Journal of Research in Reading, ISSN 0141-0423 *DOI:10.1111/1467-9817.12338*
Volume 44, Issue 1, 2021, pp 27–50

Bridging form and meaning: support from derivational suffixes in word learning

Nicola Dawson

Royal Holloway, University of London, Egham, UK

Kathleen Rastle

Royal Holloway, University of London, Egham, UK

Jessie Ricketts

Royal Holloway, University of London, Egham, UK

Background: Vocabulary development is closely associated with morphological knowledge, yet work is needed to understand the mechanisms underpinning this relationship. One possibility is that because morphological relationships entail systematic mappings between word form (phonology and orthography) and word meaning (semantics and grammar), children may take advantage of these links to form high-quality lexical representations when learning novel words. This study examined whether developing readers show superior semantic, phonological and orthographic learning of novel words when those words contain an existing suffix that is congruent with the definition of that word.

Methods: Two groups of adolescents (younger: 12–13 years, n = 39, and older: 16–19 years, n = 39) learned definitions for 18 nonwords, each comprising a nonword stem and an existing suffix (e.g., *clantist*). Half the definitions were semantically and syntactically congruent with the suffix; the other half were incongruent. Training took place across two sessions, followed by a series of post-tests measuring semantic learning (through a semantic recall task), phonological learning (through a shadowing task), lexicalisation of nonwords (through a lexical decision task) and orthographic learning (through a spelling task).

Results: Both age groups showed significantly stronger semantic recall for items taught in the congruent compared with the incongruent condition. However, this effect did not emerge in our measures of phonological and orthographic learning or in lexicalisation of nonwords.

Conclusions: These findings provide some evidence that the presence of familiar suffixes in unfamiliar words facilitates novel word learning in adolescents, but in the present study, this benefit was only observed in the mappings between word form and meaning and not in the learning of word forms.

Keywords: morphology, word learning, adolescence, lexical quality, derivation

Highlights

What is already known about this topic

- Morphological knowledge is closely associated with vocabulary acquisition
- Morphologically related words overlap in form (spelling and sound) and meaning
- Robust word knowledge is characterised by strong associations between spelling, sound and meaning information

What this paper adds

- This study is the first to directly examine whether the presence of derivational suffixes facilitates learning of novel words
- Our findings provide some evidence that adolescents form more robust lexical representations of novel words when suffixes provide consistent cues to word meaning and grammatical class, although these effects did not emerge across all measures of learning
- Effects were equivalent for 12–13 year olds and 16–18 year olds, although older adolescents outperformed younger adolescents on most measures of learning

Implications for theory, policy or practice

- Our results indicate that the semantic and grammatical properties of derivational suffixes may facilitate some aspects of word learning in adolescents, adding to the existing literature on the role of morphology in adolescent language and literacy development
- These findings have implications for theoretical accounts that propose that morphological regularities support lexical quality by facilitating links between spelling, sound and meaning
- Our findings also have implications for practitioners, including teachers and speech and language therapists, seeking to promote learning of morphologically complex words in adolescence

Word knowledge is an important component of language development. Children with larger vocabularies in the preschool years go on to be stronger readers, perform better academically and have greater employment prospects later in life (Law, Rush, Schoon, & Parsons, 2009; Morgan, Farkas, Hillemeier, Hammer, & Maczuga, 2015). The types of words children encounter change as they gain greater reading skill, with words comprising multiple morphemes increasingly common as texts become more advanced (Nagy & Anderson, 1984). Understanding the internal structure of words may be an important factor in vocabulary acquisition (Anglin, 1993), but the mechanisms underpinning this relationship are not well understood. Theoretically, overlaps in form and meaning brought about by morphological relationships may support the quality of lexical representations, with high-quality representations characterised by strong mappings between orthographic, semantic and phonological information (the lexical quality hypothesis; Perfetti & Hart, 2002). However, this is yet to be determined empirically. The present study takes a novel approach to examining whether adolescents capitalise on the semantic and syntactic properties of derivational suffixes when learning novel words.

The rate at which children learn new words is remarkable. Based on analysis of performance on a large-scale lexical decision task, Brysbaert, Stevens, Mandera and Keuleers (2016) estimated that the average 20-year-old speaker of American English knows around 71,400 words. However, this count includes overlapping words: knowing the word *accept* goes a long way to supporting understanding of *unacceptable* (Rastle, 2019). When inflections of a given word are ignored (e.g., *accepts*, *accepting* and *accepted* all listed under *accept*), estimates of vocabulary size drop to 42,000 unique lemma types, and they are further reduced if morphological families are combined under their base word (e.g., *acceptable* and *unacceptable* counted as *accept*), leaving an estimated vocabulary size of only 11,100 unique base words (Brysbaert et al., 2016).

Two things are clear from the above estimates. First, calculations of vocabulary size depend largely on what constitutes a word. Second, the ability to detect morphological relationships between words may support acquisition of novel words containing familiar morphemes. Work by Anglin (1993) revealed that children's vocabulary size is largely contingent on their understanding of morphologically complex words. He found that while children's overall vocabulary size increased between the ages of 6 and 10 years, the largest amount of growth was in their understanding of derived words such as *acceptable*, and this was particularly pronounced between 8 and 10 years. In addition, the proportion of complex words for which children derived meaning through 'morphological problem solving' increased significantly with age, rising from 56% at age 6 to 65% at age 10. Anglin's findings indicate that, at least in part, the rapid expansion of children's vocabulary knowledge during the primary school years may be linked to their ability to perceive and manipulate morphemes in words.

While Anglin's findings suggest that children make conscious use of morphological structure to *infer* word meanings, it remains to be determined whether they, implicitly or explicitly, take advantage of the availability of familiar morphemes in unfamiliar words during the learning process. Morphemes are unique linguistic units because they introduce a level of systematicity to the otherwise arbitrary relationship between form and meaning. Words sharing the same stem (i.e., morphological families) also overlap in meaning (e.g., *intense*, *intensity* and *intensify*), while affixes provide cues to word class and word meaning and function relatively systematically across different words (e.g., *intensity*, *popularity* and *similarity*). Evidence from adults (Tamminen, Davis, & Rastle, 2015) and children (Pacton, Foulin, Casalis, & Treiman, 2013; Pacton et al., 2018) suggests that readers are sensitive to these regularities when learning novel words. Tamminen et al. (2015) showed that when adults were repeatedly exposed to novel suffixes embedded in nonwords, they were able to generalise the semantic function of those suffixes to untrained items. Pacton and colleagues provided evidence that children use their morphological knowledge when learning spellings of novel words containing familiar suffixes. Our approach here is to examine whether the presence of familiar suffixes embedded in novel words aids learning of word meaning as well as word form.

If lexical quality is determined by the strength of links between word form (phonology and orthography) and meaning (semantics and grammar; Perfetti & Hart, 2002), learning of a novel word may be facilitated by the presence of a familiar morpheme, given that this establishes an immediate link between word form and meaning. While lexical quality has primarily been explored in relation to established lexical representations, Perfetti, Wlotko and Hart (2005) observed individual differences in the quality of new lexical representations after just 50 minutes of exposure. As lexical quality encompasses both individual-level and item-level variation, it should also be possible to capture differences arising from properties of the words being learned.

There is some evidence to support the view that morphological regularities support lexical quality. Reichle and Perfetti (2003) used computational simulations to show that repeated encounters with words overlapping in orthographic, phonological and semantic features (e.g., *break*, *breaking* and *unbreakable*) affected the extent to which the stem (*break*) was familiar (a proxy for how well a word is established in a reader's vocabulary) and available (a proxy for lexical quality). Interestingly, stems with high-frequency inflected forms – a measure of token frequency – were more familiar and available than stems with low-frequency inflected forms, but the same was not observed for derivations. What mattered instead was the number of different derived words containing the stem (i.e., type frequency). Stems that took many derived forms had higher availability, meaning that phonological and semantic information was retrieved more readily from orthographic input compared with stems with fewer derived forms. However, familiarity was unaffected by type frequency. Given that morphological regularities operate across both stems and affixes, it is plausible that a similar boost for lexical quality may be observed based on consistencies in the semantic and syntactic function of affixes. Several models of morphological processing posit a role for amodal affix representations (e.g., Schreuder & Baayen, 1995; Taft, 2006), although it is likely that these are slower to emerge than stem representations because their semantic function is typically less transparent (Tyler & Nagy, 1989, 1990).

