LANGUAGE AND COGNITIVE PROCESSES
2006, 21 (1/2/3), 322–354

Psychology Press
Taylor & Francis Group

Effects of age, animacy and activation order on sentence production

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The current study examines whether young and older adults have similar preferences for animate-subject and active sentences, and for using the order of activation of a verb's arguments to determine sentence structure. Ninety-six participants produced sentences in response to three-word stimuli that included a verb and two nouns differing in animacy. Dependent variables included accuracy, sentence structure produced, and production times for active vs. passive sentences. Neither group shows a strict preference for active sentences, but the two groups are differentially sensitive to animacy and the order of noun activation. Results suggest that sentence structure choice is a probabilistic, constraint-satisfaction process during which these factors interact.

INTRODUCTION

The current study examines three theoretical claims about the sentence production process from a lifespan perspective: (i) whether there is a universal, age-invariant preference for active sentences that affects sentence structure choice and speed of production; (ii) whether English speakers universally prefer animate-subject sentences; and (iii) whether the order of activation of the noun arguments of a verb determines sentence structure. Although most sentence production studies have only used young adult subjects, there are good reasons to suspect that the sentence production process in older adults might differ from that of young adults due to age-related limitations in processing speed, inhibitory ability, and processing resources like working memory (WM). For example, older

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http://www.tandf.co.uk/journals/pp/01690965.html DOI: 10.1080/0169096054400006

adults' responses in single word production studies are slower than those of young adults (Balota & Duchek, 1988; Bowles & Poon, 1985; Burke, MacKay, & James, 2000), and older adults use less complex syntax in spontaneous speech compared to young adults (e.g., Norman, Kemper, Kynette, Cheung, & Anagnopoulos, 1991; Kemper, Herman, & Lian, 2003a). Consequently, we might expect older adults to respond more slowly and use less complex syntax than young adults in a constrained sentence production task. On the other hand, older adults typically score better on vocabulary tasks than young adults do and have many more years of experience as language users. A few studies have found that older adults take advantage of this experience and develop strategies to allow their performance to be comparable to that of young adults (e.g., Kemtes & Kemper, 1997). In the following sections, we first discuss age-differences in speech production and current theories of cognitive ageing and how these might apply to these findings. Second, we discuss the sentence production process with special attention to functional level processing where sentence structure choices occur. Subsequently, we discuss three constraints on sentence production that have been postulated in the literature and describe how the current study allows these constraints to compete.

Age differences

The speech production of young and older adults varies in a number of quantifiable ways. Performance on word generation tasks, such as picture naming and naming to definition, is slower and less accurate with age (Wingfield & Stine-Morrow, 2000). In spontaneous speech, older adults also producer fewer complex constructions, such as centre-embedded relative clauses, compared with young adults, and this tendency correlates with WM capacity (for a review, see Kemper & Mitzner, 2001). Indeed, Burke, MacKay, and James (2000) argue that language production abilities are more vulnerable in ageing than language comprehension abilities. Due to the apparent preservation of comprehension abilities, many of these studies assume that linguistic processing per se is not impaired in older adults, but is restricted by the amount of information that can be activated, stored, and manipulated at one time due to general, age-related deficits in cognitive processing (Wingfield & Stine-Morrow, 2000). Therefore, we might expect speech production in older adults to be slower, less fluent and less complex than in young adults.

While language production abilities seem particularly vulnerable in ageing, constrained sentence production tasks may be even more taxing on older adults' speech, because speakers have no control over the content words that must be included in a sentence (Altmann, 2004; Altmann, Kempler, & Andersen, 2001). A recent paper by Kemper, Herman, and Lian, (2003b) suggests that constrained sentence production can present a serious challenge to older adults. In this study, young and older adults produce sentences that include one, two, or three pre-specified words. Older adults are impaired only when two or more words must be included in the sentence. Older adults also have difficulty using verbs that have more complex argument structures (e.g., verbs that require sentential complements as objects), but perform similarly to young adults when using verbs with simpler argument structures (e.g., that require nouns as objects). In the current study, we investigate the effects of other types of verb complexity on the sentence production of young and older adults, as well as age-related differences in the effects of animacy and the order of noun activation on sentence type produced.

All theories of cognitive ageing must account for the pervasive findings that older adults are slower and less accurate than young adults in nearly all cognitive domains, and that this age difference becomes exaggerated in more complex conditions (Perfect & Maylor, 2000). We will consider the predictions of three hypotheses of cognitive ageing: General slowing, inhibitory deficit, and reduced resources. The general slowing hypothesis attributes all decrements in older adults' performance to an overall slowing of cognitive computations (Salthouse, 1994, 2000). Thus, it predicts slower response times across the board for older adults relative to young adults. The inhibitory deficit hypothesis attributes age differences in performance to an inability to delete no longer relevant information from WM and to a subsequent over-reliance on overlearned ''default'' responses (Zacks, Hasher, & Li, 2000). Consequently, this theory predicts that in a sentence production task older adults will overuse ''default'' responses, such as simple active sentences, and will perform more poorly in conditions that prohibit the use of ''default'' responses. The reduced resources hypothesis accounts for age-related differences in performance by postulating that older adults have diminished processing resources, operationalised as working memory capacity, to carry out complex cognitive computations (Craik, 1986; Craik & Byrd, 1982). This theory suggests that age-differences will emerge only in more complex conditions, and that older adults may rely on environmental support, such as perceptual characteristics of the stimuli, to optimise their performance. In sum, the three theories of cognitive ageing make distinct predictions about older adults' performance on the current task.

Sentence production

The sentence production process, as detailed in Bock and Levelt (1994), begins with the activation of a message at the conceptual level of processing. The message is sent for grammatical encoding, first to the functional level, then the positional level of processing, before being sent for articulatory processing. The message-level representation includes information about ''who is doing what to whom'', therefore, participants in the event, often called ''arguments'', must be tagged with thematic roles indicating the part that is played by each argument (e.g., agent, recipient, theme). At the functional level of processing, message-level information about the event activates the best-fitting verb and noun lemmas.[1] Noun lemmas, which have access to their thematic roles at the message level, are then assigned to grammatical roles (e.g., nominative, dative, accusative). At the positional level of processing, these nouns tagged with grammatical roles are then assigned to the appropriate syntactic positions (e.g., the noun tagged ''nominative'' is assigned to the subject position, the noun tagged ''accusative'' is assigned the direct object position) in a hierarchical sentence representation that is built a constituent at a time. Crucially, a noun retains the same grammatical role (e.g., nominative) assigned at the functional level throughout the remainder of the sentence production process. Consequently, in this theory, passive sentences are not produced through movement of constituents but are generated by events that occur during functional-level processing.

Bock and Levelt (1994) describe the functional representation of a noun as including information about definiteness and number, which are realised at the positional level as specifications for a determiner and a plural affix as part of the noun phrase frame. However, they do not treat verb processes in the same detail. To expand on this process, functional information that must be included in the verb representation in order to guide positional-level structure building includes tense, aspect, number, and person information. Tense and aspect are likely to be represented at the message level as well as the functional level, because these are associated with differences in meaning (Bates & Wulfeck, 1989; Levelt, 1989). Number- and person-marking information for the verb, however, must be copied from the item marked for the nominative role at the functional level of processing and so cannot be determined until this role has been assigned. Similarly, the voice of the verb, active or passive, cannot be determined until the nominative case has been assigned to one of the verb's arguments. It is crucial that verb voice be encoded at the functional level so that the correct positional structure can be built.

For example, consider the sentences that can be constructed using the words: *butler*, *juice*, *poured*. The lemma of *poured* includes both a passive

[1] A lemma is the level of word representation at which syntactic information is encoded.

and an active argument structure, specifying which thematic role gets assigned to which grammatical role (e.g., active: V, nom-NP_{AGENT}, accu-NP_{THEME}; passive: V, nom-NP_{THEME}, by-NP_{AGENT}). Consequently, if the lemma for the agent, *butler*, is assigned the nominative role, the active argument structure of *poured* that specifies an agent in the nominative role is chosen, *juice* is assigned the accusative role, and positional-level processors build the structure for the sentence, ''The butler poured juice''. However, if *juice*, the theme, is assigned the nominative role, the passive argument structure of *poured*, which specifies a theme in the nominative role, is chosen. Subsequently, the passive argument structure assigns the remaining argument, the agent *butler*, to a by-phrase. Therefore, the building of the functional representation of a sentence is both sequential and interactive: The assignment of the nominative role to a noun lemma must precede the choice of sentence structure for the verb, and that sentence structure choice depends on the interaction of the thematic role of the noun lemma that has been assigned the nominative role with the verb's argument structure possibilities. Furthermore, assignment of grammatical roles other than the nominative requires the interaction of information about the thematic role of the noun in question, the argument structure chosen for the verb, and an awareness of the grammatical roles that have already been assigned.

