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ORIGINAL ARTICLE

Perceptual salience and structural ambiguity resolution

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Abstract

This study investigates whether the perceptual salience of grammatical morphemes influences the online processing of temporarily ambiguous sentences during adult first-language (L1) comprehension. In a bidirectional self-paced reading task, adult L1 English participants ($N = 44$) read sentences with time adjuncts that were in a structural position in which they could attach either to the most recent verb phrase (VP) or to a VP in a higher clause. Consistent with previous findings, the reading times on these sentences indicated processing difficulty when this adjunct allowed only for high attachment. Crucially, this effect was modulated by the perceptual salience of the grammatical morphemes used to indicate time reference in these clauses. Specifically, the processing cost for high attachment was larger when time in the lower clause was indicated by the auxiliary verb *will* compared to when it was indicated by the relatively less salient past *-ed* morpheme. These findings were taken to indicate that the influence of perceptual salience extends beyond the acquisition of and sensitivity to grammatical morphemes during L1 and L2 development. Rather, the perceptual salience of these forms also appears to affect online structural processing during adult L1 sentence comprehension.

Keywords: Bidirectional self-paced reading; grammatical morphemes; low-attachment bias; perceptual salience; temporary ambiguity; time reference

Salience, broadly construed, refers to the properties of a stimulus, information unit, or event that make it more or less noticeable. It is generally assumed that more salient items are more likely to be perceived/recognized, to command attention, and to contribute to subsequent cognitive processing. With respect to language, the concept of salience has been invoked to explain phenomena in a range of domains, including phonetic accommodation (MacLeod, 2015), language change (Kerswill & Williams, 2002; Trudgill, 1986), the interpretation of word meaning (Giora, 2003; Kecskes, 2006), and discourse processing (Chiarcos et al., 2011). The present study examines the effects of *perceptual salience*—i.e., the physical properties that make elements more or less noticeable in the input—on structural processing during online sentence comprehension. This investigation is motivated by findings indicating that perceptual salience influences morphosyntactic acquisition and specifically the acquisition of inflectional morphemes (e.g., plural *-s*, past *-ed*) and closed-class free morphemes that primarily serve grammatical functions in a sentence (e.g., articles, auxiliary verbs). For ease of exposition, these elements will often be referred to collectively as *grammatical morphemes* (see e.g., Brown, 1973). A number of studies have attributed disparities in learners' acquisition of and sensitivity to grammatical morphemes during first-language (L1) and second-language (L2) development to differences in the perceptual salience of these forms (see below; for comprehensive review, see Gass et al., 2018a). The present study investigates whether perceptual salience similarly influences morphosyntactic processing in adult L1 comprehenders. A clear answer to this question is important in order to understand the extent of the influence of this factor on syntactic processing—i.e., whether it primarily affects the acquisition of L1/L2 morphosyntax or whether it affects structural processing more generally. With regard to this question, there is some evidence to suggest that the perceptual salience of relevant grammatical morphemes influences the detection of syntactic violations during adult L1 comprehension (see e.g., Dube et al., 2016). The present study builds on this research to examine the effects of this factor on other aspects of structural processing. Specifically, this study investigates whether the perceptual salience of grammatical morphemes influences the online processing of temporarily ambiguous structures during adult L1 sentence comprehension.

Before proceeding, it is important to note that the properties that make a linguistic element more or less salient are a matter of debate. Although recent research—and in particular L2 acquisition work by DeKeyser and colleagues (DeKeyser et al., 2018; Goldschneider & DeKeyser, 2001)—has gone a long way in terms of identifying a number of phonetic, (morpho)phonological, syntactic, semantic, and distributional factors that might influence salience, the precise contribution of these factors has yet to be determined. However, it is possible to formulate a working definition of perceptual salience that will help to frame the discussion to follow. First, it is important to reiterate that perceptual salience, sometimes also called *psychophysical salience* (see e.g., Ellis, 2018), refers to the physical characteristics of a stimulus that make it more or less noticeable in the input. In spoken language, it is generally assumed that elements are more perceptually salient when they are more substantial in terms of their acoustic characteristics—for example, longer in duration or more sonorous. Comparably, in terms of written language, orthographic forms that are longer (in terms of number of letters) and more easily isolable are considered to be more perceptually salient. It is also important to emphasize that perceptual salience is generally thought of in terms of a continuum. That is, a given linguistic element cannot be defined as perceptually salient or not, but can only be considered more or less salient relative to some other element(s) (for an overview of different types and determinants of salience, see e.g., DeKeyser et al., 2018; Ellis, 2018; Gass et al., 2018b).

A number of studies have appealed to the idea of perceptual salience in investigations of L1 and L2 morphosyntactic development. Many of these studies have focused on the possible effects of this factor in the acquisition of inflectional morphemes and closed-class grammatical function words. One line of this research has suggested that perceptual salience contributes to cross-linguistic differences in the acquisition of such elements (for general discussion of this issue, see e.g., Slobin, 1985). For example, although children often do not successfully comprehend subject-verb agreement marking on verbs until late in L1 development (Johnson et al., 2005), several studies have indicated that the learning trajectory for verbal agreement morphology appears to relate in part to the perceptual salience of these forms in the language. Specifically, these studies have found that children acquiring languages with relatively salient verbal agreement markers, like French and Greek, tend to comprehend subject-verb agreement earlier than those acquiring languages with less salient markers, like English and Spanish (see e.g., Barrière et al., 2016; Legendre et al., 2010; Legendre et al., 2014; Kenanidis et al., 2021; but see also Gonzalez-Gomez et al., 2017). Perceptual salience also seems to influence the L1 acquisition trajectories of different grammatical morphemes within a given language. For instance, Brown (1973) observed that the perceptibility of certain forms appears to affect their order of acquisition in English. This is the case, for example, with uncontractible copulas and auxiliary verbs, which tend to be acquired earlier than their less salient contractible counterparts (for similar findings in the L1 acquisition of English negators, see Cameron-Faulkner et al., 2007). There is also evidence indicating that the L1 acquisition of grammatical morphemes can be influenced by their perceptual salience as it relates to their position in the input. For instance, it has been observed that children acquiring English typically gain productive control over plural *-s* before third-person singular *-s* (see e.g., Brown, 1973). In a study examining child-directed speech, Hsieh and colleagues (1999) found that both of these morphemes were longer in duration in utterance-final position than in utterance-medial positions. However, plural *-s* occurred much more frequently in utterance-final position than third-person singular *-s*. Consequently, plural *-s* morphemes were found to be reliably longer than instances of third-person singular marking. Hsieh et al. (1999) argued that this disparity in the perceptual salience of plural *-s* and third-person singular *-s* likely contributes to differences in the timing of their acquisition. Similarly, Song and colleagues (2009) found that children acquiring English produce third-person singular *-s* more accurately when the verb occurs at the end of the utterance compared to when it occurs in the middle of the utterance, which they attributed in part to differences in the perceptual salience of this morpheme in these positions. Consistent with a perceptual account for these findings, subsequent research by Sundara et al. (2011) indicated that 2-year-olds show greater sensitivity to subject-verb agreement violations involving the presence/absence of third-person singular *-s* when the verb occurs utterance finally compared to when it occurs utterance medially.

Perceptual salience also appears to influence the L2 acquisition of grammatical morphology. For example, it has been noted that there is a relatively consistent order in the L2 acquisition of English grammatical morphemes (see e.g., Bailey et al., 1974; Dulay & Burt, 1974; Larsen-Freeman & Long, 1991; Pica, 1983), which has been attributed in part to the perceptual salience of these forms. Indeed, in a meta-analysis of L2 English morpheme order studies, Goldschneider and DeKeyser (2001) found that the perceptual salience of these forms—as measured by their phonetic substance (i.e., the number of phones in the morpheme), syllabicity (i.e., whether or not the morpheme constitutes a syllable), and sonority (i.e., the acoustic "strength" of the morpheme)—accounted for a large portion of the variance in their acquisition order. This was particularly the case when this factor was considered along with others that might influence how noticeable these morphemes are in the input, including their frequency, morphophonological regularity, semantic complexity, and syntactic category. DeKeyser and colleagues (2018) also found that a comparable set of factors affects the L2 acquisition of Hebrew grammatical morphology, with more salient forms tending to be acquired earlier than less salient forms, especially for learners at later ages of acquisition.

Perceptual salience also seems to influence L2 learners' acquisition of and sensitivity to tense morphology. For example, it has been observed that L2 learners tend to use lexical cues to time reference—with, for instance, time adverbs and other adjuncts (e.g., *now*, *yesterday*)—before they are able to reliably produce inflectional tense morphology on verbs (see e.g., Bardovi-Harlig, 1992). Comparably, L2 training studies have indicated that learners are more attuned to lexical cues to time reference than to cues provided by inflectional morphology (Cintrón-Valentín & Ellis, 2015, 2016; Ellis & Sagarra, 2010, 2011). Although a number of factors appear to contribute to these differences—including whether the learner comes from an L1 with a rich system of inflectional tense morphology as well as their overall proficiency in the L2—these disparities have been attributed at least in part to perceptual salience, with the idea that lexical indicators of time reference are generally more salient than verbal inflections (for discussion, Ellis, 2018).

