verbs, or reflecting a shallow parse that is not fully licensed by the syntactic structure, OPT verbs); or (c) erroneously maintaining the initial incorrect “garden-path” parse without incorporating new information. Thus, the study investigated the effects of age and various linguistic factors not only on the speed and accuracy of sentence processing but also on the types of erroneous representations that are formed.

Previous research mostly used data from comprehension question tasks, showing that comprehenders do not always engage in full syntactic (re)analysis of garden-path sentences in order to comprehend them on some level (Christianson et al., 2001). However, with binary-choice comprehension probes, it is not possible to test whether two different parses of the “garden-path” noun phrase are maintained simultaneously. Answering “yes” to both “Did the man hunt the deer?” and “Did the deer run into the woods?” does not necessarily mean that these interpretations are combined in one and the same representation. Instead, they can be part of two competing representations or even a result of a strategic repair in response to being confronted with a comprehension question. The contribution of the present study is that it addresses this issue by more directly probing sentence representations, adding to research that used text-change and paraphrasing paradigms (Christianson, 2008; Patson et al., 2009).

A limitation of the present study is that due to a “ceiling effect” in performance accuracy, the number of responses other than “correct” responses was not high: Within garden-path sentences, it was 21.9% on average (range 3.3–46.7%, SD 10.5%) in the younger group and 32.4% on average (range 16.7–50%, SD 11.5%) in the older group. Thus, only a limited dataset could be used in the analysis of preferences for “blended” versus “garden-path” responses. However, even though the number of errors made by individual participants was generally not high, all participants made at least some “blended” or “garden-path” responses. The analysis therefore included data from 100% of participants and had enough power to reveal the most prominent effects or trends that influence the representation type.

Linguistic factors
The main contribution of the study with regard to investigating linguistic factors in “garden-path” processing was directly addressing their influence on the type of sentence representation that is formed if full syntactic reanalysis does not occur. Overall, participants more frequently made “blended” responses, which reflect the blending of the initial garden-path representation with the incoming sentence material, than pure “garden-path” noun phrases. Therefore, the correlation analysis revealed that slower processing speed was associated with lower accuracy (r = .480, p = .002; however, the correlation was not significant either in the younger or in the older group separately), and, at the level of a statistical trend, lower accuracy was also associated with a greater tendency to select “blended” responses (r = .297, p = .063; reaching statistical significance in the analysis of the younger group, r = .602, p = .001, but nonsignificant within the older group). No other correlations were significant.

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path” responses, in which the initial representation is maintained without incorporation of new incoming sentence material.

However, the likelihood of “blended” or “garden-path” representations was affected by the semantic factor of plausibility. The number of “blended” responses was smaller for globally implausible sentences than for locally implausible sentences, which was smaller than that for plausible sentences. Comprehenders were most likely to block blending and endorse the initial “garden-path” interpretation without attempting to incorporate new information in globally implausible sentences like “[While the man hunted the deer paced in the woods]” (in this example, the “garden-path” representation would be the one where “the deer” is the object of the subordinate clause but not the subject of the main clause). Since lack of blending appears to be due to the semantic incompatibility of two propositions, the second of which (e.g., the deer pacing in the woods) only becomes available at the end of the sentence, it probably reflects postsyntactic processing rather than an online abortion of blending. Interestingly, the plausibility condition that ranked second to the globally implausible condition on the likelihood of forming a “garden-path” rather than a “blended” representation was the locally implausible condition, rather than the plausible—that is, when errors were made at all, comprehenders were more likely to maintain the initial representation without adding new information to it in sentences like “[While the man hunted the plane flew over the woods]” than “[While the man hunted the deer ran in the woods]”. We return to this apparently unexpected result below, when we discuss how the prevalence of particular misrepresentation types correlates with the overall accuracy.