Three constraints on sentence production

The assignment of the nominative role (that will later become the subject) to a noun argument depends on several factors. Functional processing procedures are strongly biased to assign the nominative role to animate noun phrases as shown by the strong preference for animate subjects in sentence production (Bock, 1986a; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992; Clark, 1966; Dewart, 1979; McDonald, Bock, & Kelly, 1993). Consequently, when speakers must describe a scene in which the agent of the action is inanimate and the theme is animate (e.g., a car hitting a man); they often produce a passive to ensure an animate-subject sentence (e.g., *The man was hit by a car*), rather than active sentence with an inanimate subject (e.g., *The car hit the man*) (Bock, 1986a; Bock & Loebell, 1990; Bock et al., 1992). This effect may be due to the conceptual prominence of the animate participant in the scene, which may lead to faster activation times (McDonald, et al., 1993). This propensity to use animate nouns as subjects will be referred to as the animate-subject constraint here.

Discourse information also plays a role in the assignment of a noun to the subject position (Bock & Irwin, 1980; Bock & Warren, 1985); old or given information occurs primarily in the subject position while new information typically is found post-verbally. This pattern may reflect another factor that has been posited to affect subject choice, the order of activation of the arguments of the verb (Bock & Levelt, 1994). In particular, it is posited that the noun that reaches activation first grabs the sentence subject position (Bock, 1986a), forcing the rest of the sentence to accommodate to this (as in the *juice* example above). Since old information is already active due to the previous discourses, it is likely more highly activated and more accessible to the speaker than a new element and, thus, more likely to assume the subject position. While the effects of pragmatics and animacy have been investigated, research has not addressed the power of the order of activation of the verb's arguments to determine sentence structure, especially when the first-activated noun is not animate. Thus, it is unknown whether activating inanimate nouns first will actually increase the number of inanimate-subject sentences produced or whether sentences produced with different verb types are differentially sensitive to the effects of order of activation. The current study makes a first attempt to address the existence of an order-of-activation constraint on sentence structure choice.

Speakers of English also strongly prefer active sentences over passives in spoken utterances, in which actives outnumber passive by about 99 to 1 (Bates & Devescovi, 1989). Much of the experimental research on sentence production has been aimed at overcoming the tendency to produce active sentences (Bock, 1986b, 1989; Bock Loebell, 1990; Bock et al., 1992; F. Ferreira, 1994; V. S. Ferreira, 1996); however, for the most part, attempts to elicit passive sentences using typical transitive verbs have achieved only moderate success. Indeed, active transitive sentences can be considered the default sentence form in English due to the very high frequency and low complexity of this construction. In fact, some researchers have suggested that speakers have a sort of template for active-sentence construction, which would permit or even encourage the relatively automatic production of active sentences without necessarily completing functional-level processing (Bates, Marchman, Harris, Wulfeck, & Kritchevsky, 1995; Ferreira, 1994). For example, in Bates et al. (1995) individuals with probable Alzheimer's disease produced active sentences regardless of pragmatic information that should have led to passive production, a phenomenon Bates et al. attribute to the use of an active-sentence template. This template would be expected to strongly bias sentence structure choice in favour of actives, regardless of the order of activation of the nouns for the sentence. Moreover, it would facilitate active sentence production so that active sentences were produced faster than passives. This study seeks to determine whether speakers use an active-sentence template when producing sentences with transitive verbs, and, if so, what types of verbs might take advantage of this active-sentence template.

The current study

In the current study, participants must produce a grammatical sentence that includes three orthographically presented stimulus words, a verb and two nouns differing in animacy. The stimuli have been designed to encourage the production of single clause, active and passive sentences and, in particular, to allow the three constraints discussed above to compete during the sentence construction process. One might argue that this type of sentence production task is far removed from spontaneous speech which typically begins with a message to encode, because the current task begins with printed words that must be included in a sentence and the speaker must create a message that includes these words. This is certainly a more artificial task than other experimental sentence production tasks such as picture description; however, the methodology does allow for experimental control of the lexical items to be used and, thereby, allows the examination of constraints inherent in these lexical items (e.g., the argument structures or morphological forms of verbs) that are difficult to address when speakers have control of their own word choice. Moreover, there are situations in which speakers are constrained in their word choice. For example, classroom situations and procedural discourse may often constrain word choice in similar ways to that found here. Therefore, although the current task is not as close to spontaneous speech as picture description, it does have overlapping demands with certain types of discourse and allows the examination of lexical constraints that otherwise would be much more difficult to address.

In addition to comparing the relative strengths of the three constraints discussed above, the current study also allows us to test a common assertion of linguistic theory: That passive sentences are more complex than actives (Chomsky, 1967, 1981) and, thus, should take longer to produce (Ferreira, 1994). Several studies addressed this issue in the early days of psycholinguistic research, but little evidence was found to support this hypothesis (for a review see Harley, 1995, Chapter 5). Nevertheless, the assumption continues to be resurrected (Ferreira, 1994). In contrast, the theory of sentence production described above suggests that this might not be so. According to Bock and Levelt (1994), the only differences in the production of these two sentence types are at the positional level, where processing proceeds quickly and automatically. Therefore, any differences found in accuracy of production, sentence structure choice, or processing time can likely be traced to differences in conceptual/semantic (as suggested in Bock, 1982) or functional-level processing, due either to the processing requirements of the stimuli (discussed below) or individual differences in the activation and retrieval of this information from semantic memory.

The baseline or control verb type used here consists of transitive verbs with an agent-theme argument structure and regular morphology (e.g., *stirred*, *knitted*, *grabbed*), a verb type that is exceedingly frequent in English. This verb type is predicted to be the easiest for speakers to use, and is expected to result in the fastest response times and highest accuracy rates regardless of age group. Moreover, we expect most responses to these CONTROL verbs to be active sentences, reflecting the relative frequency of actives and passives in the language.

In order to test the relative strength of the active-sentence constraint against the animate-subject constraint, the first experimental verb type consists of theme-experiencer (TE) verbs. TE verbs require an animate direct object in an active sentence, but put no constraints on the animacy of the subject. Thus, when producing sentences in the current study, participants must produce either an inanimate-subject active (e.g., *The book bored the student*) or an animate-subject passive sentence (e.g., *The student was bored by the book*). Ferreira (1994) demonstrates that participants consistently produce more passives with TE verbs than with ‘‘normal’’ verbs, and that this effect is exaggerated when the arguments of the verb differ in animacy; however, the proportion of passives produced in Ferreira's experiments is relatively low (i.e., a maximum of 31%). Ferreira postulates that the participants' responses reflect the operation of a default active-sentence template that applies to active sentences with either animate or inanimate subjects. She finds converging evidence for this conclusion in the fact that participants produced active sentences faster than passives in her experiments. However, only item analyses combined across verb types are reported, so any differential effects of verb type on the speed of active and passive production are lost. According to this hypothesis, when a message fits the template, the resulting sentence should be an active sentence that is produced very quickly. The current study tests Ferreira's hypothesis that a default active-sentence template applies to both CONTROL and TE verbs by comparing sentence production with these two verb types, examining accuracy, speed of production, the proportion of active and passive sentences produced, and the production times for active versus passive sentences.

The second experimental verb type tests whether the active-sentence constraint, or an active-sentence template, applies to all active sentences or only to simple active sentences with no auxiliary verbs. In this condition, participants produce sentences using the irregular past participle forms (e.g., *shaken*, *woven*, *stolen*) of agent-theme verbs from the same verb categories as the CONTROL verbs (according to Levin, 1993) paired with the same noun sets as CONTROL verbs are. One goal is to determine whether active perfectives (e.g., *The butler had shaken the juice*) are preferred over passives to the same degree as simple actives are preferred over passives. Using irregular past participles is expected to be difficult, because it requires a degree of metalinguistic awareness not necessary when using control verbs: The participants needs to recognise that either a perfective or passive sentence is appropriate with this verb type, but not a simple active sentence (e.g., **The butler shaken the juice*). Because of the additional metalinguistic processing required, irregular past participles put a heavier processing load on speakers and, therefore, the reduced resources hypothesis of cognitive ageing would predict that this condition would be particularly difficult for older adults or people with limited WM capacity (Altmann, 2004). Alternatively, preparing responses using this verb type requires the inhibition of the simple active response that can be used with all other verb types in this study. Therefore, the inhibitory deficit hypothesis of cognitive ageing also predicts that older adults will have disproportionate difficulties with this verb type. Irregular past participle use has not been addressed in the psycholinguistic literature with respect to either sentence production or comprehension; thus, the current study breaks new ground in this regard.