Studies have also shown that L2 learners are differentially sensitive to grammatical morphemes during online sentence processing depending on the perceptual salience of these forms (Behney et al., 2018; Simoens et al., 2018). For example, Simoens et al. (2018) investigated Dutch-English bilinguals' processing of grammatical morphemes in a semi-artificial language based on English. In this language, they created two novel inflectional affixes to express possession, -*olp* and -*u*. The suffix -*olp* attached to a noun when the possessive pronominal determinative *his* was used (e.g., *his hotel**olp***), while the suffix -*u* was used in conjunction with the pronominal determinative *her* (e.g., *her hotel**u***). Crucially, these inflectional affixes differed in terms of perceptual salience, in that -*olp* is orthographically longer than -*u*. In a training phase, participants read sentences containing these forms and answered comprehension questions. This was immediately followed by a test phase in which participants read grammatical and ungrammatical sentences involving these novel inflections (e.g., *his hotel**olp**/*her hotel**olp***, *her hotel**u**/*his hotel**u***) while their eye movements were tracked. The study found that participants were more likely to fixate on the more perceptually salient inflectional morpheme -*olp* than the less salient -*u* and that words marked with this more salient form had longer first-pass reading times. Furthermore, when the test phase required participants to judge the grammaticality of each sentence, their reading times indicated that they were especially sensitive to ungrammaticality involving this more salient form. While ungrammatical nouns with this form (**her hotel**olp***) had longer total times and rereading times than their grammatical counterparts (*his hotel**olp***), there were no reading time differences between ungrammatical and grammatical nouns involving the less salient inflectional morpheme (i.e., **his hotel**u*** vs. *her hotel**u***). These findings were interpreted to indicate that perceptual salience modulates the extent to which grammatical

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morphemes are attended to during L2 reading as well as L2 learners' sensitivity to the information that these forms provide. The authors further note that differences in the salience of the forms that were tested in this study might have been enhanced by markedness considerations. In particular, they note that although the masculine category is the default in most languages and, as such, is often formally unmarked, the nouns associated with this category in this study were inflectionally marked, which might have made this morphology more noticeable to comprehenders. That is to say, while this study focused on the influence of perceptual salience—as defined by differences in orthographic length—on L2 comprehension processes, the researchers emphasize that the overall salience of a linguistic form is likely determined by a number of components (for further discussion, see Simoens et al., 2018, p. 125; see also DeKeyser et al., 2018; Goldschneider & DeKeyser, 2001).

In an eye-tracking study with (intermediate-level) L1 English learners of Italian, Behney and colleagues (2018) examined the processing of Italian sentences in which a time adjunct (e.g., *adesso,* "now"; *ieri*, "yesterday") matched or mismatched with the tense of the verb. The study focused on sentences in which the verb was marked either for present or past tense. In Italian, present tense is typically marked with bound inflectional morphology on the verb (e.g., *studi**a***, "She studies"), while past tense is usually marked with the combination of a free auxiliary verb and a verb in its past particle form (***ha*** *studi**ato**,* "She studied"). This past tense form was considered to be more perceptually salient than the present tense form because it is orthographically longer and involves both a free auxiliary verb as well as an inflected verb form. The study found that L2 comprehenders had longer first-pass reading times on the more salient past tense verb forms than on their less salient present tense counterparts. They also found longer total reading times for verbs of both types when they were incongruent with the time adjunct. However, this processing difficulty for incongruous sentences was more pronounced when they involved the more perceptually salient past tense form. Indeed, there were more regressive eye movements from the point of incongruity in sentences with past tense verbs compared to sentences with present tense verbs. These findings were interpreted to indicate that the more perceptually salient past tense marking made it easier for learners to attend to the information provided by this form during online L2 sentence processing.

In light of these findings, it is important to consider precisely how the perceptual salience of grammatical morphemes influences structural processing. As one step toward accomplishing this goal, it is necessary to determine the extent of this influence. On the one hand, it could be the case that perceptual salience is a factor that affects morphosyntactic processing in developing language users, but has relatively little, if any, influence on adult L1 sentence processing. Under this conception, perceptual salience primarily affects the speed at which certain grammatical morphemes are acquired and the sensitivity to the information provided by these forms during the acquisition process. However, this factor has relatively little influence on the processing of these morphemes once they have been fully acquired. Suggestions along these lines come from studies of L2 acquisition and processing. For instance, as mentioned above, DeKeyser and colleagues (2018) found that salience had a greater influence on the L2 acquisition of Hebrew grammatical morphology for learners at later ages of acquisition. These age-related

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effects were taken to indicate that salience primarily affects explicit L2 learning processes, which are arguably more important for older learners (for discussion, see DeKeyser et al., 2018). If it is the case that the influence of perceptual salience is largely limited to such learning processes, this factor should have relatively little effect on adult L1 sentence processing.

Alternatively, it could be the case that the perceptual salience of grammatical morphemes has a more pervasive influence, affecting syntactic processing even in adult L1 language users. Although no current L1 sentence processing model posits a central role for perceptual salience in particular, effects of this factor would seem to be compatible with rational probabilistic models of sentence comprehension under which comprehenders maintain uncertainty about the input and use subsequent information to resolve this uncertainty (see e.g., Levy et al., 2009). Under such a model, the perceptual salience of grammatical morphemes could be seen as a factor that modulates this uncertainty. Such effects would also seem to be consistent with "good enough" models of sentence comprehension (see e.g., Ferreira & Patson, 2007). Under such models, the salience of grammatical morphemes might influence the extent to which these forms (and the information they encode) are integrated into developing sentence representations. (See the *Discussion* section for more on perceptual salience in relation to these models.)

Partial support for the idea that the perceptual salience of grammatical morphemes affects structural processing generally comes from studies investigating grammaticality judgments by adult L1 speakers during auditory comprehension tasks in which they are exposed to various stressors (see e.g., Blackwell & Bates, 1995; McDonald, 2006). Interestingly, these stressors appear to affect grammaticality judgments differentially depending on the constructions that are targeted in the test sentences. For instance, McDonald (2006) found that although adult English native speakers' identification of word-order violations (e.g., **The teacher the tests graded.*) was largely unaffected by stressors related to memory load, input quality, or task/input speed, their judgment accuracy on sentences requiring regular past tense marking (e.g., **Last night my friend walk home after dark.*) was reduced under all of these stressor conditions (for comparable results, see Blackwell & Bates, 1995; Dick et al., 2001; Kilborn, 1991). In fact, of all of the structures tested in this study, many of which called for the use of specific grammatical morphemes, regular past was found to be the most vulnerable to these stressor conditions. Although this pattern of results was attributed primarily to the different processing demands for these structures, another possibility is that the selective deficit for regular past tense marking relates to the fact that it involves past *-ed*, a grammatical morpheme that is considered relatively low in terms of its perceptual salience (see e.g., Goldschneider & DeKeyser, 2001). Under this interpretation, these findings suggest that the influence of perceptual salience extends to morphosyntactic processing in adult L1 speakers, at least as it is reflected by grammaticality judgments during auditory sentence comprehension.

There is also evidence to suggest that perceptual salience influences the online processing of grammatical violations in adult L1 speakers. For example, in an event-related potential (ERP) experiment, Dube and colleagues (2016) investigated adult L1 English speakers' processing of subject-verb agreement violations during an auditory sentence comprehension task. The test sentences involved the presence/absence of third-person singular *-s* when the verb occurred either utterance medially (*The boys often cook/*cooks on the stove.*) or utterance finally (*The boys often cook/*cooks.*). Although violations at both positions elicited an anterior negativity and a P600 effect, those that occurred in utterance-final position produced a more robust and broadly distributed P600. These disparities were attributed primarily to differences in the perceptual salience of the violation depending on its utterance position. That is, with reference to L1 acquisition research showing that young children are more sensitive to agreement violations when they occur in utterance-final position compared to when they occur in less salient utterance-medial positions (Sundara et al., 2011; see above), these results were interpreted to indicate that adult L1 comprehenders' processing of grammatical violations is similarly influenced by the perceptual salience of relevant grammatical morphology. (One of our reviewers pointed out, however, that the larger P600 effects for grammatical violations in utterance-final conditions could also be due to sentence wrap-up effects.)

The question of interest in the present study is whether the influence of perceptual salience on adult L1 sentence processing extends beyond the detection of grammatical violations. This study takes up this issue by examining whether the perceptual salience of grammatical morphemes influences structural processing biases during adult L1 sentence comprehension. This is important because such an examination can indicate the (possible) influence of this factor on structural processing operations involved in sentence comprehension more generally—not just on the processes involved in identifying syntactic violations. The sentences of interest draw on a preference for attaching verb modifiers—and time adjuncts in particular—to the most recent verb phrase (VP) during online comprehension. Specifically, the present study examines sentences with ambiguous time adjuncts as in (1):

(1) Kim tested the program that she updated last week.

In this sentence, it is possible to attach the adjunct *last week* to the most recent verb, in the relative clause, to express when Kim updated the program (i.e., *[Kim [tested [the program [that she updated [last week]]]]]*). But it is also possible to link this modifier with the main clause verb to express when she tested this program (i.e., *[Kim [tested [the program [that she updated]] [last week]]]*). In this way, the time adjunct is in an ambiguous structural position. However, in such sentences, there appears to be a bias to attach this modifier to the most recent verb, or in other words, to attach it to the lower clause. This low-attachment bias has been taken as evidence for a general parsing principle under which incoming lexical items are preferentially attached to the current/most recent focus of processing (see e.g., Late Closure: Carreiras & Clifton, 1993; Frazier & Rayner, 1982; Recency Preference: Gibson et al., 1996; Right Association: Kimball, 1973). Indeed, the preference for local attachment of such VP modifiers provides compelling evidence for such a principle, in that it appears to apply consistently across languages—and even to languages that differ in terms of their attachment biases related to noun-phrase modifiers, such as relative clauses (for discussion, Gibson et al., 1996).

Empirical support for this bias during online sentence processing comes from a number of studies investigating the comprehension of sentences involving temporarily ambiguous time adjuncts (Altmann et al., 1998; Boyce et al., 2020;

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Hatfield, 2016; van Gompel et al., 2005; Witzel et al., 2012; Witzel et al., 2012). These studies have shown clear processing difficulty for sentences in which this adjunct cannot attach to the lower VP, but instead must attach to the higher clause, as in (2):

(2) Kim tested the program that she will update last week.

Taken together, these studies indicate that processing difficulty for high attachment in such sentences is obtained across different dialects of English (American, British, and New Zealand) and across a range of online reading methodologies, including eye tracking (Altmann et al., 1998; van Gompel et al., 2005; Witzel et al., 2012), standard moving-window self-paced reading (Boyce et al., 2020; Witzel et al., 2012), multiple versions of maze task self-paced reading (Boyce et al., 2020; Witzel et al., 2012), and self-guided reading (Hatfield, 2016). It is important to note, however, that this low-attachment bias can be modulated by other factors, at least to some extent. For instance, Altmann and colleagues (1998) showed that processing difficulty for high attachment in sentences like (2) can be eliminated or overridden when they are presented in contexts that explicitly direct readers' attention to the predicate in the higher clause.

The present study builds on these findings to examine whether this processing difficulty for high attachment is modulated by the grammatical morphemes used to indicate time in the higher and lower clauses. Specifically, this study examined the processing of sentences as in (3) in an online reading task:

(3a) Kim tested the program that she will update next week to make sure it works well.
(3b) Kim tested the program that she will update last week to make sure it works well.
(3c) Kim will test the program that she updated last week to make sure it works well.
(3d) Kim will test the program that she updated next week to make sure it works well.