Aside from theoretical implications, there are practical motivations for examining whether children benefit from the presence of familiar affixes when learning novel words. The vast majority of word learning occurs incidentally because the number of words children are exposed to during the school years far outweighs that which can feasibly be taught via direct instruction (Nagy & Anderson, 1984). Therefore, it is important to understand the factors that influence word learning in children and how this might vary across items. These questions may be particularly pertinent to older children and adolescents, as knowledge of derivational morphology continues to develop well beyond early childhood, while the proportion of morphologically complex words encountered in reading materials increases (Nagy & Anderson, 1984; Nippold & Sun, 2008). A strong oral vocabulary is likely to support access to such materials, given that word knowledge and understanding of morphological relationships play an important part not only in oral language comprehension but also in word reading and reading comprehension (Deacon, Tong, & Francis, 2017; Gough & Tunmer, 1986; Harm & Seidenberg, 2004; Nation & Snowling, 2004; Perfetti & Stafura, 2014).

The aim of the reported study was to investigate whether adolescents capitalise on the presence of familiar suffixes when learning novel words. Our approach was to teach 18 target novel words (known suffix with new stem) and manipulate the relationship between these items and their definitions. In one condition, the definition was congruent with the typical semantic and syntactic properties of the suffix (congruent condition), while in the other condition, there was a mismatch (incongruent condition). Following two training sessions on separate days, we examined the impact of this manipulation on learning, as measured through four tasks designed to tap lexical quality. These comprised a semantic recall task (measuring semantic learning), a shadowing task (measuring phonological learning), a lexical decision task (measuring lexicalisation of nonwords) and a spelling task (measuring orthographic learning). We hypothesised that if adolescents are sensitive to the semantic and syntactic properties of suffixes and use this information in the word learning process, then participants should show better learning across all tasks in the congruent condition compared with the incongruent condition. Two groups of adolescents participated (12–13 and 16–18 years), permitting exploration of developmental effects. We reasoned that if knowledge about the function of suffixes builds through accumulated experience of affixes and their syntactic, semantic and combinational properties across a range of contexts, then the congruency effect may be greater for older adolescents compared with younger adolescents (Nippold & Sun, 2008; Tyler & Nagy, 1989).

Methods

Participants

Participants were 39 younger adolescents (*M* age = 13.25, *SD* = 0.33, 18 female) and 39 older adolescents (*M* age = 18.21, *SD* = 1.09, 36 female). Younger adolescents were recruited from a mainstream secondary school based in the south-east of England. Older adolescents comprised participants recruited from a sixth form college (*n* = 21), also in the south-east of England, who were entered into a prize draw to win a £40 Amazon voucher for their participation, and first year psychology undergraduate students (*n* = 18)[1] attending Royal Holloway, University of London, who participated in return for course credits.

The study was approved by the University Research Ethics Committee at Royal Holloway, University of London. The final sample comprised participants who were all native English speakers, none of whom had a known special educational need.

Materials and procedure

Background measures. Participants completed standardised measures of nonverbal reasoning (using the Matrix Reasoning subtest of the Wechsler Abbreviated Scale of Intelligence – Second Edition [WASI-II]; Wechsler, 2013), oral vocabulary (using the Vocabulary subtest of the WASI-II; Wechsler, 2013) and word and nonword reading efficiency (using the Sight Word Efficiency and Phonemic Decoding Efficiency subtests of the Test of Word Reading Efficiency – Second Edition; Torgesen, Wagner, & Rashotte, 2012).

Experimental task

Stimuli comprised 18 nonwords and 18 definitions (see Appendix A). Nonwords were formed by combining a CCVCC phonotactically and orthographically legal nonword stem with one of three existing derivational suffixes: *-ist*, *-ise* or *-ful*. These suffixes were selected because they are early acquired (Clark & Cohen, 1984) and appear in the spontaneous speech of children under 5 years (Laws, 2019) and thus are highly likely to be familiar to adolescent readers (Mahony, 1994). Each suffix creates a different part of speech (noun, verb and adjective, respectively), and all can be considered ‘neutral’ in that they do not typically modify the pronunciation of the stem (Tyler & Nagy, 1989). All nonword items comprised eight letters corresponding to either seven or eight phonemes, and none had any existing orthographic neighbours (based on the CELEX written database and calculated using N-WATCH; Davis, 2005). Mean log bigram frequency was similar across items (see Appendix A for item characteristics). For each nonword, we created two definitions. One was congruent (syntactically and semantically) with the suffix; the other was incongruent. For example, the suffix *-ist* most commonly forms an agent noun (Laws & Ryder, 2014). The corresponding congruent definition for the nonword item *clantist* was ‘a person who investigates crop circles’, while the incongruent definition was ‘to ruin the taste of something’.

We created two lists, each containing all 18 nonwords and all 18 definitions. Pairing of nonwords and definitions was counterbalanced across lists, such that each nonword was matched with its congruent definition in one list and an incongruent definition in the other list. Thus, each list contained nine items with a congruent nonword–definition pairing and nine items with an incongruent pairing. In both lists, each suffix appeared three times in each condition. Participants were randomly assigned to List 1 (n = 38) or List 2 (n = 40), such that each child learned the same set of nonwords and the same set of definitions, but matching of nonword to definition depended on which version of the experiment they completed.

Procedure. Testing took place across two sessions, spaced 1 week apart, and these were completed individually or in pairs in a quiet room in school, college or at the university. Session 1 comprised the first training session and the majority of background measures, while Session 2 comprised the second training session, any remaining background measures and the post-tests. Unless otherwise stated, the E-PRIME 2.0 programme (Schneider, Eschman, & Zuccolotto, 2012a, 2012b) was used to present instructions and stimuli and to record responses for all experimental tasks. Figure 1 presents a summary of the procedure.

Training session 1. In the first training session, participants completed a series of five computerised tasks designed to familiarise them with the phonological, semantic and orthographic features of the nonwords. Each activity followed a test–response–feedback format to promote learning (Karpicke & Blunt, 2011). The correct target (nonword or definition) was provided in the feedback regardless of the participant's response to ensure that all participants received an equal number of exposures. All 18 nonwords were presented in each task. The trained definition associated with each nonword depended on condition (congruent versus incongruent). All examples presented here are taken from the congruent condition: a full list of stimuli for each condition is available on the Open Science Framework (https://osf.io/s897h/?view_only=6781ade268cf4744859b5a3b283e6fcc).

In Task 1, participants were asked to guess the definition of the nonword when it was presented in a meaningful sentence context (e.g., 'as the lead clantist, Rav arrived at the field early to study the mysterious shapes in the corn'). They were then provided with the correct definition. In Task 2, they were asked to select the target definition from a choice of three, receiving feedback on accuracy and the target definition. In Task 3, each definition was presented via audio, and participants were asked to recall the item aloud. Feedback included the target pronunciation. In Task 4, participants were presented with the nonword in the context of two sentences. One was congruent with the taught definition but did not provide additional cues to meaning; the other was incongruent. For example, if the definition for *clantist* was 'a person who investigates crop circles', then the target (congruent) sentence was 'Abby trained for several years as a clantist' while the distractor (incongruent) sentence was 'Lucy worried that she might clantist the cake'. Participants were asked to select the appropriate sentence for the given item and were provided with feedback on accuracy, along with the trained definition for that item. In the final task, each of the nonwords was displayed on the screen followed immediately by either its associated definition or a distractor, which was randomly sampled from the 17 other definitions. Participants were required to indicate whether the pairing matched by pressing *m* or *z* on the keyboard.