Moreover, plausibility entered into a significant interaction with verb type—that is, the effect of plausibility on the selection of “blended” or “garden-path” representation was modulated by whether the sentence included an OPT or a CAU/RAT verb. Contrary to our expectations, the factor of verb type did not demonstrate an independent main effect on the type of incorrect representation. As mentioned above, this may be a null result due to insufficient number of observations and statistical power; although the numerical difference did not approach statistical significance, probably due to high individual variability, the average number of “blended” responses was higher for OPT than for CAU/RAT verbs. This pattern is consistent with the findings by Christianson et al. (2006) who showed that “yes”-answers to questions targeting the role of the noun phrase as both the subject of the main clause and the object of the subordinate clause were significantly more numerous for OPT verbs than for RAT verbs. “Blended” responses probably reflect the tendency of comprehenders to incorporate incoming sentence material without revising the initial incorrect representation unless this is precluded by verb argument structure characteristics. However, another possibility is that both the findings by Christianson et al. (2006) and our own observation (which did not reach statistical significance) can actually be due to linguistically acceptable postsyntactic inferencing mechanisms that are possible for OPT but not for CAU/RAT verbs—namely, a comprehender may parse the sentence as “[While the man hunted], [the deer ran into the woods]”, and subsequently, since the verb “to hunt” implies an external object of the action even when used syntactically intransitively, a comprehender might make an inference that the object of the action was “the deer”. Such an influence of postsyntactic inferential processing on the final meaning representation is also corroborated by the finding (discussed above) that blending occurred the least often in response to globally implausible sentences, where comprehenders have to first form the meanings of two propositions in order to then recognize their incompatibility and turn away the “blended” representation.

The study adds to the body of research investigating the effects of linguistic factors on the speed and accuracy of garden-path processing. To summarize our findings, sentence processing was more challenging in the following conditions, as indicated by both reaction times and accuracy: intransitive sentence structure and subordinate–main clause order (which together with intransitive sentence structure constituted garden-path sentences). Note that the
transitivity effect may possibly be mediated by the first noun phrase having a longer duration in two of the intransitive sentence types than in one of the transitive sentence types (by 15 and 19 ms on average), as revealed by the post hoc acoustic analysis of the experimental stimuli, although we are not convinced that this difference fully accounts for the sentence processing effects in both reaction times and accuracy. For sentences with OPT verbs, compared to CAU/RAT verbs, the pattern is ambivalent; they are processed more slowly in general, yet accuracy is higher for intransitive-structure sentences with OPT verbs. Accuracy reflects the ultimate success of building a syntactically licensed sentence representation, while reaction times may have more diverse interpretations, pertaining to several possible mechanisms and reflecting, among other possibilities, additional time needed to go back to the previous structure/representation and revise it (or select an alternative competitor), or to fit new material into an existing structure/interpretation, or even to apply any post hoc processing strategies to generate a response to the experimental task.

The effects of linguistic factors on processing cost in terms of reaction times and percentage of “correct” responses largely replicated the findings from earlier research. Consistent with Christianson et al. (2006), we found that intransitive verb use with subordinate–main clause order makes sentence processing more challenging in terms of both processing speed and accuracy. This appears to be mostly driven by the garden-path effect, which is formed by the combination of these two parameter values. However, the effects are not limited to garden-path sentences. Within transitive–structure sentences as well, subordinate–main clause order presents a greater challenge, as reflected by response accuracy. This is consistent with a large body of literature showing that initial subordinate clauses, even in the absence of syntactic ambiguity, are always processed less completely than initial main clauses (Bever & Townsend, 1979; Jarvella, 1971). In order to fully process the meaning of a subordinate clause, it must be placed into the context of information from the main clause. If the main clause is not available yet, incompletely processed information from the subordinate clause must be held in memory, which increases processing costs.