In sentences (3a) and (3b), time reference in the higher clause is indicated by the bound inflectional morpheme *-ed*, while in the lower clause, it is indicated by the modal auxiliary *will*. The opposite is true in sentences (3c) and (3d). In these sentences, time in the higher clause is indicated by the auxiliary *will*, while in the lower clause, it is indicated by past *-ed*. These differences are important in light of disparities between these morphemes in terms of their perceptual salience. Past *-ed* and *will* are of course comparable in that both are part of the English system of marking tense, aspect, and mood with verbs, which is done both inflectionally with bound affixes and analytically with auxiliary verbs. However, there are a number of dimensions on which the auxiliary *will* might be considered more salient than past *-ed*. In the context of this reading study, it is perhaps most appropriate to focus on the differences between these morphemes in terms of their orthographic form. Specifically, following the ways in which relative salience was defined in the L2 reading studies reviewed above (Behney et al., 2018; Simoens et al., 2018), the auxiliary *will* can be considered more salient than past *-ed* by virtue of the fact (i) that *will* is a free morpheme whereas

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past *-ed* is a bound verbal affix and (ii) that *will* is orthographically longer than *-ed* (four letters vs. 1–2 letters; see the *Discussion* section for consideration of other dimensions of perceptual salience on which these forms differ). These sentences thus allow for a test of whether this difference in perceptual salience affects the processing difficulty associated with high attachment of the temporarily ambiguous time adjunct (*next week/last week*).

The specific predictions for these sentence types are as follows: In line with previous findings, there should be clear processing difficulty when the time adjunct mismatches with the lower clause and must attach to the higher clause—i.e., when this adjunct is consistent only with high attachment. With reference to the example sentence set, this means that there should be indications of processing difficulty at and after the time adjunct (*last week/next week*) in sentences like (3b)/(3d) when compared to their counterparts (3a)/(3c), in which the time adjunct allows for low attachment. If this processing difficulty is influenced by the perceptual salience of the grammatical morphemes that indicate time in these clauses, it is predicted that this difficulty will be larger in cases where time in the lower clause is marked with *will*. This is because the auxiliary *will* is arguably more perceptually salient than past *-ed*. That is, just as previous studies have indicated more processing difficulty for grammatical violations involving relatively more salient forms (see above), it is predicted that high-attachment costs will be larger in cases where the mismatching grammatical morpheme in the preferred attachment site is the more salient auxiliary *will*. In statistical terms, the prediction is that there will be an interaction indicating more processing difficulty for high attachment at and after the time adjunct (*last week/next week*) when time is marked with *will* in the lower clause compared to when it is marked with past *-ed*. With reference to the example item set, such an interaction would indicate more processing difficulty for high-attachment sentences like (3b) relative to their low-attachment counterparts as in (3a) than for high-attachment sentences like (3d) relative to their low-attachment counterparts as in (3c). If, however, the perceptual salience of grammatical morphology is a factor that largely only influences language acquirers, the processing cost for high attachment should be unaffected by the different forms used to indicate time in these clauses. Again, in statistical terms, this would be supported by a clear effect indicating processing difficulty for the high attachment at and after the time adjunct (*last week/next week*) that is not modulated by the morphology of the lower clause. With reference to the example item set, such findings would indicate that the processing difficulty for high-attachment sentences like (3b) relative to their low-attachment counterparts as in (3a) is comparable to the processing difficulty for high-attachment sentences like (3d) relative to their low-attachment counterparts as in (3c).

The processing of these sentences was investigated using bidirectional self-paced reading (Paape & Vashishth, 2021a, 2021b). In this task—as in standard, moving-window self-paced reading (see e.g., Just et al., 1982)—participants read through each sentence one word at a time. However, in the bidirectional version of this task, the participant can return to earlier parts of the text. This aspect of the task allows it to more closely approximate normal reading than standard self-paced reading tasks (Paape & Vashishth, 2021b). It also allows for both first-pass and regressive reading times on regions of interest and thus for measures of initial processing difficulty as well as of later/global processing difficulty in these regions. In this way, this method has the potential to provide a more sensitive index of processing costs incurred during real-time sentence processing than is possible under standard self-paced reading as well as information related to the time-course of these costs. For the purposes of the present experiment, it is also important to note that this method has been shown to reliably detect online processing difficulty during the comprehension of a range of sentence types, including those involving temporary structural ambiguity (Paape & Vashishth, 2021a, 2021b).

Method

Participants

Forty-nine (49) undergraduate students at the University of Texas at Arlington (38 female, 11 male; age: $M = 19.41$, $SD = 2.58$) participated in the experiment for course credit. All participants indicated that they had normal or corrected-to-normal vision. They also reported that English was their dominant language and that they had started learning this language in early childhood (at or before the age of 5).

Materials

Forty-eight (48) item sets as in (3) were created. The basic structure of these items was consistent with that of items used in previous investigations into sentences involving temporarily ambiguous time adjuncts (Altmann et al., 1998; Boyce et al., 2020; Hatfield, 2016; van Gompel et al, 2005; Witzel et al., 2012). Each item began with a common first name as the main clause subject. This was followed either by the auxiliary *will* and a verb (*will*+verb), indicating future time, or by a verb marked with past *-ed*, indicating past time. The object of this verb was then modified by an object-extracted relative clause. The time of this relative clause contrasted with that of the main clause: For items with *will*+verb in the main clause, the relative clause had a past *-ed* verb; for items with a past *-ed* verb in the main clause, the relative clause had *will*+verb. The relative clause verb was followed by a time adjunct that matched with the lower relative clause or with the higher main clause. Each item set used one of the following time adjunct pairs: *tomorrow/yesterday*, *next week/last week*, *next month/last month*. These pairs were selected in order to match the adjunct as closely as possible in terms of length (*tomorrow*: 1 word, 8 letters/ *yesterday*: 1 word, 9 letters; *next week*: 2 words, 8 letters/*last week*: 2 words, 8 letters; *next month*: 2 words, 9 letters/*last month*: 2 words, 9 letters) and SUBTLEXUS log word frequency (Brysbaert & New, 2009; *tomorrow*: 4.23/*yesterday*: 3.69; *next*: 4.36, *week*: 4.09/*last*: 4.57, *week*: 4.09; *next*: 4.36, month: 3.69/*last*: 4.57, *month*: 3.69) across conditions for each item. The items thus conformed to a 2x2 design in which the morphology indicating time in the lower clause (future *will*, past *-ed*) and its match with the time adjunct (matching, mismatching) were manipulated. The time adjunct was then followed by a non-finite clause that could plausibly attach to either the lower clause or higher clause. This was confirmed in a judgment experiment, in which adult L1 English participants ($N = 32$) rated sentences that paired the non-finite clause with each possible form of the verb in each item (e.g., *Kim tested/will test/will update/updated the program to make sure it works well.*). This was done

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using a 7-point plausibility scale, with 7 being highly plausible and 1 being highly implausible. All four sentence versions received consistently high ratings on this plausibility scale (*Kim tested* [$M = 6.46$; $SD = 0.50$]/*will test* [$M = 6.46$; $SD = 0.51$]/*will update* [$M = 6.41$; $SD = 0.59$]/*updated* [$M = 6.43$; $SD = 0.60$] *the program to make sure it works well.*). The experimental items were organized into four counterbalanced lists according to a Latin square design. (See the Appendix for the complete list of experimental items. All materials and code for this project can be accessed on the following Open Science Framework site: https://osf.io/kze79/) Forty-eight (48) length-matched filler sentences were also included in these lists. In order to match some of the relevant structural properties of the experimental items, each filler began with a common name and included morphological marking for future and/or past time (with *will* and past *-ed*, respectively), a modifying (e.g., adverb, prepositional) phrase expressing time, and a non-finite clause (e.g., *Jenny will make a campfire next to the tent this evening to help everyone keep warm.*). Each item was followed by a yes/no comprehension question, with an equal number of correct "yes" and "no" answers. These questions targeted different portions of the experimental and filler items, and none explicitly asked about the timing of the events described (e.g., for the example item set, *Will/Did Kim uninstall the program?*). This was done in order to avoid drawing participants' attention to the temporarily ambiguous structures of interest in the experiment.

Procedure

The experiment began with a brief questionnaire run through QuestionPro, in which participants indicated their age, sex, the state of their vision, and their language learning background. Participants were then routed to a site that provided directions for the reading task and a link to this task. The experimental list referenced by this link changed at random so that participants were randomly assigned to the counterbalanced lists. The reading task was run using the web-based implementation of the DMDX software package, version 6.0.0.6 (Forster & Forster, 2003; Witzel et al., 2013). As discussed above, the experiment used a bidirectional self-paced reading task. Each trial began with a line of dashes on the computer screen in place of the words in the sentence. The first word was displayed when the participant pressed the right ctrl key. The participant then advanced through the rest of the sentence using the right ctrl key. That is, each time the right ctrl key was pressed, the next word in the sentence was displayed and the previous word was masked. At any point in the sentence, the participant could return to earlier words using the left ctrl key. The participant could also return directly to the first word of the sentence by pressing the spacebar or advance directly to the comprehension question by pressing the enter key. Each sentence was followed by a yes/no comprehension question, which the participant answered by pressing the right ctrl (yes) and left ctrl (no) keys. After answering this question, the participant received feedback (*CORRECT*/*<<WRONG>>*), and the next trial began automatically. Sentences and their accompanying questions were presented on a single line in the center of the computer screen. Participants were instructed to read at their natural reading speed, but carefully enough to provide correct answers to the comprehension questions. The task began with eight practice items. Experimental and filler items were then presented in a unique random order for each participant, with a short break after each set of 16 items.

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Results

Analysis procedures

The data from participants with accuracy rates of less than 80% on the comprehension questions were eliminated from the analyses. Based on this criterion, the data from five participants were excluded. For the remaining 44 participants, the mean accuracy rate on the complete set of comprehension questions was 93.02% ($SD = 4.05$). For the experimental items, the mean accuracy rate was 91.50% ($SD = 5.58$). The data for trials in which any single reading time was longer than 5000 ms were also eliminated from the analyses (2.27% of the trials).