Training session 2. The second training session repeated the first task from Session 1, followed by a multiple choice activity in which participants were presented with each

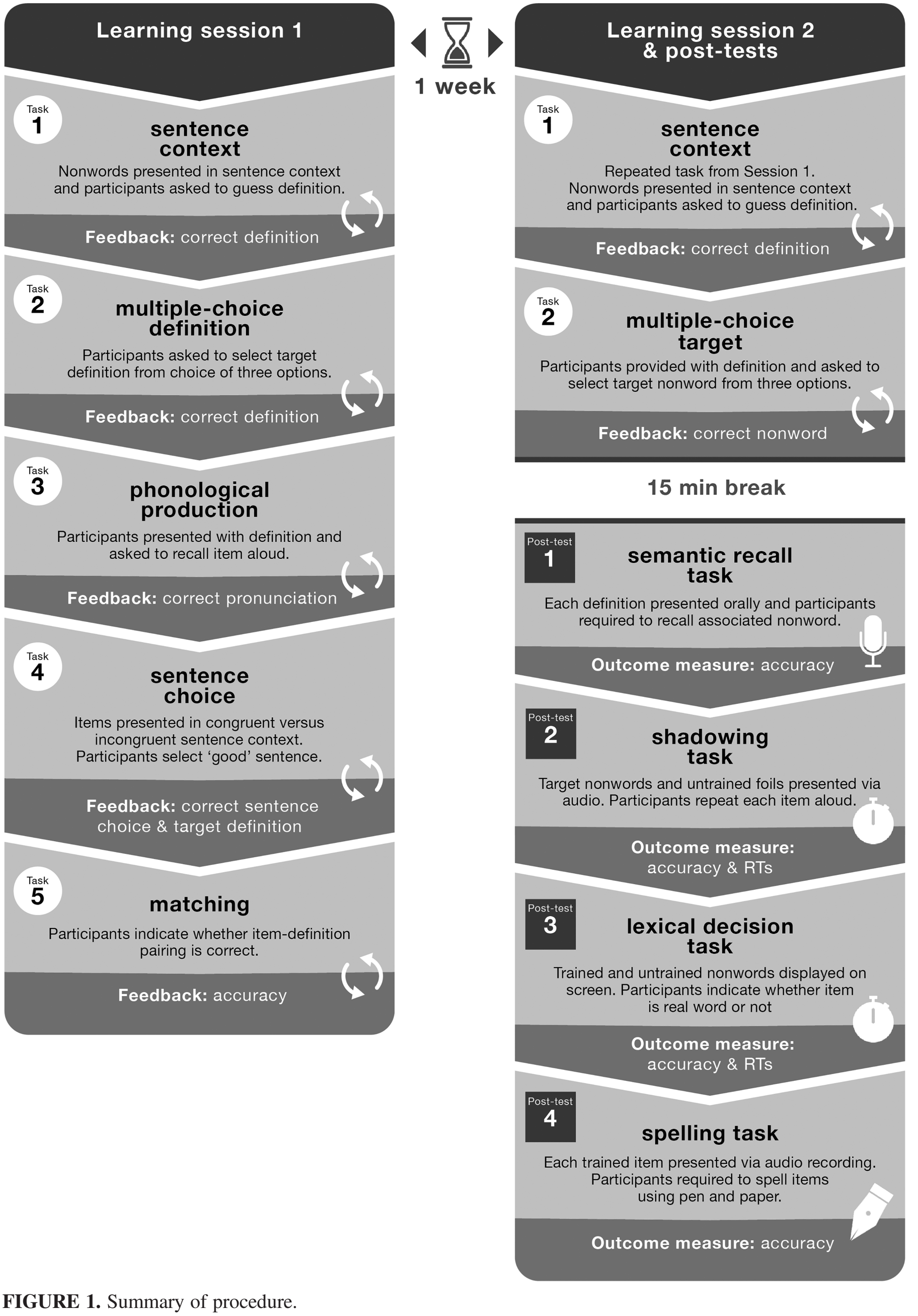

FIGURE 1. Summary of procedure.

definition in turn and were required to select from a choice of three nonwords: the target item and two distractors. The distractors were both other trained items, one sharing a suffix with the target and the other comprising a different suffix. Feedback included the correct target.

Post-tests. Four post-tests were conducted at the end of the second session, following a break of approximately 15 minutes while participants completed an unrelated activity. These were completed in set order as outlined below:

1 Semantic recall task. This task assessed learning of mappings between semantics and phonology. Each definition was presented orally in random order and participants were required to respond verbally with the associated nonword. Responses were audio recorded and later transcribed. Accuracy was calculated using Levenshtein phonological distances. These scores captured the phonological proximity of responses to target pronunciations based on the number of substitutions, deletions, additions and transpositions. Levenshtein distances were calculated using the stringdist package (van der Loo, 2014) in R and were inverted to give a similarity score between 0 and 1, where 0 represents complete dissimilarity and 1 represents complete similarity. Reliability for semantic recall scores was good (Cronbach's α = .81).

2 Shadowing task. Learning of phonological forms was assessed using a shadowing task (Bates & Liu, 1996), in which 18 trained nonwords and 18 untrained foils were presented in random order via audio recordings, and participants were required to repeat each item aloud as quickly and accurately as possible. Untrained foils were derived from each of the trained items by substituting two phonemes: the vowel in the trained nonword 'stem' was replaced by an alternate vowel, and one phoneme was substituted from the suffix to create a nonmorphological ending (e.g., the foil for *clantist* was *clontilt*). Two practice items were presented at the start of the procedure. DMDX software (Forster & Forster, 2003) was used to present stimuli and audio record responses.Following testing, each audio file was processed manually by marking stimulus and response onset times using CHECKVOCAL software (Protopapas, 2007) by an experimenter who was blind to the congruency condition. Response times were calculated as the time in milliseconds between stimulus onset and response onset. This approach was taken to allow for formulation of responses prior to the offset of the stimulus (Marslen-Wilson, 1973). Because stimulus length varied marginally across items, stimulus duration was calculated for each item. To maximise accuracy, stimulus duration was calculated twice for each item, once using CHECKVOCAL and once using PRAAT software (Boersma & Weenink, 2017), and mean stimulus length across the two measures was included as a covariate in the models. Stimulus duration did not vary systematically across trained (M = 817.44, SD = 88.78) and untrained (M = 830.48, SD = 96.53) conditions, t (34) = −0.42, p = .676. Shadowing data were only available for half of the older adolescent group (the participants recruited from university). The inclusion of untrained foils in this task permitted exploration of general effects of training on phonological learning in addition to the congruency effect. Reliability was acceptable for accuracy (Cronbach's α = .72) and good for reaction times (RTs; Cronbach's α = .99).

3 Lexical decision task. A lexical decision task was used to establish whether the training sessions made the targets (newly learned words) harder to reject as nonwords, thus indicating lexicalisation, and whether this effect was greater in the congruent versus incongruent condition. Seventy-two words were presented with 72 nonwords, and participants were asked to indicate by pressing a letter on the keyboard whether or not each was a real word that they knew, as quickly as possible. Nonwords comprised the 18 trained items (e.g., *clantist*), 18 nonword items created by recombining the trained stems with trained suffixes (recombined; e.g., *clantful*), 18 nonword items that combined untrained stems (formed by substituting a vowel in the trained stem) with

trained suffixes (untrained stem; e.g., *clontist*), 18 nonword items that combined trained stems with untrained suffixes (untrained suffix; e.g., *clantify*) and 18 nonword items in which the stem comprised a vowel substitution and the suffix also contained a letter/phoneme substitution (distant; e.g., *clontilt*). Participants were asked to treat targets as nonwords so that comparisons could be made across responses to different nonword types without the additional confounds associated with comparing 'yes' versus 'no' responses (e.g., RTs and handedness). Participants were shown 12 practice items followed by the experimental items. Each trial began with a black fixation cross, which appeared in centre of the screen for 1,000 ms, followed by the target, which appeared on screen until a response was made. For the practice items only, participants were given feedback on RTs and accuracy.Training effects were indexed by comparing response accuracy and RTs to trained items (e.g., *clantist*) versus each type of untrained nonword. Evidence of learning was indexed through interference in rejection of trained nonword relative to other types of nonword. The effect of congruency was investigated by comparing accuracy and RTs to trained items taught in the congruent versus incongruent condition. If stronger lexical representations were formed for items taught in the congruent condition, then a congruency effect would be expected for trained items, with greater interference observed for congruent versus incongruent items. Reliability was good for accuracy scores (Cronbach's α = .90) and acceptable for RTs (Cronbach's α = .78).