The current study also examines whether the active-sentence constraint or template applies equally to a verb type that does not assign the subject of an active sentence the role of agent, but still requires an animate subject: Experiencer-theme (ET) verbs (e.g., *adored*, *detested*). Experiencers differ from agents primarily in that experiencers must be entities that can experience the psychological state encoded by the verb; therefore, experiencers must be humans or, by extension, animals. In contrast, agents can also include vehicles (e.g., *The car hit the pedestrian*), natural phenomena (e.g., *The lightning struck the church*), or even inanimate nouns (e.g., *The alarm clock woke the boy*). Thus, the question addressed in this analysis is whether the active-sentence template specifies that the subject of the sentence must be an agent or just that it must be animate.

In order to test the strength of the animate-subject constraint against the order-of-activation constraint, the current study also pairs each verb with noun sets in which either an animate noun or an inanimate noun is in the prominent, top position (Clark & Chase, 1974). The animate-subject constraint would encourage speakers to produce all animate-subject sentences, regardless of which noun was activated first. In contrast, the order of activation constraint predicts that in inanimate-first conditions (when the inanimate noun is at the top of the stimulus set) a majority of inanimate-subject sentences will be produced but when an animate noun is prominent a majority of responses will have animate subjects. Alternatively, speakers may choose to reorder the nouns in the stimuli in order to produce the preferred, highly frequent animate-subject sentence, a process that may very well slow production times.

In the following analyses, we examine the effects of verb types, order of noun activation and age-group on accuracy, speed of production, choice of active or passive sentence structure, as well as the time to produce active versus passive sentences.

METHOD

Subjects

One hundred and ten subjects volunteered for this study and were compensated for their time. Of the 51 younger adults (YA), two were disqualified due to equipment malfunctions. Fifty-nine older adults (OA) were tested. Two were disqualified due to pre-existing medical problems and two due to equipment malfunction. In addition, each subject was required to produce at least three of the eight responses per condition fluently and grammatically while including all three words. This led to the exclusion of one additional young adult and seven additional older adults, leaving a total of 48 in each age group. Young adults ranged in age from 18 to 24 ($M_{YA} = 20.1$, $SD = 1.5$); older adults ranged in age from 64 to 84 ($M_{OA} = 75.9$, $SD = 5.7$).

In addition to the experimental tasks, all subjects completed the vocabulary test from the WAIS-R (Wechsler, 1981) and two working memory tasks: digit span (total forward and backward) (Wechsler, 1987) and digit ordering (MacDonald, Almor, Henderson, Kempler, & Andersen, 2001). Older adults had better vocabularies ($M_{OA} = 61.5$, $SD = 7.4$; $M_{YA} = 58.2$, $SD = 7.2$), $t(94) = 2.18$, $p < .04$, and higher education than younger adults ($M_{OA} = 15.7$, $SD = 3.3$; $M_{YA} = 14.4$, $SD = 1.3$), $t(94) = 2.57$, $p < .02$. However, they performed more poorly than young adults on WM tasks, i.e., digit span: $M_{OA} = 15.3$, $SD = 4.2$; $M_{YA} = 17.5$, $SD = 3.8$, $t(94) = -2.75$, $p < .01$; digit ordering: $M_{OA} = 16.6$, $SD = 3.8$; $M_{YA} = 19.4$, $SD = 2.9$, $t(94) = -3.96$, $p < .01$.

Procedure

Stimuli for the following experiments were presented by a computer running E-Prime (Schneider, Eschman, & Zuccolotto, 2001) that was equipped with a voice key to detect response times. In the experimental task, participants first saw a centred fixation star for 500 ms, followed by a stimulus set consisting of three words—a verb form and two nouns differing in animacy. For half of the participants, stimuli disappeared immediately when a response was begun; for the other half of the participants, stimuli remained visible throughout the response. In both cases, stimulus presentation was followed by a Ready screen (i.e., ''Ready? Push the blue button.''). The duration of stimulus presentation variable

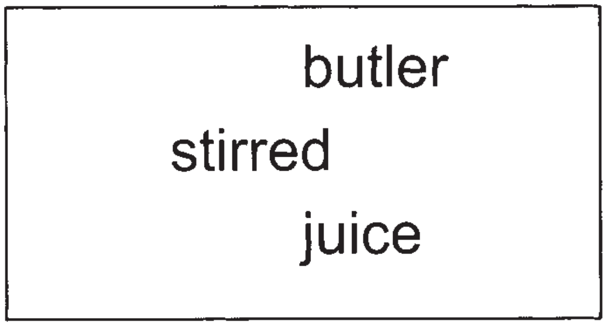

Figure 1. Sample of the stimuli. Nouns are justified to the centre of the screen; verbs were offset about an inch to the left.

had no effects on any of the analyses to follow, and so has been omitted from further consideration.[2] Responses were audio-taped and transcribed verbatim, including fillers, stutters, and pauses.

The stimuli appeared on a computer screen in 24 point Arial type arranged as shown in Figure 1. The verb was always offset to the left of the centre of the screen, with nouns positioned one line above and below the verb, left justified to the midline of the screen. Nouns either appeared with the animate noun at the top of the display (An) or the inanimate noun at the top (In). The rationale behind this arrangement was to allow the syntactic constraints associated with the verb to interact with the animacy of the noun at the top of the display, rather that presupposing a completely linear activation sequence. However, we did assume that, overall, participants would tend to fixate the top noun before the bottom noun (Clark & Chase, 1974), because English speakers tend to read or describe pictures from the top down.

Materials

This experiment used three-word stimuli that included a verb from one of the four types described below, paired with two nouns chosen to be relatively plausible arguments for it. Each noun set included an animate noun, typically referring to a career (e.g., *author*, *teacher*, *banker*) and an inanimate noun (e.g., *poem*, *bracelet*, *invitation*). The animate and inanimate nouns did not differ in mean frequency ($M_{AN} = 29.40$, $SD = 5.75$; $M_{IN} = 37.05$, $SD = 5.60$), $t(126) < 1$. The position of the nouns in the stimuli (see Figure 1) was counterbalanced between subjects. All verbs

[2] Participants also completed an off-line version of the task. However, accuracy and sentence structure choice did not differ with mode of presentation, so only on-line results are presented here.

appeared in their past participle form, In total, there were 64 stimuli, 16 examples of four verb types, which were presented in random order for each subject. The full set of stimuli is shown in the Appendix.

Baseline sentence production performance was gauged using 16 transitive verbs with regular past tense morphology (e.g., *stirred*, *parked*, *knitted*), referred to as CONTROL verbs throughout. These verbs require animate subjects in active sentences and assign the thematic roles agent and theme to their subjects and objects, respectively. Their mean frequency was 40.56 ($SD = 58.35$) per million (Francis & Kučera, 1982).

The first set of comparisons below contrasts sentence production using control verbs and 16 theme-experiencer (TE) verbs (e.g., *amused*, *surprised*, *thrilled*). TE verbs assign the thematic roles theme and experiencer to their subjects and objects, respectively (Levin, 1993). Consequently, these verbs require animate objects in active sentences (e.g., *The poem amused the author*). The mean frequency of TE verbs was 25.56 ($SD = 19.65$) per million (Francis & Kučera, 1982). CONTROL and TE verbs did not differ in frequency, $t(30) < 1.00$.

The second set of comparisons contrasts sentence production using CONTROL verbs and irregular past participles (IRR-PP) (e.g., *eaten*, *shaken*, *hidden*). Both of these verb types prefer animate, agent subjects in active sentences. Further, the CONTROL verbs and IRR-PP were chosen from the same verb subcategories (Levin, 1993) and occurred with the same noun sets counterbalanced across lists. Because of their morphological forms, IRR-PP cannot be used in simple past constructions (e.g., **The butler shaken the juice*), but are limited to perfectives (e.g., *The butler had shaken the juice*), passives (e.g., *The juice was shaken by the butler*), and adjectival usages (e.g., *The shaken butler poured the juice*). IRR-PP were significantly more frequent than control verbs ($M = 242.69$, $SD = 363.10$), $t(30) = 2.20$, $p < .04$.

The third set of comparisons contrasts sentence production using CONTROL verbs and experiencer-theme (ET) verbs (e.g., *adored*, *treasured*, *cherished*). These verbs assign the thematic roles experiencer and theme to their subjects and objects, respectively, and require animate subjects in active sentences (e.g., *The author adored the poem*). The mean frequency for ET verbs was 52.46 ($SD = 76.06$). CONTROL and ET verbs did not differ in frequency, $t(30) < 1.00$. ET and TE verbs shared noun sets across lists.