Reading times on the lower clause verb, the critical region of the time adjunct, and an immediately following two-word spillover region were analyzed. These regions are bolded and delineated with vertical bars in (4):

(4) Kim (tested/will test) the program that she (will) | **(update/updated)** | **(next week/last week)** | **to make** | sure it works well.

For each of these regions, first pass time, regression path time, and total time were analyzed. First pass time is the sum of the reading times in a region after entering that region until leaving it in any direction. Regression path time is the sum of all reading times after entering a region until leaving that region to the right. This measure includes regressive reading times on previous regions. Finally, total time is the sum of all reading times in a region. These three measures were included in order to provide indications of processing time differences on the initial pass through the test sentences (first pass time and regression path time) as well as later/global processing differences (total time) on these items. These measures also correspond with those used in previous eye-tracking examinations into comparable sentence types (Altmann et al., 1998; van Gompel et al, 2005; Witzel et al., 2012) and thus allow for clear comparisons with the findings of those studies. With regard to the analysis regions, the lower clause verb (*update/updated*) was included to assess effects related to verb form differences on the initial pass through the test sentences (i.e., under first pass time and regression path time). The total time measure on this verb, which included regressive reading times on this word after the time adjunct was encountered, was also used as an index of processing difficulty for high-attachment sentences. The time adjunct (*last week/next week*) is the critical region for the effects of high attachment in these sentences—the effects of primary interest in this study. Finally, the spillover region (*to make*) was included in light of the fact that processing time differences in self-paced reading and eye tracking are often observed on regions/words after those that are hypothesized to give rise to processing difficulty. Indeed, such spillover effects have been observed in previous reading studies investigating processing difficulty for high attachment in similar sentence types (Altmann et al., 1998; Boyce et al., 2020; Witzel et al., 2012).

The reading times in these regions were analyzed with mixed-effects regression models using the lme4 package (Bates et al., 2015) in R (version 4.2.2; R Development Core Team, 2022). In these models, lower clause (LC) morphology (verb-*ed*, *will*+verb) and time adjunct match (matching, mismatching) were sum-coded fixed effects (with conditions coded as -0.5 and 0.5 for each factor). The

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models included the maximal random effects structure whenever possible (Barr et al., 2013). In the one case in which the maximal model failed to converge (total time in the lower clause verb region), the random effects structure was simplified by removing the random slope for the interaction that was associated with the smaller variance (see Table 2 and the online supplementary materials for detailed model specifications). The p-values for these models were estimated using the Satterthwaite approximation implemented in the lmerTest package (Kuznetsova et al., 2017). The raw reading times for each measure in each region were log-transformed prior to analysis in order that the residuals of the statistical models would approximate a normal distribution. Estimated marginal means and standard errors for the log-transformed reading times were calculated based on the mixed-effects model reported for each measure/region using the emmeans package (Lenth, 2020). This package was also used to conduct relevant pairwise comparisons. For these pairwise comparisons, the p-values were again based on the Satterthwaite approximation.

Analysis results

Table 1 presents the estimated marginal means and standard errors for the log-transformed reading times for each measure in each region. Table 2 presents the results of the mixed-effects regression analyses of these data. These analyses revealed two key findings: First, consistent with previous research, there was clear processing difficulty for sentences in which the time adjunct mismatched with the lower clause—i.e., when this adjunct was consistent only with high attachment. Crucially also, this processing difficulty for high attachment was larger in sentences in which time in the lower clause was marked with the auxiliary *will* (i.e., in sentences like (3b) compared to sentences like (3a)) than in sentences in which time in this clause was marked with past *-ed* (i.e., in sentences like (3d) compared to sentences like (3c)). The details related to the findings in each of the regions of interest are provided below.

In the lower clause verb region (*update*/*updated*), there were no reliable effects under first pass time or regression path time, indicating comparable reading times among the sentence conditions immediately prior to the critical region of the time adjunct. Under these measures, there was a numerical trend suggesting that sentences with verb-*ed* (*updated*) were read more slowly than sentences with the bare form of the verb following the modal *will* (*update*), but this difference was not statistically significant. A different pattern of results was found under the total time measure—which again takes into consideration all of the reading times in the region, including regressions from subsequent regions. Under this measure, there was a reliable effect of adjunct match, indicating longer reading times for sentences in which the adjunct mismatched the time indicated in the lower clause (e.g., ... *will update last week* .... / ... *updated next week* ....) than for their matching counterparts (e.g., ... *will update next week* .... / ... *updated last week* ....). That is, under this total time measure—and only under this measure—there was a clear effect at the lower clause verb indicating processing difficulty for sentences in which the time adjunct required high attachment.

At the region of the time adjunct (*next week*/*last week*), the results indicated that this processing difficulty for high attachment was modulated by the morphology in the lower clause. Under first pass time, there was a reliable interaction of LC

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Table 1. Estimated marginal means and standard errors (in parentheses) for the log-transformed reading times for each measure in each analysis region, by sentence condition. Millisecond equivalents for the estimated marginal means are provided in brackets

	Region		
	Lower clause verb	Time adjunct	Spillover
	. . . update/updated	*next week/last week*	*to make . . . .*
First pass time			
will+verb/matching	5.49 (.05) [242]	6.05 (.06) [424]	6.24 (.04) [513]
will+verb/mismatching	5.50 (.04) [245]	6.10 (.07) [446]	6.40 (.05) [602]
verb-*ed*/matching	5.53 (.04) [252]	6.10 (.06) [446]	6.28 (.04) [534]
verb-*ed*/mismatching	5.52 (.04) [250]	6.07 (.07) [433]	6.29 (.04) [539]
Regression path time			
will+verb/matching	5.52 (.05) [250]	6.09 (.07) [441]	6.27 (.04) [528]
will+verb/mismatching	5.51 (.04) [247]	6.16 (.07) [473]	6.47 (.06) [645]
verb-*ed*/matching	5.54 (.05) [255]	6.11 (.06) [450]	6.29 (.04) [539]
verb-*ed*/mismatching	5.54 (.04) [255]	6.10 (.07) [446]	6.33 (.04) [561]
Total time			
will+verb/matching	5.63 (.05) [279]	6.16 (.07) [473]	6.34 (.05) [567]
will+verb/mismatching	5.71 (.06) [302]	6.30 (.08) [545]	6.56 (.06) [706]
verb-*ed*/matching	5.61 (.05) [273]	6.18 (.06) [483]	6.35 (.04) [572]
verb-*ed*/mismatching	5.66 (.05) [287]	6.18 (.07) [483]	6.40 (.05) [602]

Note: Kim (tested/will test) the program that she (will) (update/updated) (next week/last week) to make sure it works well.

morphology and adjunct match. This effect reflects the fact that although there were longer reading times for high attachment in sentences with *will*+verb in the lower clause, there were shorter reading times for high attachment in sentences with verb-*ed* in this clause. This interaction should be interpreted with caution, however, in light of the fact the simple effect of adjunct match was not reliable for either of these sentence types (*will*+verb/match vs. *will*+verb/mismatch: $\beta = 0.05$, $SE = 0.03$, $t = 1.68$, $p = 0.102$; verb-*ed*/match vs. verb-*ed*/mismatch: $\beta = -0.03$, $SE = 0.03$, $t = -1.19$, $p = 0.235$). For the total time measure in this region, there was a reliable effect of adjunct match that was qualified by a significant interaction of LC morphology and adjunct match. This pattern of results reflects that fact that there was clear processing difficulty when the adjunct mismatched the time expressed in the lower clause, but only for sentences with *will*+verb in this clause (*will*+verb/match vs. *will*+verb/mismatch: $\beta = 0.14$, $SE = 0.04$, $t = 3.65$, $p < .001$; verb-*ed*/match vs. verb-*ed*/mismatch: $\beta = 0.00$, $SE = 0.03$, $t = 0.10$, $p = 0.919$).

A similar pattern of results was obtained across measures in the spillover region (*to make*). Under all three reading time measures, there were reliable main effects of LC morphology and adjunct match as well as a significant interaction of these factors. This

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Table 2. Mixed-effects regression estimates for the fixed effects of lower clause morphology, adjunct match, and their interaction on the log-transformed reading times for each measure in each analysis region

	Region											
	Lower clause verb				Time adjunct				Spillover			
	. . . update/updated				*next week/last week*				*to make . . . .*			
	β	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
First pass time												
Intercept	5.51	0.04	134.79	<.001	6.08	0.06	97.96	<.001	6.30	0.04	161.92	<.001
Lower clause (LC) morphology	−0.03	0.02	−1.71	0.096	−0.01	0.02	−0.52	0.608	**0.04**	**0.02**	**2.10**	**0.040**
Adjunct match	0.00	0.02	0.12	0.906	0.01	0.02	0.54	0.594	**0.09**	**0.02**	**4.80**	**<.001**
LC morphology × Adjunct match	0.02	0.03	0.59	0.558	**0.09**	**0.04**	**2.04**	**0.046**	**0.14**	**0.03**	**4.08**	**<.001**
Regression path time												
Intercept	5.53	0.04	133.90	<.001	6.12	0.06	94.95	<.001	6.34	0.04	158.74	<.001
LC morphology	−0.03	0.02	−1.46	0.148	0.02	0.02	0.70	0.486	**0.06**	**0.03**	**2.32**	**0.024**
Adjunct match	0.00	0.02	−0.15	0.881	0.03	0.03	1.11	0.273	**0.12**	**0.02**	**4.88**	**<.001**
LC morphology × Adjunct match	−0.01	0.04	−0.37	0.717	0.09	0.06	1.68	0.099	**0.17**	**0.05**	**3.63**	**<.001**
Total time†												
Intercept	5.65	0.05	120.63	<.001	6.20	0.07	91.65	<.001	6.41	0.04	147.39	<.001
LC morphology	0.03	0.02	1.24	0.222	0.05	0.02	1.88	0.065	**0.08**	**0.02**	**3.18**	**0.002**
Adjunct match	**0.06**	**0.03**	**2.38**	**0.021**	**0.07**	**0.03**	**2.75**	**0.008**	**0.14**	**0.02**	**5.62**	**<.001**
LC morphology × Adjunct match	0.03	0.05	0.67	0.502	**0.14**	**0.05**	**2.71**	**0.009**	**0.17**	**0.04**	**3.93**	**<.001**

Note: Kim (tested/will test) the program that she (will) (update/updated) (next week/last week) to make sure it works well.
†The statistical model for total time in the lower clause verb region was coded as follows: lmer (dv ~ LC morphology * adjunct match + (1 + LC morphology * adjunct match | subj) + (1 + LC morphology + adjunct match | item); for all other regions/measures, the statistical model was coded as follows: lmer (dv ~ LC morphology * adjunct match + (1 + LC morphology * adjunct match | subj) + (1 + LC morphology * adjunct match | item).