With regard to semantic plausibility, the processing of intransitive-structure sentences was both faster and more accurate for locally implausible sentences (“While the man hunted the plane flew over the woods”) than for plausible sentences (“While the man hunted the deer ran into the woods”) and globally implausible sentences (“While the man hunted the deer paced in the zoo”). The facilitatory effect of local implausibility relative to plausible sentences was consistent with results of an eye-tracking study by Pickering and Traxler (1998) who showed that local implausibility of an object was a strong cue that led to disruption in building the structure early during processing of the noun phrase: Implausible objects are only very briefly treated as direct objects. Similarly, Slattery et al. (2013) concluded that implausibility of the disambiguating region blocks the initial attachment of the critical noun phrase to the structure, and DeDe (2010) showed that semantic plausibility of the ambiguous noun phrase influenced listening times, also suggesting a contribution of plausibility to online parsing.

Christianson et al. (2006), however, found a facilitatory effect of global implausibility that was absent in our experiment (they did not include a locally implausible condition). This discrepancy can probably be accounted for by task-specific effects. It is possible that seeing a visual representation of a “globally implausible” event in the picture helps to conceptualize it and makes the described situation seem less improbable than when probed through comprehension questions, where participants do not have any visual cues and can only rely on building a mental representation of the meaning of the sentence. On the other hand, a conflict between the meanings of the verb and the noun in locally implausible sentences points so strongly against parsing the noun as the verb’s object that even seeing the situation in the picture is not a sufficiently strong cue to consider this parsing. Also, local implausibility might present a stronger cue than global plausibility not only because it is a lexical factor but also because this information is received at the time point of
ambiguity and probably participates in the online analysis, whereas global plausibility information is received after the ambiguous point in a sentence and provides a cue for a post hoc reanalysis rather than for initial online parsing. Even if locally implausible postverbal nouns are also initially parsed as direct objects, as suggested by Sturt (2007) and DeDe (2010), the semantic cue inhibiting that parse comes much earlier than the global implausibility cue, in which case comprehenders probably maintain the erroneous parse for a longer period, before receiving contradictory information.

To summarize the results with regard to the effects of verb type on processing speed and accuracy, the study found that (a) responses to OPT verbs were slower than those to CAU/RAT verbs across sentence types, although the finding was not significant in by-item analysis of transitive-structure sentences; (b) OPT verbs elicited a greater number of “correct” responses in intransitive-structure sentences than CAU/RAT verbs; (c) the effect of semantic plausibility on reaction times was greater for OPT verbs in intransitive-structure sentences; and (d) the effect of clause on reaction times was greater for CAU/RAT verbs in intransitive sentences. Partially, the pattern may be attributed to a greater use of the preferred “blending” strategy for OPT verbs—hence their slower processing in intransitive sentences (reflecting the process of “blending” the initial representation with incoming material) and the modulation of the processing speed by semantic plausibility (reflecting that blending is blocked in the presence of strong semantic cues). Additionally, in sentences that are not garden-paths and have a main–subordinate clause order, “blended” representations may result from postsyntactic inferencing, which is possible for OPT but not CAU/RAT verbs, hence a smaller effect of clause order in the former than in the latter. However, the remaining findings need to have an additional explanation. One possible account for the lower number of “correct” responses for CAU/RAT verbs in intransitive structures is that their inchoative or reflexive use, as forced by the intransitive but not by the transitive construction, is inherently associated with a greater processing cost, drawing on a more complex verb argument structure in which the verb subject does not (only) bear the canonical theta role of an “agent”. Rather, the verb subject bears the theta role of a “patient” in case of CAU verbs and the theta roles of both an “agent” and a “patient” in case of RAT verbs (“theta-role bundling”, cf. Reinhart & Siloni, 2005), which possibly makes argument structure processing more complex.