Scoring

Responses were scored as correct only if they were fluent, grammatical, and included all three stimulus words. Correct responses were then categorised as accurate active or passive sentences, or unscoreable "other" usages of the target verb. Active usages consisted of simple active sentences (e.g., *The butler stirred the juice*) and active perfective sentences (e.g., *The butler had stirred the juice*). The passive usages included sentences with an auxiliary form of ''be'' and a prepositional phase including one of the stimulus nouns. In addition, there had to be an active paraphrase for the sentence with nearly identical meaning (e.g., *The soldier was impressed with/by the motorcycle. The motorcycle impressed the soldier*).[3] Unscoreable ''other'' responses, which included truncated passives, deverbal adjectives, prepositional constructions indicating time or place (e.g., *The student was depressed after the exam, The drummer was bored at the opera*), and responses including context words other than the stimuli were excluded from reaction time and sentence structure choice analyses; these accounted for about 2% of responses to control verbs and ET verbs, 6% of responses using irregular past participles, and 3% of responses using TE verbs. There were no group differences in the distribution of these responses. Response times of scoreable, accurate responses were measured from the onset of the stimulus until the participant began a response. Responses with times under 750 ms were excluded from analysis as machine errors; these made up less than 2% of total responses. Responses not begun within 8000 ms of stimulus onset, time-outs, were also excluded and accounted for another 1.5% of responses. The distribution of accurate responses, response times, and the proportion of active responses for the two groups are analysed below.

Design

In the following analyses, the responses of older and young adults are examined to determine whether they are equally sensitive to the constraints inherent in the stimuli, as shown by production accuracy, sentence structure choice, and response times. These analyses address several theoretical questions: (1) Can the order of noun activation override the English preference for animate-subject sentences?; (2) Is there a default active-sentence template?; (3) Is it more difficult to produce sentences with different verb types?; (4) Do passive sentences take longer to produce than active sentences?

Analyses of accurate responses, sentence structure choices, and response times employ $2 \times 2 \times 2$ (Group by Verb Type by Noun Order) repeated measures ANOVAs. In the analysis of sentence structure use, only the

[3] Levin (1993) points out that TE verbs often form passives with prepositions other than ''by'' (e.g., *impressed with, scared of, annoyed with*). These alternative passives made up about 20% of responses to TE verbs. Analysis of the data without these alternative passives yield identical patterns of results to that reported here. We include them in these analyses because they meet the criteria for passives stated above.

proportion of active sentences is analysed, since the proportion of passives is complementary (i.e., 75% actives means 25% passives were produced). To compare production times for active or passive sentences for each group in each condition we employed paired-sample *t*-tests, comparing subject means of only those subjects who produced both sentence types in a condition, and item means only for those items used in both active and passive structures.

RESULTS

Baseline performance: CONTROL verbs

Accuracy.[4] Participants were very accurate when using CONTROL verbs ($M = 0.94$, $SD = 0.08$) as shown in Figure 2a. Only the effect of noun order was significant, $F_1(1, 94) = 4.74$, $p < .04$, $\eta^2 = .05$, $F_2(1, 15) = 4.96$, $p < .05$, $\eta^2 = .25$. Participants produced more accurate responses to inanimate stimuli ($M = 0.96$, $SD = 0.09$) than they did to animate-first stimuli ($M = 0.93$, $SD = 0.12$).

Sentence structure choice. Overall, participants produced a majority of their CONTROL verb responses as active sentences ($M_A = 0.90$, $SD = 0.30$), and actives were more prevalent in the animate-first condition ($M = 0.97$, $SD = 0.18$) than in the inanimate-first condition ($M = 0.84$, $SD = 0.37$), $F_1(1, 94) = 22.93$, $p < .01$, $\eta^2 = .20$; $F_2(1, 15) = 39.535$, $p < .01$, $\eta^2 = .73$. The noun order by group interaction was also significant, $F_1(1, 94) = 5.52$, $p < .03$, $\eta^2 = .06$; $F_2(1, 15) = 12.56$, $p < .01$, $\eta^2 = .46$. As shown in Figure 3a, older adults produced significantly fewer actives and, consequently more passives, in the inanimate-first condition than in the animate-first condition, $t(47) = 4.222$, $p < .01$. However, the proportion of actives and passives young adults produced did not differ between noun order conditions, $t(47) = 1.528$, $p > .10$.

Response times. Analysis of response times using CONTROL verbs showed no significant effects. However, responses using animate-first stimuli were marginally faster ($M = 2260$, $SD = 1027$) than responses using inanimate-first ($M = 2376$, $SD = 922$), $F(1, 94) = 3.556$, $p = .06$.

Response times for actives and passives. Response times for those participants who produced both active and passive sentences with CONTROL verbs are shown in Table 1. Both young and older adults produced actives faster than passives in the animate-first condition. In the inanimate-first condition, older adults produced passive sentences faster

[4] The pattern of effects in accuracy, structure choice, and overall response times were nearly identical whether considering all correct responses or just scoreable responses.

TABLE 1
Response times for producing active and passive sentences using control verbs

Group	N	Actives M	Actives SD	Passives M	Passives SD	t-tests t	t-tests p
Young adults							
Animate-first	11	2646	1382	3128	1890	−2.28	.05
Inanimate-first	16	2111	953	2222	1041	−0.57	.58
Older adults							
Animate-first	15	2597	984	3098	1105	−3.31	.005
Inanimate-first	19	2898	805	2521	840	2.31	.03
Total							
Animate-first	26	2617	995	3111	1454	−4.03	.000
Inanimate-first	35	2538	950	2384	935	1.17	.25

than actives, but young adults produced actives and passives similarly fast. *T*-tests for item response times in the same four conditions were limited to those items that occurred in both active and passive forms. Only one of these four *t*-tests was significant: In the inanimate-first condition older adults produced passives faster than actives, $t(16) = 6.203$, $p < .01$.

Discussion. Noun order had pervasive effects on sentence production with CONTROL verbs. In the animate-first condition, participants produced more active sentences than passives and produced them faster than actives; however, they were less accurate in this condition also, suggesting there was a speed accuracy trade-off. In the inanimate-first condition, both groups continued to produce a majority of active sentences; however, older adults' sentence structure choices were affected by noun order: They produced fewer active sentences and more passives in this condition than young adults did. Furthermore, older adults who produced both actives and passive sentences in this condition produced passive sentences faster than actives. Regarding the use of an active-sentence template, although in the animate-first condition participants showed a strong preference for active sentences and produced active sentences faster, in the inanimate-first condition participants produced increased numbers of passives and these passives were produced at least as fast, sometimes faster, than active sentences. Consequently, there is little support here for the use of an active-sentence template.

CONTROL verbs versus theme-experiencer verbs

These analyses contrast sentence production with CONTROL verbs and TE verbs (e.g., *bored*, *surprised*, *scared*). While CONTROL verbs require

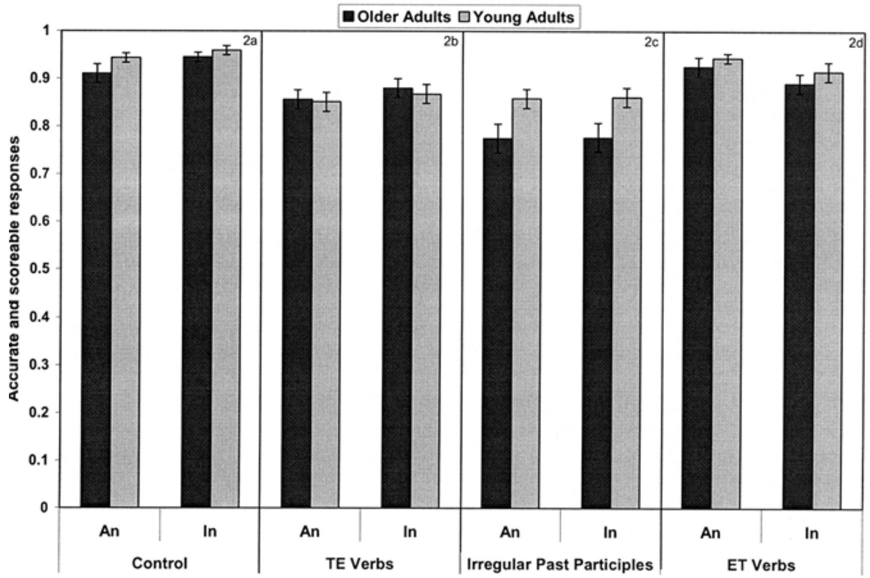

Figure 2. The proportion of accurate responses produced across conditions. Participants were significantly more accurate using control verbs than any of the other verb types. Age differences in accuracy were limited to responses to irregular past participles. TE, theme-experiencer; ET, experiencer-theme.

animate subjects in active sentences, TE verbs require animate objects in active sentences (e.g., *The assignment bored the student*). Because active sentences made with TE verbs have inanimate subjects here, we can determine whether there is a preference for (1) active sentences regardless of the animacy of the sentence subject, or (2) animate-subject sentences regardless of the sentence structure chosen.