4 Spelling task. To measure orthographic learning, participants were presented with each trained item via audio recording and produced spellings using pen and paper. Responses were scored as correct (1) or incorrect (0). Illegible responses were removed from the analyses. Two participants did not complete the spelling task due to time constraints. We expected that performance on this task would be near ceiling, given that participants could rely on their existing knowledge of grapheme–phoneme correspondences to spell the items correctly. Therefore, a second score was calculated for accuracy of suffix spellings to examine any effect of condition on the use of morphological spelling strategies. Reliability was good for general spelling accuracy (Cronbach's α = .82) and suffix spelling accuracy (Cronbach's α = .83).

Results

Table 1 summarises performance by age group on background measures. Mean scores indicate that both groups performed close to test norms on standardised measures. All analyses reported below were conducted using R (R Core Team, 2019) and the lme4 package

TABLE 1. Means and standard deviations for background measures by age group

Measure	Younger (*M* age = 13.25)		Older (*M* age = 18.21)	
	M	*SD*	*M*	*SD*
Nonverbal ability[a]	46.05	7.81	51.76	9.72
Oral vocabulary[a]	49.85	7.37	54.97	8.93
Word reading efficiency[b]	98.51	11.62	105.49	13.65
Nonword reading efficiency[b]	100.64	11.72	104.95	9.89

[a]*t* scores: *M* = 50, *SD* = 10.
[b]Standard scores: *M* = 100, *SD* = 15.

(Bates, Maechler, Bolker, & Walker, 2015). Binary outcome measures (e.g., accuracy) were analysed using generalised linear effects models, while continuous outcomes (e.g., RTs) were analysed using linear mixed effects models. Inverse transformations were performed on all RT data prior to analysis to correct for distribution skews, and only RTs for correct responses were analysed. For the analyses, outliers were removed by excluding RTs exceeding 3.5 standard deviations from the mean for each participant.

Two-level factors were centred using deviation coding, and continuous predictors were centred around the mean. Random effects structures were determined by identifying the maximal model (Barr, Levy, Scheepers, & Tily, 2013), which included by-participant and by-item random intercepts, along with by-participant random slopes for within-subjects predictors and by-item random slopes for within-item predictors. Where the maximal model failed to converge or resulted in a singular fit, indicating that the model was overparameterised, we followed suggestions outlined in Brauer and Curtin (2018) to identify the most complex model supported by the data. Output summaries for each model, along with the R scripts and raw data files used for the analyses, can be found on the Open Science Framework.

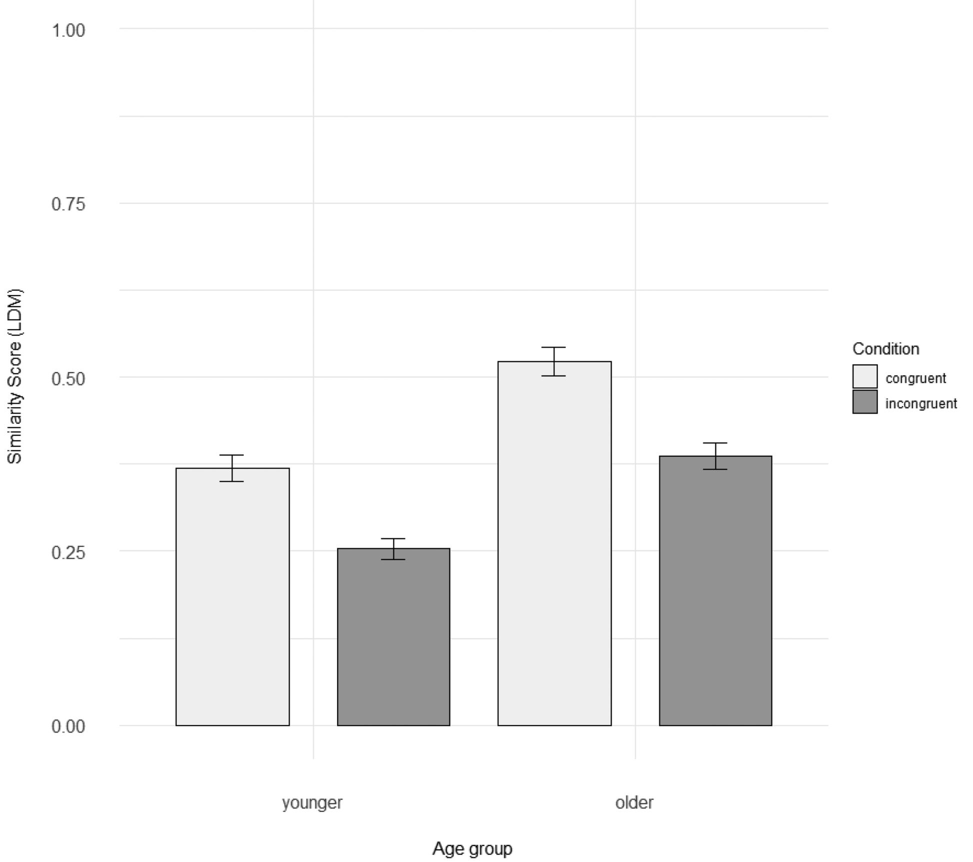

FIGURE 2. Mean Levenshtein similarity score with standard error bars by age group and condition (semantic recall task).

Semantic recall task

Learning of mappings between phonology and semantics was indexed through performance on the semantic recall task using Levenshtein phonological distances (Figure 2).

Condition (congruent versus incongruent), age group (younger versus older adolescents) and the condition by age group interaction were entered into the model as fixed effects, with similarity score as the dependent variable. Analysis revealed a significant effect of condition (congruent > incongruent; $\beta = .13$, $SE = 0.02$, $t = 7.17$, $p < .001$), a significant effect of age group (older adolescents > younger adolescents; $\beta = .14$, $SE = 0.04$, $t = 3.54$, $p < .001$), but no condition by age group interaction ($\beta = .02$, $SE = 0.04$, $t = 0.53$, $p = .600$).