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pattern of results reflects the fact that there was more processing difficulty for high attachment in sentences with *will*+verb in the lower clause than in sentences with past-*ed* in this clause. Indeed, there were longer reading times across measures when the time adjunct mismatched the future time indicated by *will*+verb in the lower clause (first pass time—*will*+verb/match vs. *will*+verb/mismatch: $\beta = 0.16$, $SE = 0.03$, $t = 5.79$, $p < .001$; regression path time—*will*+verb/match vs. *will*+verb/mismatch: $\beta = 0.20$, $SE = 0.04$, $t = 5.30$, $p < .001$; total time—*will*+verb/match vs. *will*+verb/mismatch: $\beta = 0.22$, $SE = 0.04$, $t = 6.10$, $p < .001$). However, this adjunct match effect was not statistically reliable under any measure for sentences with verb-*ed* in the lower clause (first pass time—verb-*ed*/match vs. verb-*ed*/mismatch: $\beta = 0.02$, $SE = 0.02$, $t = 0.78$, $p = 0.438$; regression path time—verb-*ed*/match vs. verb-*ed*/mismatch: $\beta = 0.03$, $SE = 0.03$, $t = 1.23$, $p = 0.222$; total time—verb-*ed*/match vs. verb-*ed*/mismatch: $\beta = 0.05$, $SE = 0.03$, $t = 1.75$, $p = 0.082$).[1]

Discussion

This study examines whether the perceptual salience of grammatical morphemes affects the online processing of temporarily ambiguous sentences during adult L1 comprehension. This was done by investigating the comprehension of sentences with time adjuncts that were in a structural position in which they could attach either to the most recent VP or to a VP in a higher clause. Consistent with previous findings (Altmann et al., 1998; Boyce et al., 2020; Hatfield, 2016; van Gompel et al., 2005; Witzel et al., 2012), the reading times on these sentences indicated processing difficulty when the time adjunct mismatched with the most recent/lower VP, but matched with the higher VP. That is, there were clear processing costs when this adjunct allowed only for high attachment. Crucially, this effect was modulated by the perceptual salience of the grammatical morphemes used to indicate time reference in these clauses. Specifically, these high-attachment costs were larger when time in the lower clause was indicated by the more salient auxiliary *will* compared to when it was indicated by the relatively less salient past *-ed* morpheme. These findings therefore indicate that the influence of perceptual salience extends beyond the acquisition of and sensitivity to grammatical morphemes during L1 and L2 development (see the review of this literature above). Rather, the perceptual salience of these forms also affects online structural processing biases during adult L1 comprehension.

Before considering the implications of this study in more detail, it is necessary to address several issues that might obscure the interpretation of its findings. One of these issues relates to the items that were tested in the experiment. As detailed above, processing difficulty related to high attachment was assessed by comparing reading times at and after time adjuncts that matched or mismatched with the time expressed in the lower clause. As in previous studies examining attachment biases in such sentences (Altmann et al., 1998; Boyce et al., 2020; Hatfield, 2016; van Gompel et al., 2005; Witzel et al., 2012), this required comparing sentences with different time adjuncts. In this study, the time adjunct pairs *tomorrow*/*yesterday*, *next week*/*last week*, and *next month*/*last month* were used. However, as one of our reviewers pointed out, these comparisons could be problematic, especially if there were particular

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processing difficulty for the past time adjuncts in these pairs. The suggestion was that if past time adjuncts were generally more difficult to process, this might (i) exacerbate the processing difficulty for high attachment when there was a mismatch between this adjunct and future time in the lower clause (e.g., *... will update last week ....*) and (ii) cancel out the processing advantage when there was a match between this adjunct and past time in the lower clause (e.g., *... updated last week ....*). As noted in the discussion of the experimental materials, in order to limit the influence of extraneous factors on this comparison, the adjunct pairs in each item set were matched for length and frequency. And in light of these matching procedures, there is no reason to suspect that there would be a larger processing cost for the past time adjuncts in two of the three adjunct pairs that were tested in this study: *next week*/*last week* and *next month*/*last month*. These adjuncts are perfectly matched for length and, to the extent that there is any word frequency difference between them, it is slightly higher for each past time adjunct compared with its future time counterpart. This is not the case, however, for *yesterday*/*tomorrow*. In this pair, length and word frequency differences could give rise to a processing disadvantage for the past time adjunct—*yesterday* is one letter longer and has a slightly lower frequency of occurrence than *tomorrow*.

A relevant question then is whether the critical interactions observed in this study were driven by items that used the *yesterday*/*tomorrow* adjunct pair. This question was addressed in a set of post hoc analyses in which these items—which constituted 16 of the 48 experimental items (or exactly four per condition in each experimental list)—were eliminated. These analyses were conducted using the same procedures as in the main analyses reported above. (On the accompanying OSF site for this study, see Supplementary Table S1 for descriptive statistics and Supplementary Table S2 for the results of the mixed-effects regression models.) At the critical region of the time adjunct, there was a reliable effect of adjunct match under the total time measure, indicating longer reading times for sentences in which the adjunct mismatched with the time indicated in the lower clause (e.g., *... will update last week ..../... updated next week ....*) than for their matching counterparts (e.g., *... will update next week ..../... updated last week ....*). This effect was not qualified by a reliable interaction of LC morphology and adjunct match. In the immediately following spillover region, however, there was a significant effect of adjunct match as well as a reliable interaction of LC morphology and adjunct match under all three reading time measures. This pattern of results reflects the fact that there were larger effects of adjunct match in sentences with *will*+verb in the lower clause. Indeed, there were longer reading times across measures when the time adjunct mismatched the future time indicated by *will*+verb in the lower clause (first pass time—*will*+verb/match vs. *will*+verb/mismatch: $\beta = 0.15$, $SE = 0.03$, $t = 5.35$, $p < .001$; regression path time—*will*+verb/match vs. *will*+verb/mismatch: $\beta = 0.17$, $SE = 0.03$, $t = 5.01$, $p < .001$; total time—will+verb/match vs. will+verb/mismatch: $\beta = 0.22$, $SE = 0.04$, $t = 5.14$, $p < .001$). However, this adjunct match effect was statistically reliable only under the total time measure for sentences with verb-*ed* in the lower clause (first pass time—verb-ed/mismatch vs. verb-ed/match: $\beta = 0.05$, $SE = 0.03$, $t = 1.80$, $p = 0.073$; regression path time—verb-*ed*/mismatch vs. verb-*ed*/match: $\beta = 0.07$, $SE = 0.04$, $t = 1.91$, $p = 0.062$; total time—verb-*ed*/mismatch vs. verb-*ed*/match: $\beta = 0.09$, $SE = 0.03$, $t = 2.61$, $p = 0.011$). These post hoc analyses thus clearly indicate that the crucial interactions observed in this study were not driven by the sentences that contained the adjunct pair *yesterday/tomorrow*. Even after removing these items from the analyses, there were larger high-attachment processing costs when time in the lower clause was indicated by the auxiliary *will* compared to when it was indicated by past *-ed*.

Another issue with respect to the items in this study relates to the switch in time reference in these sentences. As detailed above, items with past time in the main clause had future time in the lower clause (*Kim tested the program that she will update* . . . .), while items with future time in the main clause had past time in the lower clause (*Kim will test the program that she updated* . . . .). The results reported above revealed larger processing costs for high attachment in the former sentence type than in the latter, which was attributed to differences in the relative salience of the forms used to indicate time reference in these sentences. However, one of our reviewers suggested that these differences in high-attachment costs might relate to differences in the acceptability of these sentences. In order to investigate this possibility, a rating experiment was conducted on the experimental sentences up to the time adjunct. Specifically, adult L1 English participants ($N = 41$) rated sentences with *will*+verb in the lower clause—e.g., *Kim tested the program that she will update*—and sentences with verb-*ed* in the lower clause—e.g., *Kim will test the program that she updated*—on a 7-point acceptability scale, with 7 being completely acceptable and 1 being completely unacceptable. This experiment revealed slightly lower ratings for sentences with *will*+verb in the lower clause ($M = 5.33$, $SD = 0.84$) than for sentences with verb-*ed* in this clause ($M = 5.96$, $SD = 0.72$). A relevant question is whether this difference accounts for the larger high-attachment costs in sentences with *will*+verb in the lower clause.

In order to test this, we first conducted post hoc comparisons for all three reading time measures in each of the analysis regions for versions of these sentences that allowed for low attachment; that is, between *will*+verb/match sentences and verb-*ed*/match sentences. Since these items do not involve processing costs for high attachment, they should provide a clear indication of processing difficulty related specifically to differences in acceptability between these sentences. These analyses did not reveal a clear processing cost for sentences with *will*+verb in the lower clause. In fact, *will*+verb/match sentences had numerically longer reading times compared with verb-*ed*/match sentences only under the total time measure at the lower clause verb (279 ms vs. 273 ms; *n.s.*). Under all other measures in the analysis regions, there were numerically shorter reading times for *will*+verb/match sentences than for *verb*-ed/match sentences. (This difference was statistically reliable for first pass time in the adjunct region, *will*+verb/match: 424 ms vs. *verb*-ed/match: 446 ms, $p = 0.045$).

Another possibility is that processing difficulty for sentences with future time in the lower clause reveals itself only in conjunction with high-attachment processing difficulty. In order to test this, the rating difference between sentences with *will*+ verb in the lower clause and sentences with *verb*-ed in the lower clause was calculated for each item set. This rating difference was then used as a (scaled, centered) covariate in the analysis of all three reading measures, in each analysis region. The idea was that if differences in the high-attachment costs for sentences with *will*+verb in the lower clause and sentences with verb-*ed* in the lower clause were due to acceptability differences between these sentence types, these costs

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should be greater for items in which there were larger rating differences. This, however, was not the case. There were no reliable main effects or interactions involving this rating difference factor under any measure, in any of the three regions. Furthermore, the inclusion of this factor had very little influence on the pattern of results reported in the main analyses. As in the original analyses, there were robust interactions indicating larger high-attachment costs for sentences with *will*+verb in the lower clause under the total time measure at the time adjunct and across reading time measures in the spillover region. (See the OSF site for the study for the details of these analyses.)