Accuracy.[4] Participants produced more accurate responses when using CONTROL verbs ($M = 0.94$, $SD = 0.08$) than when using TE verbs ($M = 0.86$, $SD = 0.19$), $F_1(1, 94) = 43.59$, $p < .01$, $\eta^2 = .32$, $F_2(1, 30) = 78.16$, $p < .01$, $\eta^2 = .72$. The main effect of noun order was also significant, $F_1(1, 94) = 4.09$, $p < .05$, $\eta^2 = .04$, $F_2(1, 30) = 18.27$, $p < .01$, $\eta^2 = .38$, as shown in Figures 2a and 2b. Participants produced more accurate responses when using inanimate-first stimuli ($M = 0.91$, $SD = 0.14$) then when using animate-first stimuli ($M = 0.89$, $SD = 0.14$). In sum, responses to CONTROL verbs were more accurate than those to TE verbs, and responses to both verb types were more accurate in the inanimate-first condition.

[4] The pattern of effects in accuracy, structure choice, and overall response times were nearly identical whether considering all correct responses or just scoreable responses.

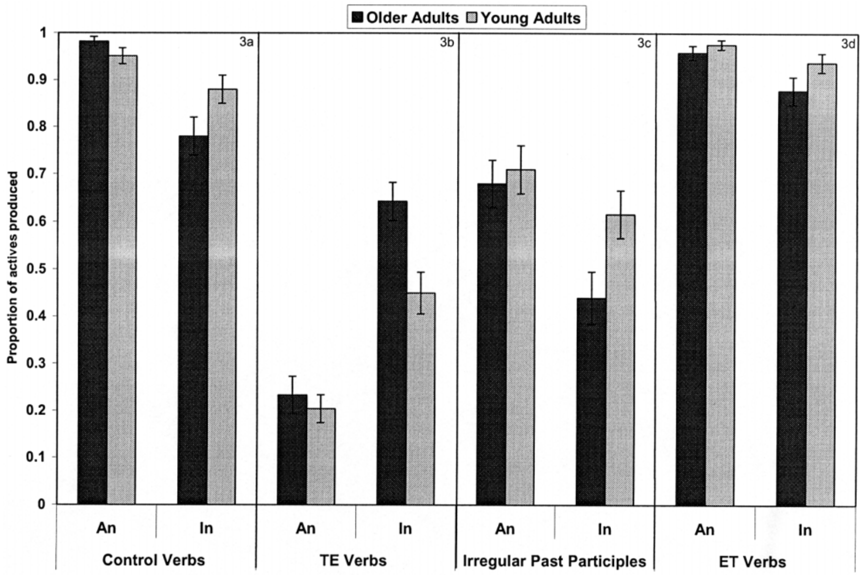

Figure 3. The proportion of active sentences produced across conditions. Participants produced very few non-active sentences with control and experiencer-theme verbs, but many more with the other two verb types. Note the consistent group by noun order interactions across verb types. TE, theme-experiencer; ET, experiencer-theme.

Sentence structure choice. The analysis of sentence choice yielded a main effect of verb type, $F_1(1, 94) = 338.84$, $p < .01$, $\eta^2 = .78$; $F_2(1, 30) = 773.91$, $p < .01$, $\eta^2 = .96$. Participants produced many more active sentences when using CONTROL verbs ($M = 0.90$, $SD = 0.30$) than when using TE verbs ($M = 0.38$, $SD = 0.42$). The interaction between verb type and noun order was also significant, $F_1(1, 94) = 71.25$, $p < .01$, $\eta^2 = .43$; $F_2(1, 30) = 241.73$, $p < .01$, $\eta^2 = .89$. As shown in Figures 3a and 3b, participants produced more actives in the animate-first condition than the inanimate-first condition with CONTROL verbs; however, they produced more actives in the inanimate-first condition than the animate-first condition when using TE verbs. In addition, the verb type by age group interaction was significant, $F_1(1, 94) = 5.95$, $p < .02$, $\eta^2 = .07$; $F_2(1, 30) = 19.92$, $p < .01$, $\eta^2 = .40$. However, this interaction was secondary to the significant three-way interaction between verb type, noun order, and age group, $F_1(1, 94) = 6.86$, $p < .02$, $\eta^2 = .07$; $F_2(1, 30) = 22.66$, $p < .01$, $\eta^2 = .43$. The two age groups did not differ significantly in the proportion of actives they produced in the animate-first condition with either CONTROL verbs or with TE verbs (all ps $> .08$). In contrast, in the inanimate-first conditions, older adults produced significantly more actives than young adults did when using TE verbs, ($M_{OA} = 0.64$, $SD = 0.31$; $M_{YA} =$

0.45, $SD = 0.31$), $t(94) = 3.18$, $p < .01$, but produced fewer actives than young adults did when using CONTROL verbs, as described above. In brief, participants produced many fewer actives with TE verbs than with CONTROL verbs, and the distribution of actives reflected both verb argument structure and noun order constraints. Furthermore, older and young adults produced similar proportions of actives and passives in animate-first conditions, but older adults produced significantly more inanimate-subject sentences than young adults did in inanimate-first conditions with both verb types.

Response times. In the analysis of response times only the main effect of verb type was significant, $F_1(1, 94) = 9.14$, $p < .01$, $\eta^2 = .09$; $F_2(1, 30) = 4.06$, $p = .05$, $\eta^2 = .12$. Participants responded more slowly to TE verbs stimuli ($M = 2453$, $SD = 1027$) than to CONTROL verb stimuli ($M = 2324$, $SD = 974$).

Response times for actives and passives. Response times for those participants who produced both active and passive sentences using TE verbs are shown in Table 2. None of these *t*-tests were significant; therefore, producing active sentences with TE verbs was no faster than producing passive sentences with this verb type. *T*-tests for item response times in the same four conditions were limited to those items that occurred in both active and passive forms. In the animate-first condition, both groups produced actives and passives equally fast. In the inanimate-first condition, older adults produced actives faster than passives, $t(15) = -3.23$, $p < .01$, but young adults produced actives and passives equally fast, $t(15) = 1.71$, $p > .10$.

TABLE 2
Response times for producing active and passive sentences using theme-experiencer (TE) verbs

		Actives		*Passives*		*t-tests*	
Group	*N*	*M*	*SD*	*M*	*SD*	*t*	*p*
Young adults							
Animate-first	30	2622	1155	2428	1446	0.90	.38
Inanimate-first	34	2550	1299	2327	905	1.58	.12
Older adults							
Animate-first	62	2577	982	2614	1203	−0.17	.86
Inanimate-first	27	2709	918	3038	1200	−1.35	.19
Total							
Animate-first	62	2599	1060	2524	1319	0.50	.62
Inanimate-first	61	2620	1140	2642	1096	−0.16	.88

Discussion. Participants responded faster and more accurately, and produced more active sentences when using CONTROL verbs than when using TE verbs. Indeed, participants showed no bias toward producing active sentences with TE verbs, instead opting to produce a majority of animate-subject passive sentences with this verb type. Moreover, the relative proportion of active and passive sentences produced was highly influenced by the order of nouns in the stimuli, and this order affected older adults' responses more strongly than those of young adults. Specifically, compared with young adults, older adults produced more inanimate-subject sentences than young adults did in inanimate-first conditions with both verb types.

These findings contrast with those reported in Ferreira (1994) both in the proportion of passives produced and in the times to produce them. The current study finds no evidence of a preference for active sentences with TE verbs. Moreover, for participants who produced both active and passive responses using TE verbs, the times to produce actives and passives did not differ. Thus, these findings suggest that an active-sentence template, or even an active-sentence preference, does not apply to sentence production with TE verbs. Instead, these findings suggest that English speakers prefer passives with this verb type. If speakers are not using an active-sentence template here, it is possible that the active-sentence preference may *also* not extend to all agent-theme verbs. For example, to produce an active sentence with an irregular past participle, the speaker must use an active perfect (e.g., *The jockey had hidden the carrot*), but it is unknown whether there is a preference or advantage for active sentences with this verb form. This question is addressed next.

Control verbs versus irregular past participles

In this section, we compare sentence production using CONTROL verbs and IRR-PP (e.g., *hidden*, *eaten*, *shaken*) that have agent-theme argument structures (according to Levin, 1993). While both verb types require animate-agent subjects in active sentences, IRR-PPs require the production of either an active perfective or passive sentence rather than a simple active sentence and, consequently, may require additional processing to use in a sentence. We hypothesise that this requirement for additional metalinguistic processing may increase the processing load on the speaker, and this may cause disproportionate difficulties for older adults.