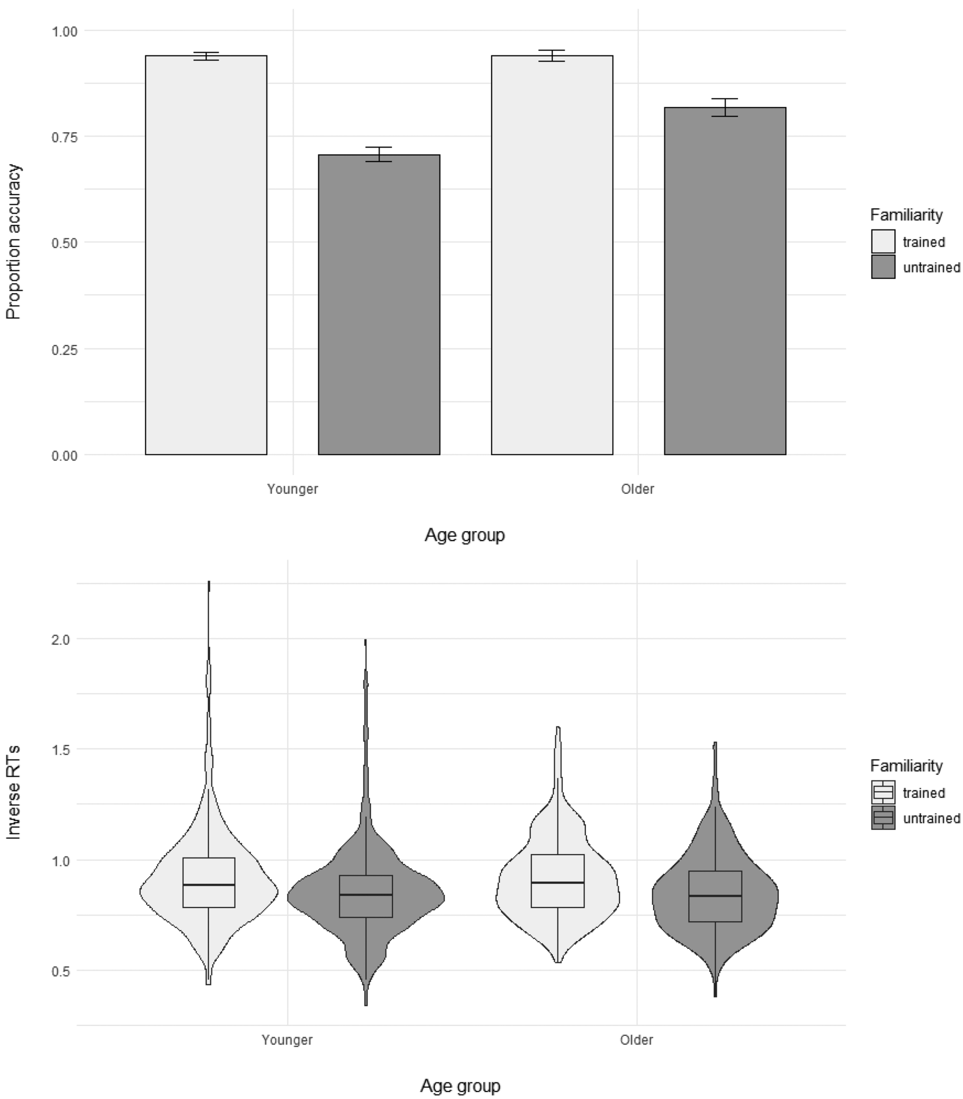

FIGURE 3. Mean proportion accuracy (upper panel) and inverted reaction times (RTs) (lower panel) for trained versus untrained items by age group (shadowing task).

Shadowing task

Learning of phonological forms was indexed through performance on the shadowing task.

Effect of training. To examine whether training led to learning of phonological forms, we compared accuracy and RTs between the 18 trained items and 18 untrained foils. Figure 3 shows mean proportion accuracy and inverse RTs for trained versus untrained items by age group.

Accuracy. Four individual data points were removed due to a software audio recording error: three from the younger adolescent group and one from the older adolescent group. Analysis revealed a significant effect of training, with higher accuracy in responses to trained versus untrained items ($\beta = 1.65$, $SE = 0.36$, $z = 4.65$, $p < .001$). The effect of age group was not significant ($\beta = .31$, $SE = 0.29$, $z = 1.06$, $p = .290$), but there was a slight trend towards a significant familiarity by age group interaction ($\beta = -.74$, $SE = 0.44$, $z = -1.67$, $p = .096$), with a greater effect of training for the younger adolescents.

Reaction times. Analysis of the RT data revealed a significant effect of training ($\beta = .06$, $SE = 0.01$, $t = 5.81$, $p < .001$), with shorter RTs to trained compared with untrained items. There was also a significant effect of stimulus duration: longer stimulus durations were associated with longer RTs ($\beta = -.02$, $SE = 0.00$, $t = -4.89$, $p < .001$). Age group ($\beta = .00$, $SE = 0.05$, $t = 0.03$, $p = .975$), the age group × familiarity interaction ($\beta = .01$, $SE = 0.01$, $t = 0.53$, $p = .600$) and the stimulus duration × familiarity interaction ($\beta = -.01$, $SE = 0.01$, $t = -0.77$, $p = .449$) were not significant.

Effect of condition. To examine the effect of condition on phonological learning, analyses of accuracy and RTs were conducted on trained items only. In each analysis, condition (congruent versus incongruent), age group (younger versus older) and their interaction were entered into the model as fixed effects. Figure 4 shows mean proportion accuracy and inverse RTs for congruent versus incongruent items by age group.

Accuracy. Three individual data points were removed due to a software audio recording error: two from the younger adolescent group and one from the older adolescent group. Response accuracy did not differ significantly between items taught in the congruent compared with the incongruent condition ($\beta = -.28$, $SE = 0.29$, $z = -0.97$, $p = .332$), and neither was age group ($\beta = -.03$, $SE = 0.36$, $z = -0.07$, $p = .942$) or the condition × age group interaction ($\beta = .29$, $SE = 0.58$, $z = 0.50$, $p = .615$) a significant predictor of accuracy.

Reaction times. There was a significant effect of stimulus duration ($\beta = -.02$, $SE = 0.01$, $t = -4.83$, $p < .001$), with longer durations associated with slower RTs. The effects of condition ($\beta = -.00$, $SE = 0.01$, $t = -0.24$, $p = .808$), age group ($\beta = .00$, $SE = 0.05$, $t = 0.10$, $p = .921$), the condition × age group interaction ($\beta = .02$, $SE = 0.02$, $t = 0.92$, $p = .360$) and the condition × stimulus duration interaction ($\beta = .01$, $SE = 0.01$, $t = 1.29$, $p = .197$) on RTs were not significant.

Lexical decision task. Lexicalisation of nonwords was measured through performance on the lexical decision task.