Taken together, the findings confirm that the language processor may not favour performing a syntactic reanalysis of the structure if a good-enough interpretation is acceptable (i.e., plausible). Revising the structural representation of the sentence may not be the preferred strategy: Sturt, Pickering, Scheepers, and Crocker (2001) suggest that it is “the last resort”, and Christianson et al. (2006) point out that reanalysis may be prompted by the probe question in an experiment and would not have necessarily been attempted under other processing conditions. However, so as not to ignore the incoming sentence material, comprehenders may attempt to incorporate it without revising the initial interpretation, resulting in “blended” representations. These are formed as long as blending is not precluded by strong linguistic cues such as semantic plausibility or verb argument structure. However, blending does take additional processing time, resulting in slower reaction times for those conditions where attempts of blending are not aborted early on. With regard to the syntactic nature of such “blended” representations, Christianson et al. (2001) note that it would be radical, although not impossible, to assume that they are merged in one “spliced” syntactic tree; rather, “stolen” material is likely to be copied across multiple syntactic structures in the process of revising the representation.

**Age**

The main contribution of the study with regard to investigating the effect of age in “garden-path” processing was directly addressing whether older and younger comprehenders differ in the type of sentence representations that they form when they do not perform full syntactic reanalysis of
“garden-path” sentences. We found that at the level of a statistical trend, the older group tended to give more “garden-path” responses, in which the initial “garden-path” interpretation is maintained without a repair attempt (i.e., the critical noun phrase is interpreted as the object of the first, subordinate clause but not as the object of the second, main clause), than did the younger group. This indicates that older adults are less inclined to blend new incoming material with an existing representation, which seems to be a relatively favoured strategy among younger comprehenders.

The reduced inclination to blend might be due to a general age-related decline in cognitive processing speed (Salthouse, 1996), consistent with the overall slower processing by older adults in the present experiment. At the time point when the predicate of the main clause is presented, older adults might still be engaged in processing the critical noun phrase in the role of the object of the first, subordinate clause. They are not able to “keep up” with the incoming sentence material and do not have sufficient time to add new information to the sentence representation. This speed-of-processing hypothesis may be tested in future research that would either manipulate the speed of stimuli presentation or use self-paced presentation and investigate whether the processing patterns of older adults, when they are given enough time, become more similar to those of the younger group. Results of Experiment 1b by Christianson et al. (2006), however, do not support this hypothesis, as they still found age-related processing differences even though the experiment presented older adults with stimuli for a longer time than younger adults. Also note that, in the present study, response speed was correlated with overall accuracy, but not with the prevalence of particular error types.

Alternatively, the older adults’ response pattern may reflect a decline in working memory (Caplan & Waters, 1999). Syntactic reanalysis and updating tax working memory resources, since these processes require maintaining lexical and syntactic representations in working memory and manipulating several syntactic units and parsing options. Older adults may have reduced working memory capacity to allocate for this, which causes them to adhere to the initially built erroneous representation, whether consciously/strategically or not. This indicates that it would require more working memory resources to revise or add to an existing representation, rather than to maintain it. The working memory account is consistent with earlier findings showing that older adults’ working memory is a predictor of the accuracy of their comprehension of “garden-path” sentences with RAT verbs (Christianson et al., 2006), as well as that the performance of older adults on garden-path sentence processing is similar to the performance of younger adults with lower working memory span (Kemper et al., 2004).

The analysis of correlations between individual participants’ processing speed, accuracy, and prevalence of particular misrepresentation types also suggests differences between the processing of garden-path sentences by younger versus older comprehenders. In younger but not older participants, lower accuracy was associated with a greater tendency to make errors of the “blended”, as opposed to the “garden-path”, type. In other words, as the rate of errors in individual younger participants increases, the proportion of “blended” responses also increases, indicating the role of blending in “good-enough”, as opposed to highly accurate, language processing. However, this pattern was not found in the older group, possibly due to the aforesaid lack of processing resources that impedes keeping up with the sentence material overall. The fact that the proportion of “blending” increases with an overall rise in the number of errors (provided that there are sufficient processing resources, as in the younger group) is also consistent with the seemingly unexpected result showing a larger proportion of “blended” responses for plausible than locally implausible sentences: As the overall error rate increases in plausible compared to locally implausible sentences, the role of “blending” also increases.