Regarding sentence structure choice, if the active-sentence template applies to both simple actives and active perfectives, then there should be similar patterns of active use with both CONTROL and IRR-PP verbs (i.e., $> 80\%$ of responses in the active voice), because both verb types have similar argument structures. However, if the preference for active sentences does not extend to active perfective sentences, speakers should produce more passives and fewer actives with IRR-PP than with CONTROL verbs.

Accuracy. In the analysis of accurate responses, the main effect of group was significant, $F_1(1, 94) = 7.50$, $p < .01$, $\eta^2 = .07$; $F_2(1, 30) = 22.08$, $p < .01$, $\eta^2 = .42$; Older adults produced fewer accurate responses (M = 0.85, SD = 0.08) than young adults did (M = 0.91, SD = 0.06). The main effect of verb type was also significant, $F_1(1, 94) = 60.78$, $p < .01$, $\eta^2 = .39$; $F_2(1, 30) = 27.03$, $p < .01$, $\eta^2 = .47$. Participants produced more of their responses accurately when using CONTROL verbs (M = 0.94, SD = 0.08) than when using IRR-PP (M = 0.82, SD = 0.16). In addition, the interaction between group and verb type, shown in Figures 2a and 2c, was significant, $F_1(1, 94) = 4.29$, $p < .05$, $\eta^2 = .04$; $F_2(1, 30) = 7.341$, $p < .02$, $\eta^2 = .20$. To investigate this interaction, we compared the difference scores between the proportion of accurate responses when using CONTROL verbs and when using IRR-PPs. Older adults' accuracy scores dropped significantly more (M = 0.15, SD = 0.17) than young adults scores did (M = 0.09, SD = 0.09) when using IRR-PPs, $t(94) = 2.071$, $p < .05$. Thus, while both groups produced fewer accurate responses using IRR-PP relative to control verbs, older adults produced disproportionately fewer accurate responses compared with young adults in this condition.

Sentence structure choice. As shown in Figures 3a and 3c, the verb type main effect was significant, $F_1(1, 94) = 85.50$, $p < .01$, $\eta^2 = .48$; $F_2(1, 30) = 101.88$, $p < .01$, $\eta^2 = .77$. Participants produced more active sentences and, consequently, fewer passives, when using CONTROL verbs (M = 0.90, SD = 0.30) than when using IRR-PP (M = 0.63, SD = 0.48). The noun order main effect was also significant, $F_1(1, 94) = 31.60$, $p < .01$, $\eta^2 = .25$; $F_2(1, 30) = 57.95$, $p < .01$, $\eta^2 = .66$, reflecting the similar argument structures of the two verbs. Participants produced about 83% of their responses to animate-first stimuli as actives (SD = 0.20), and 69% of their responses to inanimate-first stimuli as actives (SD = 0.27). Furthermore, noun order also interacted with age group, $F_1(1, 94) = 6.99$, $p < .01$, $\eta^2 = .07$; $F_2(1, 30) = 13.31$, $p < .01$, $\eta^2 = .35$. To explore this interaction, differences scores were computed between the proportion of actives produced in animate-first versus inanimate-first conditions. Older adults showed a significantly larger drop (M = 0.22, SD = 0.27) in the proportion of actives produced in inanimate-first conditions relative to animate-first conditions than young adults did (M = 0.08, SD = 0.24), $t(94) = 2.64$, $p = .01$. In sum, more actives were produced in response to CONTROL verbs than to IRR-PPs. In addition, individuals produced more actives in animate-first than inanimate-first conditions with both verb types, reflecting the similar argument

TABLE 3
Response times for producing active and passive sentences using irregular past participles

Group	N	Actives		Passives		t-tests	
		M	*SD*	*M*	*SD*	*t*	*p*
Young adults							
Animate-first	24	2826	1150	2589	866	1.45	.16
Inanimate-first	32	2744	1392	2634	1297	0.61	.55
Older adults							
Animate-first	27	2403	544	3130	1471	−3.33	.003
Inanimate-first	35	2495	917	2624	981	−1.05	.30
Total							
Animate-first	51	2602	899	2876	1243	−1.78	.08
Inanimate-first	67	2614	1166	2629	1134	−0.14	.89

structures of these two verb types. Finally, older adults showed a larger effect of noun order on sentence structure choice than young adults did.

Response times. In the response time analysis, only the main effect of verb type was significant, $F_1(1, 94) = 48.89$, $p < .01$, $\eta^2 = .34$; $F_2(1, 30) = 20.36$, $p < .01$, $\eta^2 = .40$. Participants were slower responding to IRR-PPs ($M = 2693$, $SD = 1109$) than they were to CONTROL verbs ($M = 2323$, $SD = 936$). There were no significant effects of age group or noun order. In sum, all participants were faster when using CONTROL verbs than when using IRR-PP.

Response times for actives and passives. Response times for those participants who produced both active and passive sentences with IRR-PPs are shown in Table 3. Only one of these *t*-tests was significant: Older adults were faster at producing active sentences than passives in the animate-first condition. *T*-tests for item response times in the same four conditions included only those items occurring in both active and passive forms; none of these comparisons were significant. Therefore, young adults produced actives and passives equally fast in both conditions, but older adults only showed this pattern in the inanimate-first condition. In the animate-first condition, older adults' produced active sentences faster than passives.

Discussion. Producing sentences with IRR-PP was more difficult than producing sentences with CONTROL verbs, leading to lower accuracy rates and longer responses times for both age groups. Accuracy dropped more for older adults than young adults when using IRR-PPs relative to

CONTROL verbs, although there were no effects of age on response times. Thus, older adults may have sacrificed production accuracy for better response times when using IRR-PPs. These findings support the hypotheses that the additional processing demands of IRR-PPs would increase difficulty for all participants, and would affect older adults disproportionately, although this effect was limited to accuracy.

Older adults also produced fewer active sentences (and proportionately more passives) than young adults did in the inanimate-first condition, apparently taking advantage of the order of the nouns in the stimuli to help choose their sentence structures. Therefore, as above, older adults demonstrated a stronger effect of order of activation, while young adults revealed a stronger effect of the animate-subject constraint by producing a majority of active sentences with animate-subjects in both noun order conditions.

Finally, the results suggest that there was no active-sentence template affecting performance with this verb type. Participants produced many fewer actives with IRR-PPs than with CONTROL verbs. Furthermore, the preference for active sentences with IRR-PPs was only consistent across noun conditions for young adults, while older adults actually produced a majority of passive sentences in the inanimate-first condition. Overall, participants from both groups produced significantly fewer actives with IRR-PP than with CONTROL verbs, despite the fact that these verbs have the same argument structures and come from the same verb categories (Levin, 1993). Response time data also do not support the use of an active-sentence template, as shown by high sentence production times using IRR-PPs across the board, as well as similar active and passive sentence production times using IRR-PPs in both noun order conditions for young adults and in the inanimate-first condition for older adults. These findings suggest that if an active-sentence template exists, it does not apply to active perfectives. The final question remaining is whether all transitive verbs with regular morphology that require animate subjects take advantage of an active-sentence template; this issue is explored in the following section.

Control verbs versus experiencer-theme verbs

Experiencer-theme (ET) verbs (e.g., *adored*, *liked*, *detested*) have regular morphology and require an animate-subject. The subject of an ET verb, however, must be the experiencer of the psychological state described by the verb; thus, subjects for ET verbs are limited to humans and animals. CONTROL verbs also have regular morphology and require animate-subjects, but assign the thematic role agent to their subjects. Agents need not be humans or animals and can include inanimate nouns (e.g., vehicles or natural phenomena: *The car hit the pedestrian. The lightning struck the church*). Nevertheless, both CONTROL and ET verbs fit the profile of verbs that should be subject to an active-sentence template, since they both require animate subjects in active sentences. If both verb types can take advantage of an active sentence template, they should show similar patterns of effects on accuracy, speed, and sentence structure choice.

Accuracy. The proportion of accurate responses showed a significant effect of verb type by subjects but not by items, $F_1(1, 94) = 5.04$, $p < .03$, $\eta^2 = .05$; $F_2(1, 30) = 2.25$, $p < .15$, $\eta^2 = .07$. Participants were more accurate producing sentences using CONTROL verbs ($M = 0.94$, $SD = 0.08$) than when using ET verbs ($M = 0.92$, $SD = 0.09$). In addition, there was a significant verb type by noun order interaction, $F_1(1, 94) = 12.42$, $p < .01$, $\eta^2 = .12$; $F_2(1, 15) = 13.22$, $p < .01$, $\eta^2 = .30$. Speakers produced the same proportion of accurate responses to both verb types in the animate-first condition ($M_{CON} = 0.93$, $SD = 0.12$; $M_{ET} = 0.94$, $SD = 0.10$). However, in the inanimate-first condition responses to CONTROL verbs were more accurate ($M = 0.96$, $SD = 0.09$) than responses to ET verbs ($M = 0.90$, $SD = 0.13$), $t(94) = 4.14$, $p < .01$. There were no significant age group effects, as shown in Figures 2a and 2d. Thus, participants produced fewer accurate responses in the inanimate-first condition with ET verbs than with CONTROL verbs.