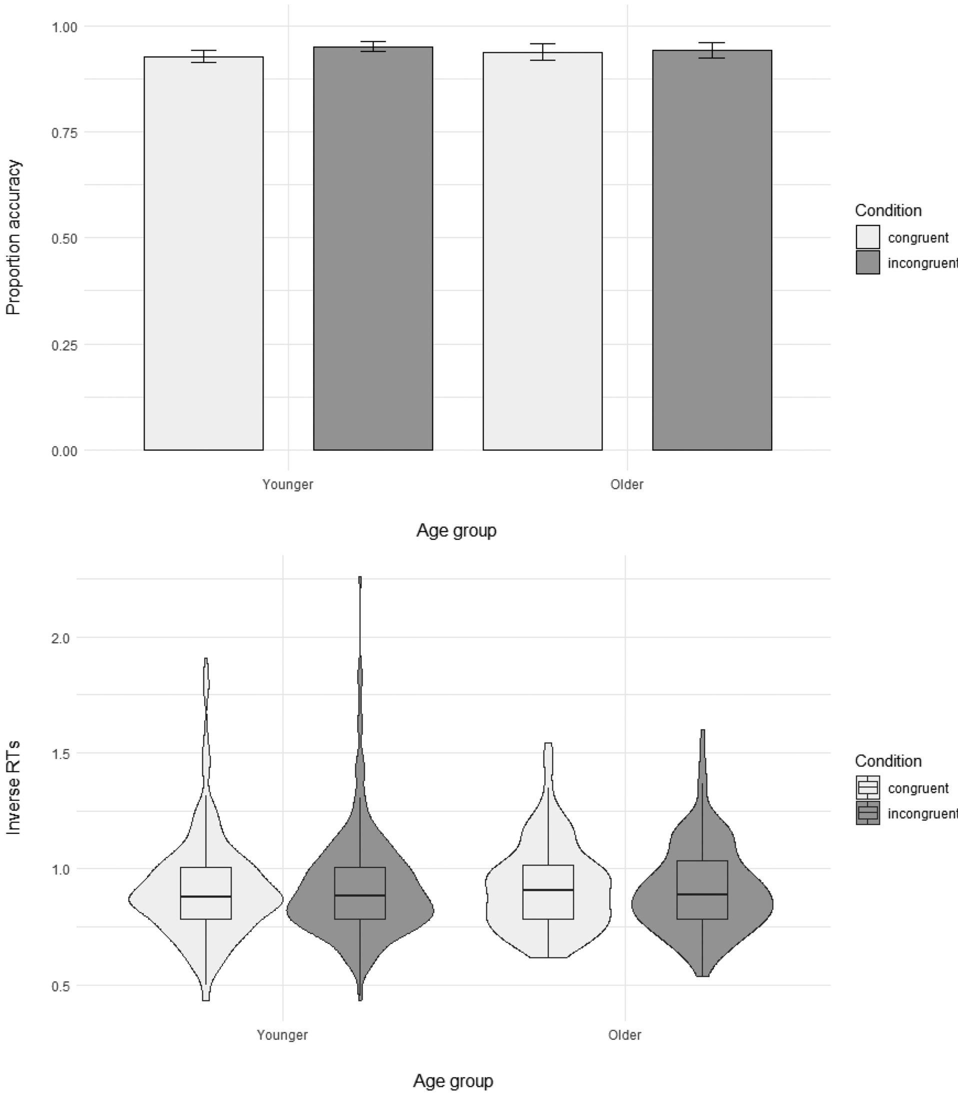

FIGURE 4. Mean proportion accuracy (upper panel) and inverted reaction times (RTs) (lower panel) for congruent versus incongruent items by age group (shadowing task).

Effect of training. To examine the effect of training on lexicalisation of nonwords (indexed by interference in nonword rejections), we compared accuracy and RTs of responses to trained versus untrained nonwords (Figure 5).

Accuracy. Analysis revealed a significant effect of nonword type: across age groups, accuracy was lower for trained nonwords compared with recombined nonwords (β = .58, SE = 0.21, z = 2.72, p = .006), nonwords with untrained stems (β = .62, SE = 0.21, z = 2.97, p = .003), distant nonwords (β = 1.47, SE = 0.27, z = 5.43, $p < .001$) and a trend towards lower accuracy relative to nonwords with untrained suffixes (β = .40, SE = 0.20, z = 1.96, p = .050). Together, these findings suggest greater interference in nonword rejections for trained nonwords relative to all other nonword types. There was also a significant

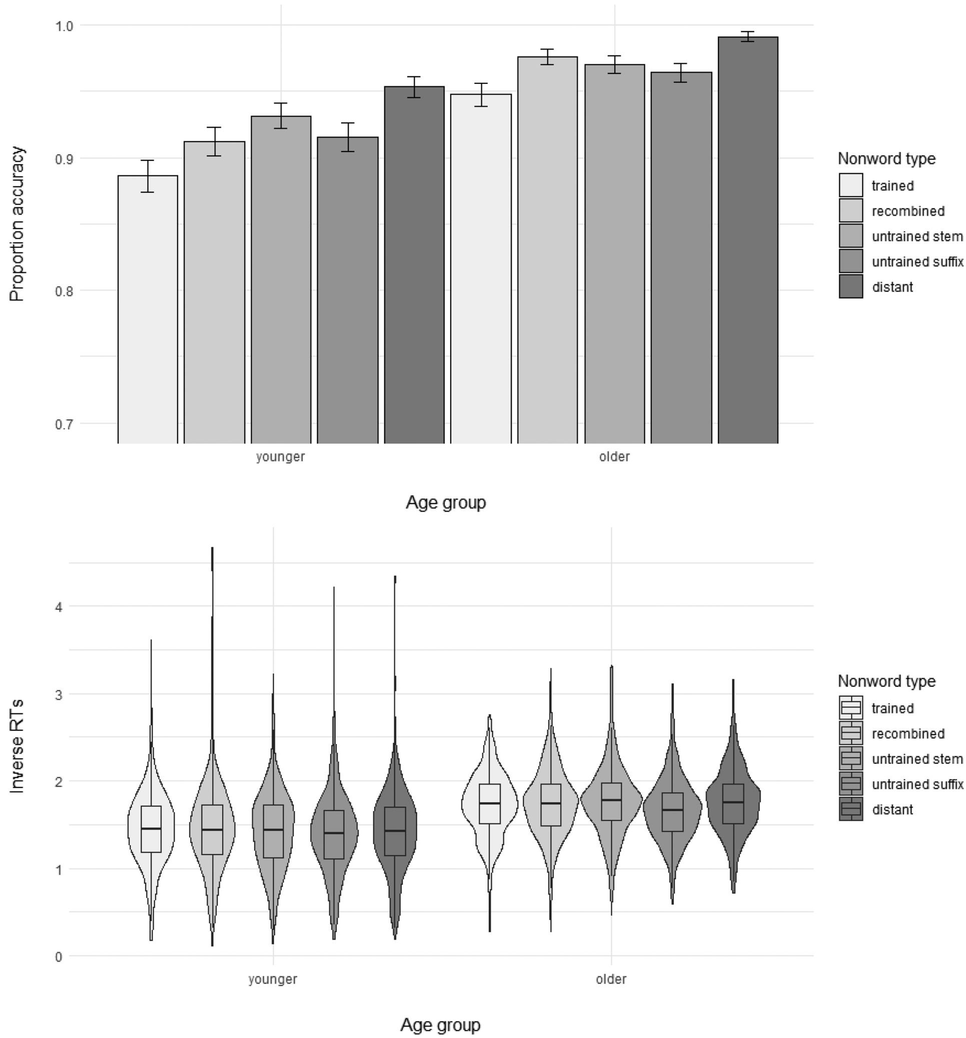

FIGURE 5. Mean proportion lexical decision accuracy (upper panel) and inverse reaction times (RTs) (lower panel) for trained versus untrained nonword types by age group (lexical decision task).

effect of age group (β = .73, *SE* = 0.31, z = 2.40, p = .016), with higher accuracy in the older age group compared with the younger age group. There was no interaction between age group and nonword type.

Reaction times. Inspection of the trimmed data revealed a number of remaining outliers in the younger adolescent group. Closer investigation showed that these arose primarily from one participant who showed large variation in response times; hence, a number of responses of less than 100 ms were not removed by the trimming procedure. Given that lower estimates of simple reaction times are around 200 ms (Woods, Wyma, Yund, Herron, & Reed, 2015), it is highly likely that such responses were initiated prior to the stimulus being displayed. Therefore, all individual RT data points below 200 ms were removed prior to analysis (n = 30).

Inspection of estimated coefficients from the model analysing RTs revealed, across age groups, a slower response to nonwords containing an untrained suffix relative to trained nonwords ($\beta = -.05$, $SE = 0.02$, $t = -2.25$, $p = .027$), an effect of age group, with older adolescents responding faster than younger adolescents overall ($\beta = .29$, $SE = 0.06$, $t = 5.22$, $p < .001$), and a significant interaction between age group and nonword type for the distant versus trained nonword comparison ($\beta = .06$, $SE = 0.03$, $t = 2.16$, $p = .031$), whereby younger adolescents showed a trend towards faster responses to trained versus distant nonwords, while older adolescents showed the inverse pattern. No other effects were significant.