Another issue relates to the participants that were tested in the experiment. The question of interest in this study was whether the perceptual salience of relevant grammatical morphemes influences online attachment biases in adult L1 English comprehenders. In order to examine this issue, we tested young adult participants (i) who began learning English at or before the age of five and (ii) who identified English as their dominant language. However, a reviewer pointed out that these criteria might not have been sufficient to screen out L2 English comprehenders. This is important because it raises the possibility that the findings of the present study do not accurately reflect adult L1 sentence processing. This possibility was therefore addressed in a set of post hoc analyses in which more stringent inclusion criteria were applied. Specifically, the participants in these analyses ($N = 30$) indicated (i) that they began learning English no later than age three, (ii) that they had not started learning any other language(s) before they started learning English, and (iii) that they did not know any other language(s) as well as they knew English (i.e., that they were only English-dominant). These analyses were again conducted using the same procedures as in the main analyses reported above. (On the accompanying OSF site for this study, see Supplementary Table S3 for descriptive statistics and Supplementary Table S4 for the results of the mixed-effects regression models.) These analyses revealed exactly the same pattern of results at and after the critical time adjunct as in main analyses. At the time adjunct (*last week*/*next week*) as well as in the immediately following spillover region (*to make*), there was a reliable interaction of LC morphology and adjunct match under all three reading time measures. Again, this pattern of results reflects the fact that there were more robust effects of adjunct match in sentences with *will*+verb in the lower clause. That is, there were longer reading times across measures when the time adjunct mismatched the future time indicated by *will*+verb in the lower clause. This was the case both in the time adjunct region (first pass time—will+verb/match vs. will+verb/mismatch: $\beta = 0.08$, $SE = 0.04$, $t = 2.16$, $p = 0.038$; regression path time—will+verb/match vs. will+verb/mismatch: $\beta = 0.13$, $SE = 0.05$, $t = 2.41$, $p = 0.023$; total time—will+verb/match vs. will+verb/mismatch: $\beta = 0.14$, $SE = 0.04$, $t = 3.58$, $p < .001$) as well as in the spillover region (first pass time—will+verb/match vs. will+verb/mismatch: $\beta = 0.17$, $SE = 0.03$, $t = 5.11$, $p < .001$; regression path time—will+verb/match vs. will+verb/mismatch: $\beta = 0.21$, $SE = 0.04$, $t = 4.90$, $p < .001$; total time—will+verb/match vs. will+verb/mismatch: $\beta = 0.22$, $SE = 0.04$, $t = 5.58$, $p < .001$). However, this adjunct match effect was not statistically reliable under any measure in either of these regions for sentences with verb-*ed* in the lower clause (all p's > 0.200). These post hoc analyses thus clearly indicate that the crucial interactions observed in this study were not driven by a subset of

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participants who indicated that they were balanced bilinguals and/or that they had started learning some other language(s) before they started learning English. Even after removing such participants from the analyses, high-attachment processing difficulty was greater when time in the lower clause was indicated by the more salient auxiliary *will* compared to when it was indicated by a less salient past *-ed* morpheme.

These results are of general empirical interest in that they add to findings indicating that online parsing biases can be influenced by a range of factors. Indeed, a number of studies have shown that attachment biases related to noun-phrase modifiers—and relative clauses in particular—can be influenced by, among other factors, the length, frequency, and animacy of potential attachment sites (for discussion and review, see e.g., Fraga et al., 2012). It is important to emphasize, however, that the present study investigated attachment biases for time adjuncts, a VP modifier, and few studies have investigated possible mediating factors with respect to the low-attachment bias that applies to these constituents. Although Altmann and colleagues (1998) have shown that this low-attachment bias can be modulated in certain discourse contexts, the present study provides the first indication that this bias can also be influenced by the relative salience of the morphology used to indicate time reference in potential attachment sites.

An important question then is exactly how the perceptual salience of these grammatical morphemes influences structural processing in these sentences. Although the present findings do not dictate the precise mechanism that gave rise to the observed effects, they suggest several possibilities that might be investigated with further research. One possible source of these effects relates to the detection of a mismatch. That is, it could be the case that the mismatch between the lower clause and the time adjunct is clearer to the comprehender when time reference in this clause is indicated with the more salient auxiliary *will*. One way to explain this process is in terms of a rational probabilistic model of sentence comprehension wherein comprehenders maintain uncertainty about the input and use subsequent information to resolve this uncertainty (see e.g., Levy et al., 2009). Under such a model, the perceptual salience of grammatical morphemes could be a factor that modulates this uncertainty, in that it influences the probability distribution associated with different structural analyses of the input—a distribution that includes analyses that correspond exactly to the input (i.e., veridical analyses) as well as perceptually similar variants that deviate from the input (i.e., non-veridical analyses). In the sentences of interest in the present study, this would mean that when the more perceptually salient auxiliary *will* occurs in the lower clause, it allows for little uncertainty about the structure of this clause as it relates to time reference. In other words, this auxiliary would establish the veridical future time analysis of the lower clause as highly probable, and crucially, much more likely than any non-veridical analyses in which the lower clause was marked for something other than future time. When this relatively stable representation is found to be incompatible with a subsequent time adjunct, clear processing costs are incurred. However, when the less perceptually salient past *-ed* occurs in the lower clause, the comprehender might maintain more uncertainty about time reference in this clause. For instance, since past *-ed* verb forms are neighbors (or near neighbors) to forms that allow for non-past interpretations (compare e.g., *updated* and *updates*), such non-veridical analyses might remain reasonably likely alternatives. In this case, a subsequent time adjunct that is incompatible with the (veridical) past time analysis of the lower clause (. . . *updated next week* . . .) but compatible with a (non-veridical) non-past analysis (e.g., . . . *updates next week* . . .) might give rise to smaller indexations of processing difficulty.

This process could also be explained in terms of "good enough" sentence processing models (see e.g., Ferreira & Patson, 2007). According to such models, the language comprehension system does not always create detailed syntactic and semantic representations of the input. Rather, it generates representations that are just "good enough" for the comprehender to perform relevant tasks. In constructing such representations, the system applies fast-acting heuristics over a few words at a time to construct locally coherent interpretations. In such a model, it is possible that the relative salience of time reference morphemes modulates the depth and detail of time reference specification in these representations. That is, assuming a "good enough" language comprehension system that prioritizes shallow heuristics for the interpretation of the input, time reference might often be underspecified unless it is clearly indicated by salient grammatical morphology (or other lexical/phrasal time reference markers). For the sentences tested in the present study, this would mean that the more salient *will* might contribute to a more detailed specification of time reference in the developing sentence representation than the less salient past *-ed* morpheme. Larger processing costs might then be incurred when a subsequent time adjunct conflicts with this more complete specification.

Another possibility is that perceptual salience influences reanalysis processes in these sentences. Under this view, once a mismatch is detected between the lower clause and the time adjunct, it might be easier for the comprehender to reanalyze the adjunct when time reference in its high-attachment site is indicated by a more salient form. In the present study, it is not clear how often participants successfully revised their initial analysis of sentences that called for high attachment. In order to determine this, it would have been necessary to probe participants' interpretation of the time adjunct with respect to the predicates in the higher and lower clauses—for instance, through comprehension questions that targeted this information. However, as noted in the *Methods* section, such questions were not used in this study in order to avoid drawing participants' attention to the structures of interest. Having said that, it is reasonable to suppose that on at least some of the high-attachment sentences in this experiment, participants attempted reanalysis. And in these cases, reanalysis might have been facilitated when time reference in the high-attachment site was indicated with the more salient form *will*.

This possibility raises interesting questions about the dimensions of perceptual salience that are relevant to these effects. In the context of this online reading experiment, perceptual salience was determined largely in terms of orthographic form characteristics: The auxiliary *will* was considered more perceptually salient than past *-ed* (i) because *will* is a free morpheme, whereas past *-ed* is a bound verbal affix, and (ii) because *will* is orthographically longer than past *-ed*. However, these forms also differ on a number of other dimensions that relate to perceptual salience. For example, (i) *will* consists of more phones than *-ed*; (ii) *will* is more sonorous than *-ed*; (iii) *will* is syllabic—i.e., it constitutes a single syllable—whereas *-ed* is often not; and (iv) *will* is morphophonologically regular whereas *-ed* exhibits

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allomorphic variation. Initially, these aspects of perceptual salience were not considered directly applicable in this reading experiment. However, it is important to reassess the possible influence of these factors in light of the idea that the perceptual salience of grammatical morphology might influence reanalysis processes. It has been proposed that one of the ways that phonological information contributes to skilled reading is that it provides the basis for a serial word-order representation of the sentence that can be consulted if reanalysis is necessary (for discussion, see e.g., Price et al., 2015). With this idea in mind, (morpho) phonological aspects of perceptual salience might indeed be relevant to online structural processing during reading. Specifically, elements that are more perceptually salient on these dimensions might allow for clearer serial word-order representations, which might in turn contribute to facilitated reanalysis processes.

It is important to note that the mechanisms sketched above are not mutually exclusive. It could be the case that in the sentences of interest in this study, the perceptual salience of the relevant grammatical morphemes affects both (i) the detection of a mismatch when the time adjunct is initially attached to the lower clause and (ii) the processes necessary to revise this misanalysis. More research is necessary in order to unpack the influence of perceptual salience on these processes during the online processing of different sentence types. As indicated above, research of this type might be particularly important to the development of sentence comprehension models that posit a key role for rational probabilistic inference or for "good enough" representations during online sentence comprehension. Such research will also contribute to a more complete understanding of how perceptual salience influences memory representations that are used during reanalysis processes.

This research should also investigate different aspects of perceptual salience and their effects on structural processing. As noted above, there are a number of ways in which a given linguistic element might be considered more perceptually salient than others. Moreover, the relative importance of these dimensions might differ depending on the stage of structural processing—e.g., when an initial structural analysis is assigned to the input and during subsequent reanalysis processes. Further research across a range of languages is necessary in order to determine the relative contribution of the various dimensions of perceptual salience at different stages of sentence comprehension.