Sentence structure choice. The main effect of verb type was significant, $F_1(1, 94) = 6.95$, $p < .01$, $\eta^2 = .07$; $F_2(1, 30) = 101.88$, $p < .01$, $\eta^2 = .77$; as was the main effect of noun order, $F_1(1, 94) = 15.65$, $p < .01$, $\eta^2 = .14$; $F_2(1, 30) = 46.44$, $p < .01$, $\eta^2 = .61$. However, both of these interactions were secondary to the interaction between verb type and noun order, $F_1(1, 94) = 12.47$, $p < .01$, $\eta^2 = .12$; $F_2(1, 30) = 4.90$, $p < .05$, $\eta^2 = .14$. As shown in Figures 3a and 3d, participants strongly preferred to produce active sentences with both of these verb types, particularly in the animate-first condition in which they treated both verb types similarly (actives: $M_{CON} = 0.97$, $SD = 0.18$; $M_{ET} = 0.96$, $SD = 0.19$), $t(95) < 1$. However, in the inanimate-first condition participants produced fewer actives in response to CONTROL verbs than to ET verbs ($M_{CON} = 0.84$, $SD = 0.37$; $M_{ET} = 0.94$, $SD = 0.24$), $t(95) = 3.06$, $p < .01$. The 3-way interaction between verb type, noun order, and age group was also significant, but only by subjects, $F_1(1, 94) = 5.11$, $p < .03$, $\eta^2 = .05$; $F_2(1, 30) = 2.06$, $p < .7$, $\eta^2 = .06$. This interaction was explored using paired *t*-tests that compared difference scores between the proportion of active sentences produced in animate and inanimate noun conditions (e.g., per cent actives in the animate-first condition −per cent actives in the inanimate-first condition) when using control verbs compared with the same difference using ET verbs for each age group. Young adults treated both verb types similarly, producing about 4–6% fewer of their responses as actives in the inanimate-first conditions regardless of verb type, $t(47) < 1.1$, $p > .25$. In contrast, for older adults there was a significantly larger difference in the proportion of actives produced between inanimate-first and animate-first conditions when using CONTROL verbs ($M = 0.18$, $SD = 0.28$), than when using ET verbs ($M = 0.07$, $SD = 0.28$), $t(47) = 3.48$, $p < .01$.

In summary, participants produced a majority of their responses to both verb types as actives in the animate-first noun condition. In response to inanimate-first stimuli, older but not young adults produced significantly fewer actives with CONTROL verbs than with ET verbs.

Response times. In the analysis of response times, there was a significant main effect of verb type, $F_1(1, 94) = 10.83$, $p < .01$, $\eta^2 = .10$; that only approached significance in the items analysis $F_2(1, 30) = 3.41$, $p < .08$, $\eta^2 = .10$. Participants responded faster when using CONTROL verbs ($M = 2323$, $SD = 936$) than when using ET verbs ($M = 2440$, $SD = 1023$). In addition, the main effect of noun order was significant, $F_1(1, 94) = 21.54$, $p < .01$, $\eta^2 = .19$; $F_2(1, 30) = 8.13$, $p < .01$, $\eta^2 = .22$. People were faster responding to animate-first stimuli than to inanimate-first stimuli ($M_{AN} = 2306$, $SD = 948$; $M_{IN} = 2464$, $SD = 993$). There were no significant effects of age group. Briefly, responses to control verbs were faster than those to ET verbs, and responses to animate-first stimuli were faster than to inanimate-first stimuli across both verb types.

Response times for actives and passives. Mean response times for those participants who produced both active and passive sentences with ET verbs are shown in Table 4. None of these *t*-tests were significant, all $p >$

TABLE 4
Response times for active and passive sentences using experiencer-theme (ET) verbs

		Actives		*Passives*		*t-tests*	
Group	*N*	*M*	*SD*	*M*	*SD*	*t*	*p*
Young adults							
Animate-first	6	2376	624	2820	663	−1.46	.20
Inanimate-first	10	2189	781	2939	2442	−.99	.35
Older adults							
Animate-first	17	2774	1091	3061	1743	−1.01	.33
Inanimate-first	10	2764	796	3297	1647	−.89	.40
Total							
Animate-first	23	2670	993	2998	1523	−1.49	.15
Inanimate-first	20	2476	822	3118	2036	−1.36	.19

.20. Thus, in the subject analyses, producing active sentences with ET verbs was no faster than producing passives. *T*-tests for item response times were limited to those items that occurred in both active and passive forms. Producing active sentences with ET verbs in the animate-first condition was significantly faster for young adults than producing passives, $t(22) = 4.04$, $p < .01$. Otherwise, production times were similar for both sentence types.

Discussion. First, older adults' responses were similar to those of young adults with respect to accuracy and speed when using ET verbs. Second, the two groups produced similar proportions of active sentences when using animate-first stimuli, but older adults produced fewer actives than young adults in inanimate-first conditions. Further, subjects' mean response times for producing actives and passives did not differ.

There was little support in these analyses for the use of an active sentence template. For example, if participants were using the same template to produce sentences with both CONTROL and ET verbs, production times should have been similar, but response times to ET verbs were slower than those to CONTROL verbs. Similarly, participants were less accurate when using ET verbs than when using CONTROL verbs. Moreover, participants produced more actives when using ET verbs than when using CONTROL verbs. Thus, although the proportion of actives produced suggests an active-sentence template might have been used more with ET verbs than with CONTROL verbs, the slower response times with ET verbs argues against this. Consequently, we conclude that there was no active-sentence template in use with either verb type. Instead, we suspect that the sentence structure choices reflected the frequency of active and passive use with that verb type, while the difference in response times reflects the relative frequency difference between agent-theme and experiencer-theme argument structures.

CONCLUSION

The current study examines several theoretical issues in sentence production from a lifespan perspective. A primary question is whether there is a universal preference for active sentences that affects sentence production accuracy, speed of response and sentence structure choice. Second, the study tests the relative strength of the animate-subject constraint against the order of noun activation in determining sentence structure choice and the consequent effects on sentence production times. Each analysis also questions whether these effects remain stable across the lifespan; this issue is discussed first.

Age effects

Earlier, predictions about the performance of older adults based on three hypotheses of cognitive ageing were discussed. There are no age-group effects on response times with any of the four verb types in the current study. Thus, the general slowing hypothesis of cognitive ageing is not supported. As predicted by the inhibitory deficit hypothesis of cognitive ageing, older adults are less accurate than young adults when using irregular past participles; however, this theory also predicts increased use of active sentences throughout the experiment. This latter prediction is contradicted; in fact, older adults actually produce more passives than young adults with three of the four verb types. The reduced resources hypothesis of cognitive ageing also predicts age differences in performance with irregular past participles, due to the increased metalinguistic demands of these verbs, and this is so. Considering the pervasive age effects on performance in a wide variety of cognitive tasks reported in the literature (Perfect & Maylor, 2000), the question becomes why so few age effects are found in this study. One possibility is that older adults have many more years of experience as language users, making them more familiar with lower frequency constructions such as the passive. If this were so, we would expect older adults to produce more passives than young adults in all conditions. To test this possibility, we compared the proportion of passives the two groups produced in the TE verb-animate-first condition, in which both groups produced many passives. As shown in Figure 3b, older adults produced 78% of their responses as passives, while young adults produced 80% of their responses as passives, $t(95) < 1$; thus, there is no evidence that older adults had a higher baseline rate of passive production than young adults.

A more likely reason for the lack of age effects is that the two groups use different strategies to accomplish the task. While young adults produce predominantly animate-subject sentences throughout the task, older adults rely more strongly on the order of the nouns in the stimuli to choose a sentence structure. This strategy has no effect in animate-first conditions—both groups produce similar proportions of animate-subject sentences with all four verb types when the animate noun is at the top of the stimulus. However, in inanimate-first conditions, older adults produce more inanimate-subject sentences than young adults with all four verb types. The possibility that older adults might use environmental support to optimise their responses is predicted by the reduced resources theory of cognitive ageing. Older adults are typically more influenced by perceptual characteristics of the stimuli (Craik, 1986; Humphrey & Kramer, 1999) than young adults are, and older adults are also more likely to take advantage of environmental support by using stimulus characteristics (e.g., the order of the nouns in the stimuli) to facilitate responses in resource-demanding tasks (Craik, 1983; McDowd & Shaw, 2000). Thus, by immediately assigning the top stimulus noun, regardless of its animacy, to the nominative role (i.e., the sentence subject) at the functional level of sentence production, older adults can then rely on automatic positional-level processing to produce a grammatical sentence. This strategy facilitates sentence production by eliminating the necessity of reordering the nouns in the stimuli or choosing the ''best'' subject. In contrast, young adults seem to adopt the latter strategy of fully scanning the stimuli, then choosing the animate noun as the ''best'' subject for the nominative role, a process that may have slowed their response times somewhat and contributed to the lack of age differences in response times.