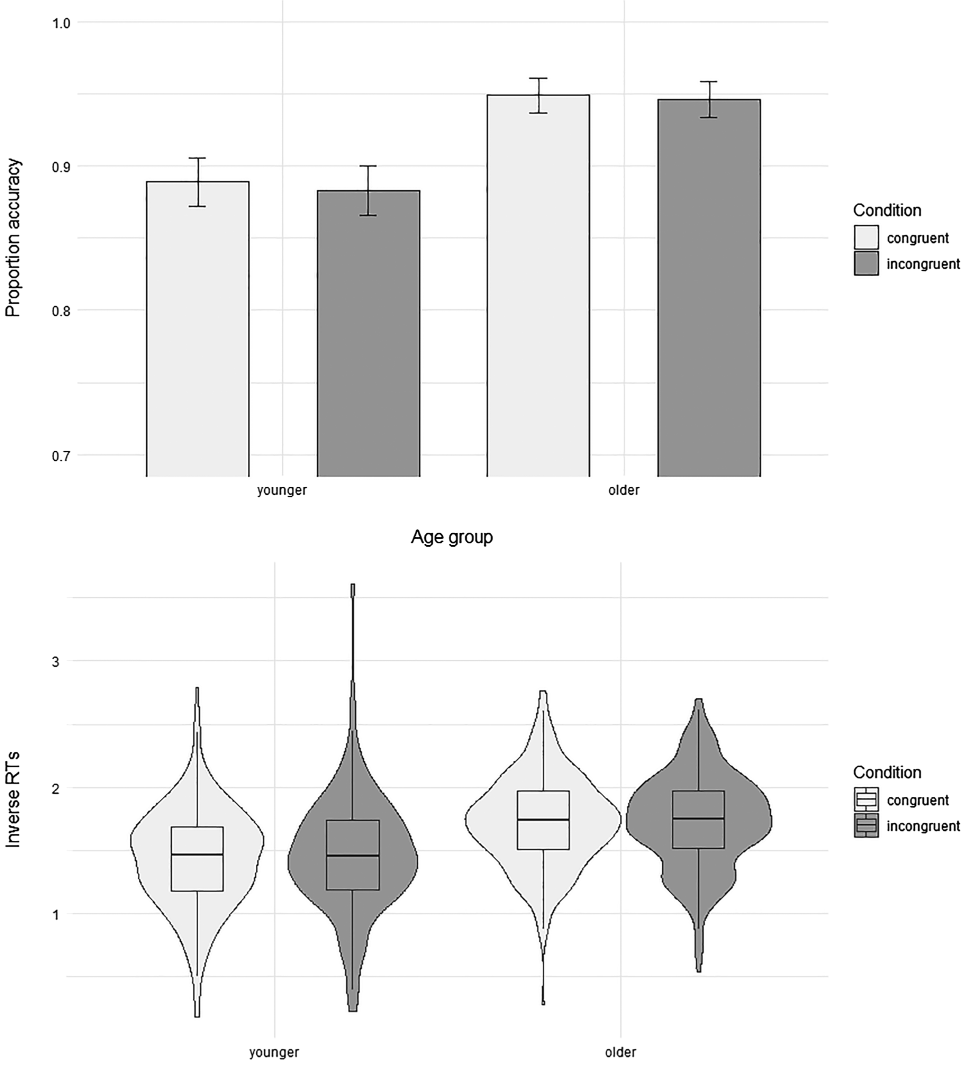

FIGURE 6. Mean proportion lexical decision accuracy (upper panel) and inverse reaction times (RTs) (lower panel) for trained nonwords taught in the congruent versus incongruent condition, by age group (lexical decision task).

Effect of condition. To examine the effect of congruency on nonword rejections, we compared accuracy and RTs of responses to trained items taught in the congruent versus incongruent conditions (Figure 6).

Accuracy. Analysis revealed a significant effect of age group, with older adolescents more accurate than younger adolescents overall (β = .79, *SE* = 0.33, z = 2.40, p = .016). However, there was no significant difference between items taught in the congruent versus incongruent condition (β = .38, *SE* = 0.39, z = 0.98, p = .330) and no interaction between age group and condition (β = − .04, *SE* = 0.50, z = −0.09, p = .929).

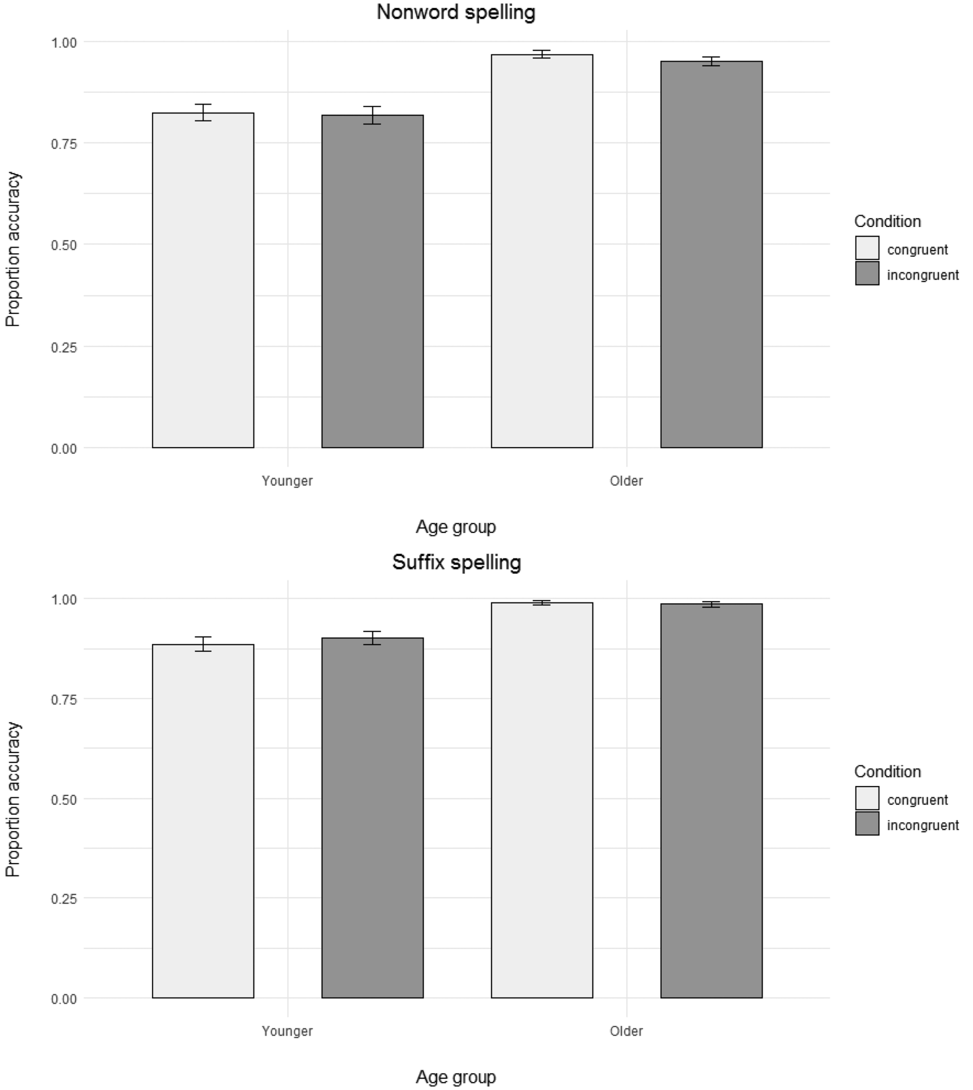

FIGURE 7. Mean proportion spelling accuracy for nonwords (upper panel) and suffixes (lower panel) with standard error bars for congruent versus incongruent items by age group.

Reaction times. Analysis revealed a significant effect of age group, with older adolescents responding faster than younger adolescents overall ($\beta = .29$, $SE = 0.05$, $t = 5.34$, $p < .001$). There was no effect of condition ($\beta = -.02$, $SE = 0.02$, $t = -0.86$, $p = .395$) and no condition × age group interaction ($\beta = .03$, $SE = 0.04$, $t = 0.62$, $p = .538$).

Spelling task

Figure 7 shows mean proportion nonword and suffix spelling accuracy for congruent versus incongruent items by age group. Inspection of means and standard deviations indicated that performance was at ceiling across both age groups.