With respect to the response types, no interactions were revealed between the effects of age and those of any linguistic variables. In other words, in cases where syntactic reanalysis was absent or incomplete, even though older adults
tended to ultimately form a different sentence interpretation (see above), there was no significant difference between the ways in which linguistic variables influenced the ultimate sentence interpretation in older versus younger adults. Older adults were not shown to be more likely than younger adults to choose “blended” responses specifically for OPT verbs, which might have reflected a greater reliance on postsyntactic inferencing. The absence of this finding is somewhat at odds with our other result showing that older comprehenders are more likely to commit an error assigning a semantically plausible interpretation to a semantically implausible transitive structure sentence. It is possible that the response types analysis, unlike the accuracy analysis that included all trials of the experiment, simply lacked power to demonstrate such interaction.

The influence of age on the speed and accuracy of garden-path processing is not a novel topic of investigation. Older adults demonstrated slower and less accurate processing across sentence conditions. This effect was not restricted to garden-path processing but was also present in transitive structure sentences. The overall detrimental effect of age on the processing speed and accuracy across sentence conditions adds to previous research showing that older adults demonstrate a decline in linguistic processing accuracy may be due to different factors (from low-level perceptual or speed-of-processing decline to higher order deficits in working memory, inhibition, linguistic ability, etc.), which may in turn have a common source.

We found that older adults differed from younger adults in the effects of linguistic variables on processing accuracy. The following effects were qualitatively the same in the two groups but larger in the older group: the detrimental effect of the subordinate–main clause order and the detrimental effect of CAU/RAT verb type within intransitive structure sentences. This replicates the results of Christianson et al. (2006). Additionally, one effect was only present in the older but not in the younger group. This was the effect of plausibility within transitive structure sentences: Locally implausible sentences elicited more errors only in the older group, but not in the younger group. That is, when presented with a sentence such as “While the man hunted the plane the pheasant flew over the woods”, older adults were more likely to commit an error by transposing the objects and thus making the interpretation plausible (in this example, they chose the picture where the man is hunting the pheasant and the plane is flying over the woods). Since the transitive sentences are not structurally ambiguous, and the semantically plausible interpretation is not legitimate at any point of online processing, the effect is most likely driven by postsyntactic or even asyntactic inferencing based on lexical and semantic cues. Again, these results show a reduced reliance on structural syntactic cues in older adults, with greater reliance on superficial (good-enough) parses based on semantic and pragmatic factors, also indicating that good-enough processing is not restricted to the syntactically most complex or ambiguous sentence types. Previous work has shown that such swapping of participant roles mediated by overreliance on semantic and pragmatic cues is not demonstrated exclusively by older adults. Rather, it is also systematic in the processing of implausible structures by other populations such as college-age adults (Christianson, Luke, & Ferreira, 2010; Ferreira, 2003) and non-native speakers of English (Lim & Christianson, 2013a, 2013b).

We found no interactions between age and any linguistic variables in their effect on reaction times. In other words, even though older adults showed generally longer response times, and some sentence types were processed less accurately by them than by the younger group, these specific sentence types did not take them particularly longer to process. This suggests that older comprehenders neither engaged in processing for a longer time nor employed compensatory processing mechanisms in addition to the processing mechanisms of the younger group. If any compensatory
mechanisms are used by the older group in more linguistically challenging conditions, these are employed in place of the mechanisms used by the younger group.

CONCLUSIONS

In a multiple-choice sentence-picture matching task with stimuli including temporarily ambiguous (“garden-path”) sentences, we found that both the speed and accuracy of sentence processing and the type of erroneous sentence representations are affected by semantic and lexical as well as syntactic factors. We found that while comprehenders may generally be inclined to blend incoming information into the initial sentence representation, which takes additional processing time, blending may be blocked in the presence of strong semantic and verb argument structure cues.