In addition, it is important to point out that the order manipulation in the current study succeeded in eliciting inanimate-subject sentences from young adults only about a quarter of the time. A stronger order manipulation, such as a more linear presentation order or staggered presentation times, may be required to induce consistent order of activation effects with this population. This hypothesis is currently under investigation.

In summary, there is evidence that young and older adults adopt different strategies to complete this task. Young adults produce a majority of animate-subject sentences in all conditions, while older adults attend more to the order of the nouns in the stimuli. We suspect that these strategy differences serve to minimise age-differences in response times on the task. These findings are consistent with the reduced resources hypothesis of cognitive ageing, which suggests that age-differences are minimal when older adults can take advantage of characteristics of the stimuli (e.g., the order of nouns) to boost performance.

Is there an active-sentence template? Using an active-sentence template should not only also increase the production of active sentences, it should increase the speed of producing actives sentences relative to passives. Speakers in this study do produce many more active than passive sentences with CONTROL verbs; however, the results do not support the hypothesis that speakers use an active-sentence template with this verb type. Active sentences are only produced faster than passives in the animate-first condition; in contrast, when using these verbs in the inanimate-first condition, young adults produce active and passive sentences equally fast, and older adults produce passives faster than actives. This pattern argues against the use of an active sentence template.

Another pattern of results that argues against the use of an active-sentence template, is found when speakers used ET verbs. Speakers produced more active sentences when using ET verbs compared to when using CONTROL verbs, but their responses are significantly slower when using ET verbs. If an active-sentence template had been in use with both verb types, participants would have generated similar proportions of actives with similar response times when using both verb types.

There is also no evidence that irregular past participles had access to an active-sentence template. Indeed, the use of irregular past participles presented a challenge to all participants, as shown by the low accuracy rates and slow response times of both groups with these verbs. These results likely stem from the fact that this task presents the sentence production system with an unusual challenge: It must activate the grammatical requirements for using irregular past participles from their orthographic forms. This requirement may overwhelm participants, leading to less than optimal performance in both speed and accuracy.

In sum, the results of the current study do not support the existence of an active-sentence template, even in the CONTROL and ET verb conditions in which both groups produce large proportions of active sentences. Instead, it appears that speakers compose their sentences online, and that various constraints inherent in the stimuli influence the speed and choice of sentence structure.

Sentence structure choice

The most comprehensive theory of sentence production to date suggests that sentence structure choice using transitive verbs is determined when one of the verb's arguments is activated first and is assigned to the nominative role and, subsequently, the sentence subject position (Bock & Levelt, 1994). If the theme is activated first, a passive sentence is produced; if the agent is activated first, an active is produced. Another, though lesser, factor affecting sentence structure choice is the strong propensity for using animate-subjects, a phenomenon attributed to overall faster activation rates for animate nouns relative to inanimate nouns (McDonald et al., 1993). Thus, both order of activation and the animacy of a verb's arguments may constrain sentence structure choice. However, Bock and Levelt only discuss the case in which order of activation and animacy coincide. The current study tests this theory further by manipulating the order in which animate and inanimate nouns are activated. The results show that when the stimuli encourage an animate-subject sentence, participants consistently (70–99% of the time) produce animate-subject sentences. In contrast, when stimuli encourage inanimate-subject sentences, participants (especially young adult participants) do not consistently produce inanimate-subject sentences (10–55%). Thus, these findings challenge the assertion that order of activation is the primary determinant of sentence structure. Two factors may have contributed to this finding: an underlying preference for animate-subject sentences regardless of activation order and the type of verb used in the sentence. This underlying preference for animate-subject sentences can best be seen in the inanimate-first conditions with the irregular past participles and TE verbs in which participants produce about half active and have passive sentences. These findings illustrate that the animate-subject constraint and the order of activation constraint may compete with each other to determine sentence structure choice. The effect of verb type on sentence structure choice is illustrated by the fact that participants produce different proportions of active and passive sentences with each of the four verb types examined here. These different proportions of active and passive sentences may reflect the relative frequency with which the active and passive argument structures of these verbs are used (Trueswell, 1996). Indeed, the proportion of passive sentences produced with each verb correlates highly, $r(62) = .48$, $p < .000$, with the relative frequency of its past participle use as specified in Francis and Kučera (1982).

These findings are consistent with a theory in which sentence structure choice is a probabilistic, constraint-satisfaction process with a variety of factors competing to constrain the choice of sentence structure. In the current study, factors that influence sentence structure choice include: the verb type, the order of activation of the verb's arguments, and the animacy of those arguments. In more naturalistic sentence production, syntactic priming and the pragmatic context of the utterance likely also compete to influence sentence structure choice.

Production times for active and passive sentences

In the current study, we test the assertion in Ferreira (1994) that actives are faster to produce than passives. Ferreira bases this conclusion on analyses of item-based response times for active versus passive sentences, combined across verb types and noun orders. The current study uses a more rigorous analysis by including the response times of only those people who produce both actives and passive in each condition. Interestingly, active sentences are only produced faster than passives in conditions in which the verb argument structure requires an animate subject and an animate noun is activated first; that is, when the animate-subject and order of activation constraints converge on the same active sentence structure (i.e., in the animate-first conditions with CONTROL verbs, irregular past participles, and ET verbs). In contrast, in the conditions where these constraints compete, production times for active and passive sentences do not differ. In one condition, older adults actually produce passives faster than actives (i.e., in the CONTROL verbs inanimate-first condition). Thus, the convergence of constraints on an active argument structure can facilitate production of actives, but when constraints compete, sentence production is opportunistic, with the first-activated sentence structure being produced, leading to similar response times for actives and passives.

In summary, the current study provides an empirical test of the theory proposed by Bock and Levelt (1994), in which sentence structure choice is affected by the type of verb chosen for the sentence, the animacy of the verb's arguments, a preference for animate-subjects, and the order of activation of the verb's arguments. The results suggest that these factors act as constraints on the sentence production process, influencing both sentence structure choice and sentence production times. Furthermore, the current study demonstrates that, although these constraints may change importance as people age, this change does not necessarily affect sentence production times or accuracy. Specifically, there are no age differences in response times or accuracy with three of four verb types, regardless of the fact that young adults are more sensitive to the animate-subject constraint than to the order of noun activation, but older adults are more sensitive to the order of noun activation than they are to animacy. Moreover, the lack of advantage for active sentences when constraints conflict argues that participants do not use an active-sentence template to produce sentences, but instead compute sentence structures as needed. The results of the current study are consistent with the theory of sentence production described in Bock and Levelt (1994) and suggest that sentence production is best described as a probabilistic, constraint-satisfaction process in which a number of constraints compete to influence sentence structure choice and speed of production.

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APPENDIX

Theme-experiencer and experiencer-theme stimuli

amused adored/author poem/jockey circus
annoyed enjoyed/ambassador speech/captain delay
bored loved/librarian symphony/drummer opera
confused appreciated/actor lights/tourist instructions
delighted cherished/hostess necklace/banker invitation
depressed dreaded/mailman holidays/student exam
disgusted liked/therapist story/publisher novel
excited regretted/politician campaign/golfer score
frightened despised/pilot lightning/umpire traffic
impressed trusted/soldier motorcycle/scientist computer
reassured respected/lawyer contract/sailor rules
scared feared/farmer blizzard/fisherman tornado
shocked admired/minister photograph/housewife sculpture
surprised treasured/dancer gift/teacher bracelet
terrified disliked/immigrant escalator/doctor weather
thrilled detested/director ballet/pianist concert

Irregular past participle and control verb stimuli

beaten whipped/baker cream/chef egg
broken cracked/busboy plate/water mug
chosen rented/detective car/plumber truck
drawn sketched/architect bridge/artist portrait
driven steered/deputy ambulance/policeman van
eaten nibbled/king cake/princess carrot
forgotten remembered/dentist umbrella/executive telephone
grown arranged/florist roses/gardener flowers
hidden concealed/barber scissors/janitor stain
seen smelled/shopper perfume/cashier cookies
shaken stirred/butler juice/bartender cocktail
stolen grabbed/burglar camera/spy document
thrown kicked/athlete football/boy apple
torn ripped/witness newspaper/prisoner envelope
woven knitted/girl shawl/ grandmother scarf
written typed/reporter letter/surgeon article