Such investigations might also consider more abstract components of salience. Following previous investigations into the possible influence of perceptual salience on structural processing, the present study focused on the physical properties that might make one linguistic form more noticeable than another. However, it is also important to note that the grammatical morphemes of interest in this study convey different information—past *-ed* indicates past time, while the auxiliary verb *will* indicates future time—and it is possible that this difference contributed to the observed pattern of results. One way to think about how this difference might influence the processing of these morphemes is to consider the different ways in which time reference is encoded. Indeed, while there is no reason to believe that future time is inherently more salient than past time, it is possible that time reference is differentially noticeable to the comprehender depending on grammatical systems that are used to convey this information. In the case of past *-ed*, time reference is indicated through inflectional tense morphology. However, the auxiliary *will* indicates time reference through a different system. Although *will* is traditionally considered to be a future tense marker, it is perhaps better analyzed as an epistemic modal expressing prediction (for discussion, see Huddleston & Pullum, 2002). In light of this difference, it could be the case that time reference is less noticeable when it is expressed relatively directly through (inflectional) tense marking compared to when it is expressed relatively indirectly through grammatical morphemes indicating mood. While investigating this possibility is beyond the scope of the current study, this issue might be taken up in further research with languages that have three-term tense systems distinguishing past, present, and future (e.g., Spanish, Irish, etc.).

The present findings also have important theoretical implications with respect to the connections between L1 and L2 processing. As discussed above, studies have shown that L2 comprehenders are differentially sensitive to the information provided by grammatical morphemes depending on the perceptual salience of these forms (see e.g., Behney et al., 2018; Simoens et al., 2018). The present study indicates that these effects also apply to adult L1 sentence comprehension. In this way, these findings can be interpreted to indicate that fundamentally similar processing procedures are engaged during L1 and L2 sentence comprehension. More specifically, these findings are consistent with the idea that L1 and L2 comprehenders draw on available information sources—including structural frequency (e.g., Dussias & Scaltz, 2008), plausibility (e.g., Lee & Witzel, 2022), and markedness (e.g., Alemán Bañón et al., 2021)—in similar ways during online sentence processing. With regard to this issue, it is important to acknowledge that comparisons of L1 and L2 sentence comprehension typically examine whether factors that are relevant to L1 processing also apply in an L2. The present study, however, investigated whether a factor that has been identified as important in L2 processing (and during L1 acquisition) similarly influences L1 sentence comprehension. In this way, this study underscores the importance of L2 sentence processing findings in the development of models of sentence comprehension generally—and even for models that are primarily concerned with native-language processing characteristics. These results also have interesting implications for how we understand the role of perceptual salience in L2 development. For instance, as mentioned above, DeKeyser and colleagues (2018) have argued that salience might primarily affect explicit L2 learning processes. However, the results of the present study—which again indicate that perceptual salience influences online parsing biases during adult L1 sentence comprehension—suggest that while this factor might be important to explicit L2 learning, its influence is certainly not limited to that domain.

Finally, this study also has a number of methodological implications. Again, in light of the fact that adult L1 comprehenders demonstrated clear effects of perceptual salience during structural processing, it is important that future L2 studies examining the influence of this factor include L1 comparison groups. It may well be the case that L2 comprehenders show larger effects of perceptual salience, but it is unlikely that they are uniquely influenced by this factor. With regard to sentence comprehension research more generally, it is important to reiterate that

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the bidirectional self-paced reading task used in this study is relatively new to the field. It is interesting to note therefore that the processing difficulty for the high attachment that was shown in this study is comparable to effects that have been found for similar sentence types in eye tracking (Altmann et al., 1998; van Gompel et al., 2005; Witzel et al., 2012), standard moving-window self-paced reading (Boyce et al., 2020; Witzel et al., 2012), multiple versions of maze task self-paced reading (Boyce et al., 2020; Witzel et al., 2012), and self-guided reading (Hatfield, 2016). These findings thus provide additional evidence in support of the validity of this task for investigating online sentence processing. This study also underscores a number of benefits of this task over other online reading methods. In comparison with standard self-paced reading and maze task self-paced reading, the advantage of bidirectional self-paced reading is that it allows for regressive reading times and thus for measures of first-pass processing difficulty as well as of later/global processing costs. For example, in the present study, processing difficulty for high attachment was shown at the lower clause verb under the total time measure, but not under first pass time or regression path time. This pattern of results was clearly due to readers spending more time in this region with regressive reading times. In other self-paced reading tasks, it would be impossible to observe an effect of this type. In comparison with eye tracking, it is also important to note that bidirectional self-paced reading does not require any specialized equipment. This task can therefore be deployed through web-based testing formats, as was the case in this study. This is an especially useful feature when in-person access to relevant participant populations is not feasible. This is also important in terms of "democratizing" psycholinguistic research in general and sentence processing research in particular. That is, while this task allows for many of the same benefits of eye tracking, it can be deployed by anyone with access to a computer to anyone with similar access. This is clearly desirable to the extent that we, as a field, would like to examine sentence comprehension in a wider variety of language communities and engage more scholars in this endeavor.

Replication package. All materials and code for this project can be accessed on the following Open Science Framework site: https://osf.io/kze79/.

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Competing interests. The authors declare none.

Note

1 At the request of one of our reviewers, analyses of right-bounded reading time, or the sum of the reading times in a region after entering that region until leaving it to the right, and first-pass regression proportion were also conducted in the time adjunct region and in the spillover region. At the time adjunct, there were no reliable effects under these measures. In the spillover region, under right-bounded reading time, there were reliable main effects of LC morphology ($p = 0.031$) and adjunct match ($p < .001$) as well as a significant interaction of these factors ($p < .001$). This interaction reflected a larger mismatch effect for sentences with *will*+verb in the lower clause. As was the case with all of the other measures in this region,

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right-bounded reading times were reliably longer when the time adjunct mismatched with *will*+verb in the lower clause (*will*+verb/match vs. *will*+verb/mismatch: $p < .001$), but not when it mismatched with verb-*ed* in this clause (verb-*ed*/match vs. verb-*ed*/mismatch: $p = 0.245$). A comparable pattern of results was found for the first-pass regression proportion. Under this measure, there were reliable main effects of LC morphology ($p = 0.045$) and adjunct match ($p = 0.030$). Although the interaction of these factors was not significant ($p = 0.553$), pairwise comparisons indicated a reliably higher proportion of first-pass regressions when the time adjunct mismatched with *will*+verb in the lower clause (*will*+verb/match vs. *will*+verb/mismatch: $p = 0.024$), but not when it mismatched with verb-*ed* in this clause (verb-*ed*/match vs. verb-*ed*/mismatch: $p = 0.111$). See the analysis code on the OSF site for this study for further details related to these analyses.

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Appendix. Experimental items

(1a) John complimented the worker that he will promote tomorrow to give him encouragement.
(1b) John complimented the worker that he will promote yesterday to give him encouragement.
(1c) John will compliment the worker that he promoted yesterday to give him encouragement.
(1d) John will compliment the worker that he promoted tomorrow to give him encouragement.
(2a) Mary emailed the applicant that she will call tomorrow to discuss the new position.
(2b) Mary emailed the applicant that she will call yesterday to discuss the new position.
(2c) Mary will email the applicant that she called yesterday to discuss the new position.
(2d) Mary will email the applicant that she called tomorrow to discuss the new position.
(3a) David moved the flower that he will water tomorrow to help it bloom nicely.
(3b) David moved the flower that he will water yesterday to help it bloom nicely.
(3c) David will move the flower that he watered yesterday to help it bloom nicely.
(3d) David will move the flower that he watered tomorrow to help it bloom nicely.
(4a) Linda dusted the furniture that she will polish tomorrow to get ready for the party.
(4b) Linda dusted the furniture that she will polish yesterday to get ready for the party.
(4c) Linda will dust the furniture that she polished yesterday to get ready for the party.
(4d) Linda will dust the furniture that she polished tomorrow to get ready for the party.
(5a) Susan described the proposal that she will mention next week to get her boss's opinion.
(5b) Susan described the proposal that she will mention last week to get her boss's opinion.
(5c) Susan will describe the proposal that she mentioned last week to get her boss's opinion.
(5d) Susan will describe the proposal that she mentioned next week to get her boss's opinion.
(6a) Joseph attempted the recipe that he will share next week to show off his country's food.
(6b) Joseph attempted the recipe that he will share last week to show off his country's food.
(6c) Joseph will attempt the recipe that he shared last week to show off his country's food.
(6d) Joseph will attempt the recipe that he shared next week to show off his country's food.
(7a) Kim tested the program that she will update next week to make sure it works well.
(7b) Kim tested the program that she will update last week to make sure it works well.
(7c) Kim will test the program that she updated last week to make sure it works well.
(7d) Kim will test the program that she updated next week to make sure it works well.
(8a) Cindy reanalyzed the data that she will check next week to confirm her findings.
(8b) Cindy reanalyzed the data that she will check last week to confirm her findings.
(8c) Cindy will reanalyze the data that she checked last week to confirm her findings.
(8d) Cindy will reanalyze the data that she checked next week to confirm her findings.
(9a) Dan sailed the boat that he will repair next month to prepare for the race.
(9b) Dan sailed the boat that he will repair last month to prepare for the race.
(9c) Dan will sail the boat that he repaired last month to prepare for the race.
(9d) Dan will sail the boat that he repaired next month to prepare for the race.
(10a) Kevin renovated the house that he will paint next month to make it look modern.
(10b) Kevin renovated the house that he will paint last month to make it look modern.
(10c) Kevin will renovate the house that he painted last month to make it look modern.
(10d) Kevin will renovate the house that he painted next month to make it look modern.
(11a) Karen redesigned the flyer that she will post next month to attract more customers.
(11b) Karen redesigned the flyer that she will post last month to attract more customers.
(11c) Karen will redesign the flyer that she posted last month to attract more customers.
(11d) Karen will redesign the flyer that she posted next month to attract more customers.
(12a) Matt published the paper that he will discuss next month to share his new ideas.
(12b) Matt published the paper that he will discuss last month to share his new ideas.
(12c) Matt will publish the paper that he discussed last month to share his new ideas.
(12d) Matt will publish the paper that he discussed next month to share his new ideas.
(13a) Nancy watered the lawn that she will mow tomorrow to please her parents.
(13b) Nancy watered the lawn that she will mow yesterday to please her parents.
(13c) Nancy will water the lawn that she mowed yesterday to please her parents.
(13d) Nancy will water the lawn that she mowed tomorrow to please her parents.
(14a) Mark tuned the guitar that he will play tomorrow to help the young musicians.