Age also had an effect on both processing accuracy and speed, as well as on the type of erroneous sentence representations. At the level of a statistical trend, older adults’ response types suggest that they are more likely to maintain the initial representation without incorporating new information, which may be due to a general decline in working memory capacity or processing speed, not differentially tested in the present study. On the other hand, there was a tendency among younger adults to blend two representations into a single interpretation, even if this is not licensed by the syntax. The task conditions in this experiment were relatively challenging, and older adults showed decreased processing speed and accuracy. Older adults’ accuracy was more affected by linguistic variables that contribute to linguistic complexity than was that of younger adults. However, this was not true for their reaction times, suggesting that if any compensatory mechanisms are applied by older adults, they are applied instead of rather than in addition to processing mechanisms utilized by younger adults. The results also suggest that even in unambiguous sentence structures, older adults show increased reliance on inferencing based on lexical and semantic cues.

REFERENCES


## APPENDIX A

### Experimental stimuli

<table>
<thead>
<tr>
<th>Sentence conditions</th>
<th>Picture description</th>
<th>Picture example in Figure A1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. While the man hunted the deer ran into the woods.</strong></td>
<td>“Correct” representation—Full syntactic analysis: The critical noun phrase is only the subject of the main clause (not the object of the subordinate clause).</td>
<td>1</td>
</tr>
<tr>
<td><strong>B. The deer ran into the woods while the man hunted.</strong></td>
<td>“Blended” representation: The critical noun phrase is both the object of the subordinate clause and the object of the main clause. “Garden-path” (initial) representation: The critical noun phrase is only the object of the subordinate clause (not the subject of the main clause).</td>
<td>2</td>
</tr>
<tr>
<td><strong>A. While the man hunted the plane flew over the woods.</strong></td>
<td>“Correct” representation—Full syntactic analysis: The critical noun phrase is only the subject of the main clause (not the object of the subordinate clause).</td>
<td>4</td>
</tr>
<tr>
<td><strong>B. The plane flew over the woods while the man hunted.</strong></td>
<td>“Blended” representation: The critical noun phrase is both the object of the subordinate clause and the object of the main clause. “Garden-path” (initial) representation: The critical noun phrase is only the object of the subordinate clause (not the subject of the main clause).</td>
<td>5</td>
</tr>
<tr>
<td><strong>A. While the man hunted the deer paced in the zoo.</strong></td>
<td>“Correct” representation—Full syntactic analysis: The critical noun phrase is only the subject of the main clause (not the object of the subordinate clause).</td>
<td>7</td>
</tr>
<tr>
<td><strong>B. The deer paced in the zoo while the man hunted.</strong></td>
<td>“Blended” representation: The critical noun phrase is both the object of the subordinate clause and the object of the main clause. “Garden-path” (initial) representation: The critical noun phrase is only the object of the subordinate clause (not the subject of the main clause).</td>
<td>8</td>
</tr>
<tr>
<td><strong>A. While the man hunted the pheasant the plane flew over the woods.</strong></td>
<td>Correct representation. “Argument swapping” representation: Object of the subordinate clause and the subject of the main clause are changed places. “Argument combining” representation: Both critical nouns are the subjects of the main clause. The object of the subordinate clause is different.</td>
<td>10</td>
</tr>
<tr>
<td><strong>B. The plane flew over the woods while the man hunted the pheasant.</strong></td>
<td>Correct representation. “Argument swapping” representation: Object of the subordinate clause and the subject of the main clause are changed places. “Argument combining” representation: Both critical nouns are the subjects of the main clause. The object of the subordinate clause is different.</td>
<td>10</td>
</tr>
</tbody>
</table>
Figure A1. Example of all pictures used for the verb “to hunt” (see descriptions in Appendix A).