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(14b) Mark tuned the guitar that he will play yesterday to help the young musicians.
(14c) Mark will tune the guitar that he played yesterday to help the young musicians.
(14d) Mark will tune the guitar that he played tomorrow to help the young musicians.
(15a) Bill reported the worker that he will scold tomorrow to punish him for the mistake.
(15b) Bill reported the worker that he will scold yesterday to punish him for the mistake.
(15c) Bill will report the worker that he scolded yesterday to punish him for the mistake.
(15d) Bill will report the worker that he scolded tomorrow to punish him for the mistake.
(16a) Paul examined the computer that he will fix tomorrow to get ready to resell it.
(16b) Paul examined the computer that he will fix yesterday to get ready to resell it.
(16c) Paul will examine the computer that he fixed yesterday to get ready to resell it.
(16d) Paul will examine the computer that he fixed tomorrow to get ready to resell it.
(17a) Daniel installed the bookcase that he will paint next week to satisfy the customer.
(17b) Daniel installed the bookcase that he will paint last week to satisfy the customer.
(17c) Daniel will install the bookcase that he painted last week to satisfy the customer.
(17d) Daniel will install the bookcase that he painted next week to satisfy the customer.
(18a) Chris organized the articles that he will print next week to distribute them to the class.
(18b) Chris organized the articles that he will print last week to distribute them to the class.
(18c) Chris will organize the articles that he printed last week to distribute them to the class.
(18d) Chris will organize the articles that he printed next week to distribute them to the class.
(19a) Jenny announced the project that she will start next week to please her boss.
(19b) Jenny announced the project that she will start last week to please her boss.
(19c) Jenny will announce the project that she started last week to please her boss.
(19d) Jenny will announce the project that she started next week to please her boss.
(20a) Beth polished the vase that she will display next week to impress her guests.
(20b) Beth polished the vase that she will display last week to impress her guests.
(20c) Beth will polish the vase that she displayed last week to impress her guests.
(20d) Beth will polish the vase that she displayed next week to impress her guests.
(21a) Andy printed the lecture that he will deliver next month to prepare for the conference.
(21b) Andy printed the lecture that he will deliver last month to prepare for the conference.
(21c) Andy will print the lecture that he delivered last month to prepare for the conference.
(21d) Andy will print the lecture that he delivered next month to prepare for the conference.
(22a) Ken edited the report that he will translate next month to prepare it for publication.
(22b) Ken edited the report that he will translate last month to prepare it for publication.
(22c) Ken will edit the report that he translated last month to prepare it for publication.
(22d) Ken will edit the report that he translated next month to prepare it for publication.
(23a) Emma called the man that she will hire next month to have him join the new project.
(23b) Emma called the man that she will hire last month to have him join the new project.
(23c) Emma will call the man that she hired last month to have him join the new project.
(23d) Emma will call the man that she hired next month to have him join the new project.
(24a) Laura photographed the mountain that she will hike next month to impress her friends.
(24b) Laura photographed the mountain that she will hike last month to impress her friends.
(24c) Laura will photograph the mountain that she hiked last month to impress her friends.
(24d) Laura will photograph the mountain that she hiked next month to impress her friends.
(25a) Julie fixed the shirt that she will iron tomorrow to please the customer.
(25b) Julie fixed the shirt that she will iron yesterday to please the customer.
(25c) Julie will fix the shirt that she ironed yesterday to please the customer.
(25d) Julie will fix the shirt that she ironed tomorrow to please the customer.
(26a) Janet printed the card that she will decorate tomorrow to get ready to send it.
(26b) Janet printed the card that she will decorate yesterday to get ready to send it.
(26c) Janet will print the card that she decorated yesterday to get ready to send it.
(26d) Janet will print the card that she decorated tomorrow to get ready to send it.
(27a) Henry washed the horse that he will train tomorrow to prepare it for the show.
(27b) Henry washed the horse that he will train yesterday to prepare it for the show.
(27c) Henry will wash the horse that he trained yesterday to prepare it for the show.
(27d) Henry will wash the horse that he trained tomorrow to prepare it for the show.

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(28a) Robert called the secretary that he will email tomorrow to discuss their weekend plans.
(28b) Robert called the secretary that he will email yesterday to discuss their weekend plans.
(28c) Robert will call the secretary that he emailed yesterday to discuss their weekend plans.
(28d) Robert will call the secretary that he emailed tomorrow to discuss their weekend plans.
(29a) Lauren stained the cabinets that she will install next week to please her client.
(29b) Lauren stained the cabinets that she will install last week to please her client.
(29c) Lauren will stain the cabinets that she installed last week to please her client.
(29d) Lauren will stain the cabinets that she installed next week to please her client.
(30a) Diane reviewed the paper that she will edit next week to prepare it for submission.
(30b) Diane reviewed the paper that she will edit last week to prepare it for submission.
(30c) Diane will review the paper that she edited last week to prepare it for submission.
(30d) Diane will review the paper that she edited next week to prepare it for submission.
(31a) Lisa discussed the article that she will post next week to create interest in the topic.
(31b) Lisa discussed the article that she will post last week to create interest in the topic.
(31c) Lisa will discuss the article that she posted last week to create interest in the topic.
(31d) Lisa will discuss the article that she posted next week to create interest in the topic.
(32a) Sarah showed the video that she will share next week to make her friends laugh.
(32b) Sarah showed the video that she will share last week to make her friends laugh.
(32c) Sarah will show the video that she shared last week to make her friends laugh.
(32d) Sarah will show the video that she shared next week to make her friends laugh.
(33a) Steve checked the computer that he will update next month to make sure it works well.
(33b) Steve checked the computer that he will update last month to make sure it works well.
(33c) Steve will check the computer that he updated last month to make sure it works well.
(33d) Steve will check the computer that he updated next month to make sure it works well.
(34a) Kathy examined the evidence that she will reanalyze next month to make sure it is correct.
(34b) Kathy examined the evidence that she will reanalyze last month to make sure it is correct.
(34c) Kathy will examine the evidence that she reanalyzed last month to make sure it is correct.
(34d) Kathy will examine the evidence that she reanalyzed next month to make sure it is correct.
(35a) Amy contacted the factory that she will visit next month to discuss their labor problems.
(35b) Amy contacted the factory that she will visit last month to discuss their labor problems.
(35c) Amy will contact the factory that she visited last month to discuss their labor problems.
(35d) Amy will contact the factory that she visited next month to discuss their labor problems.
(36a) James painted the car that he will repair next month to increase its value.
(36b) James painted the car that he will repair last month to increase its value.
(36c) James will paint the car that he repaired last month to increase its value.
(36d) James will paint the car that he repaired next month to increase its value.
(37a) Emily translated the document that she will edit tomorrow to make it more accessible.
(37b) Emily translated the document that she will edit yesterday to make it more accessible.
(37c) Emily will translate the document that she edited yesterday to make it more accessible.
(37d) Emily will translate the document that she edited tomorrow to make it more accessible.
(38a) Mike watered the garden that he will fertilize tomorrow to keep the plants healthy.
(38b) Mike watered the garden that he will fertilize yesterday to keep the plants healthy.
(38c) Mike will water the garden that he fertilized yesterday to keep the plants healthy.
(38d) Mike will water the garden that he fertilized tomorrow to keep the plants healthy.
(39a) Jason milked the cows that he will wash tomorrow to finish his work early.
(39b) Jason milked the cows that he will wash yesterday to finish his work early.
(39c) Jason will milk the cows that he washed yesterday to finish his work early.
(39d) Jason will milk the cows that he washed tomorrow to finish his work early.
(40a) Tim consulted the programmer that he will text tomorrow to discuss the new website.
(40b) Tim consulted the programmer that he will text yesterday to discuss the new website.
(40c) Tim will consult the programmer that he texted yesterday to discuss the new website.
(40d) Tim will consult the programmer that he texted tomorrow to discuss the new website.
(41a) Ryan hired the woman that he will email next week to help with the project.
(41b) Ryan hired the woman that he will email last week to help with the project.
(41c) Ryan will hire the woman that he emailed last week to help with the project.

(41d) Ryan will hire the woman that he emailed next week to help with the project.
(42a) Kate confirmed the plans that she will announce next week to get her boss's approval.
(42b) Kate confirmed the plans that she will announce last week to get her boss's approval.
(42c) Kate will confirm the plans that she announced last week to get her boss's approval.
(42d) Kate will confirm the plans that she announced next week to get her boss's approval.
(43a) Cathy revised the report that she will print next week to prepare it for her supervisor.
(43b) Cathy revised the report that she will print last week to prepare it for her supervisor.
(43c) Cathy will revise the report that she printed last week to prepare it for her supervisor.
(43d) Cathy will revise the report that she printed next week to prepare it for her supervisor.
(44a) Maria decorated the room that she will clean next week to prepare for the celebration.
(44b) Maria decorated the room that she will clean last week to prepare for the celebration.
(44c) Maria will decorate the room that she cleaned last week to prepare for the celebration.
(44d) Maria will decorate the room that she cleaned next week to prepare for the celebration.
(45a) Tom trimmed the tree that he will move next month to make the garden prettier.
(45b) Tom trimmed the tree that he will move last month to make the garden prettier.
(45c) Tom will trim the tree that he moved last month to make the garden prettier.
(45d) Tom will trim the tree that he moved next month to make the garden prettier.
(46a) Jeff checked the cameras that he will install next month to improve the security system.
(46b) Jeff checked the cameras that he will install last month to improve the security system.
(46c) Jeff will check the cameras that he installed last month to improve the security system.
(46d) Jeff will check the cameras that he installed next month to improve the security system.
(47a) Olivia repainted the house that she will renovate next month to make it easier to sell.
(47b) Olivia repainted the house that she will renovate last month to make it easier to sell.
(47c) Olivia will repaint the house that she renovated last month to make it easier to sell.
(47d) Olivia will repaint the house that she renovated next month to make it easier to sell.
(48a) Jim visited the university that he will contact next month to discuss their hiring procedures.
(48b) Jim visited the university that he will contact last month to discuss their hiring procedures.
(48c) Jim will visit the university that he contacted last month to discuss their hiring procedures.
(48d) Jim will visit the university that he contacted next month to discuss their hiring procedures.

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