General spelling accuracy. Condition, age group and their interaction were entered into the model as fixed effects. Estimated coefficients revealed a significant effect of age group, with older adolescents more accurate in their spellings than younger adolescents ($\beta = 2.09$, $SE = 0.44$, $z = 4.79$, $p < .001$). There was no effect of condition ($\beta = .06$, $SE = 0.24$, $z = 0.27$, $p = .789$) and no condition × age group interaction ($\beta = .46$, $SE = 0.49$, $z = 0.94$, $p = .347$).

Suffix spelling accuracy. Estimated coefficients again revealed a significant effect of age group, with older adolescents more accurate in their suffix spellings than younger adolescents ($\beta = 3.82$, $SE = 0.93$, $z = 4.10$, $p < .001$). Again, condition ($\beta = -.21$, $SE = 0.33$, $z = -0.65$, $p = .517$) and the condition × age group interaction ($\beta = .66$, $SE = 0.89$, $z = 0.74$, $p = .462$) were not significant.

Discussion

Our aim was to investigate whether younger and older adolescents benefit from the presence of familiar suffixes when learning novel words. We manipulated the relationship between the semantic and syntactic properties of derivational suffixes embedded in nonwords and the trained definition and examined the impact on semantic recall, phonological learning, lexicalisation and spelling of the novel words. Both groups of adolescents showed superior semantic recall of nonwords that were trained with a definition congruent with the suffix. However, while there was a clear effect of training and age group on performance in the online measures of learning (tapping phonological learning and lexicalisation of nonwords), we did not observe an effect of condition: responses to items trained in the congruent condition did not differ significantly from responses to those trained in the incongruent condition. Similarly, while older adolescents outperformed younger adolescents on the spelling measures, there was no effect of condition, although performance on this task was at ceiling. Below, we discuss each of these findings in turn.

Effects of training and congruency

We assessed semantic learning of target items by measuring the strength of the association between the trained definition and the phonological form of the nonword. Participants were provided with the definition and were asked to recall the item associated with that meaning. Analyses revealed that responses were more accurate for items taught in the congruent condition compared with the incongruent condition, and this was the case for both older and younger adolescents. These findings support the proposal that semantic and syntactic properties of suffixes facilitate links between word form and word meaning during the acquisition of new lexical representations. When this information was available (i.e., properties of the suffix were congruent with whole-word meaning), learning of semantics–phonology mappings were stronger than when the information was not available. This finding has both theoretical and practical implications. Theoretically, it aligns with the argument that morphological knowledge may contribute to word knowledge and word processing by supporting the development of high-quality lexical representations (Reichle & Perfetti, 2003). From an educational perspective, it suggests that adolescents benefit from familiar suffixes in words during word learning and that promoting understanding of morphological relationships may be a means to enhance acquisition of new vocabulary (Bowers & Kirby, 2010).

Phonological learning of target items was measured using shadowing (Bates & Liu, 1996), a speeded repetition task in which participants were presented with audio recordings of trained items and untrained foils. Given that this task has been shown to involve access to phonological information stored at the lexical level (Slowiaczek, 1994), we predicted a congruency effect, with higher accuracy and shorter RTs for items trained in the congruent compared with the incongruent condition. However, our analyses revealed no effect of congruency on either outcome measure, despite evidence of phonological learning of trained items in general, with both age groups responding faster and more accurately to trained nonwords compared with untrained foils.

Lexicalisation of trained items was investigated using a lexical decision task, in which interference in nonword rejection was used as evidence of learning (similar to the morpheme interference effect; Taft & Forster, 1975). Again, there was evidence of a general effect of training, with lower accuracy across age groups for trained nonwords compared with all other types of nonword, indicating that these items were more likely to be incorrectly accepted as words. However, neither the accuracy nor the RT data revealed any evidence of superior learning in the congruent condition. Similarly, no effect of congruency was observed in the spelling post-test, either for spelling of the whole nonword or the suffix. In both the lexical decision and spelling tasks, older adolescents outperformed younger adolescents, but this effect did not interact with condition. The findings from these outcome measures align with the absence of a congruency effect in the shadowing task but are surprising when considering the clear differences between conditions in the semantic recall task. Why might a congruency effect emerge in the semantic task but not in the speeded and written measures of learning?

One potential explanation is that the semantic recall task was the only measure to explicitly test the link between semantics (the taught definition) and word form (pronunciation). Although shadowing and visual lexical decision tasks are thought to activate representations in the phonological and orthographic lexicons, respectively (Coltheart, 2004; Slowiaczek, 1994), they could be completed without drawing on lexical–semantic knowledge at all, given that participants were asked to respond to trained items as nonwords in the lexical decision task. Similarly, the spelling task could be completed by drawing on general knowledge of phoneme–grapheme correspondences, coupled with pre-existing suffix knowledge. Because morphological structure provides links between word form and meaning, it may be that any benefits for lexical quality are best captured by tasks specifically examining these connections, as opposed to more general measures of lexical quality.

A second possibility is that because overall performance was higher on the online and spelling measures, they may not have been sufficiently sensitive to capture an effect of congruency after exposure to target items on just two separate occasions. Indeed, when responses on the semantic recall task were scored using a binary criterion (correct versus incorrect), accuracy was below 30% even for congruent items. A number of factors may have contributed to poor levels of recall. First, target items were quite similar: each suffix attached to six different items, and each stem had the same phonotactic structure (CCVCC). Second, exposure to items and their meanings was limited, with participants completing just two training sessions. Although these sessions were designed to maximise learning (e.g., by using a test–feedback procedure, providing contextual information, varying the tasks and allowing sleep consolidation between sessions; Henderson, Weighall, Brown, & Gaskell, 2012; Karpicke & Blunt, 2011), word knowledge is thought to build over repeated encounters across a diverse range of contexts (Nation, 2017). Therefore, the procedures adopted in the current study may have failed to produce sufficient variation in lexical quality to examine the effect of congruency with less sensitive measures.

Effects of age group

The comparisons across age group are interesting. We hypothesised that the effect of congruency may be greater for older adolescents than for younger adolescents, given the argument that knowledge of syntactic, semantic and combinational properties of affixes develops as a consequence of accumulated experience with those affixes across a diverse range of stems (Tyler & Nagy, 1989). Contrary to predictions, there was no interaction between congruency and age group in the semantic recall task, indicating that suffix information was equally facilitative for word learning in younger and older adolescents. However, a main effect of age group was observed across most tasks, with older adolescents outperforming younger adolescents on semantic recall accuracy, lexical decision speed and accuracy and both general and suffix spelling accuracy. No differences were observed on the shadowing task, indicating that age-related changes were primarily associated with tasks tapping orthographic or semantic representations. Evidence suggests that morphological knowledge during adolescence is best conceptualised as a multidimensional construct (Goodwin, Petscher, Carlisle, & Mitchell, 2015). It is possible, then, that advances in morphological knowledge across adolescence are not universal but reflect pockets of consolidation in specific domains.

Limitations and future directions

A potential, but important, limitation of our findings is that the incongruent definition referenced an entirely separate part of speech to the target suffix. It is therefore possible that differences in learning may have stemmed from interference in the incongruent condition, rather than facilitation in the congruent condition when suffix information was available. A more nuanced approach could be implemented by adopting the same part of speech across both conditions but varying the congruency between the semantic properties of the suffix and the definition (e.g., *clantist* might refer to ‘a person who investigates crop circles’ in the congruent condition and ‘a place under the sea’ in the incongruent condition).

A second limitation relates to the lexical decision post-test, in which participants were instructed to respond to the trained items as nonwords. This approach addressed the issue of comparing ‘yes’ versus ‘no’ responses in the subsequent analyses but was potentially confusing for participants. Our rationale was that interference effects for trained items (i.e., lower accuracy or slower RTs) would be indicative of greater familiarity with the orthographic forms of these nonwords compared with matched controls. Indeed, our analyses revealed graded effects on accuracy, whereby accuracy was most impaired for trained nonwords, less impaired for nonwords containing an existing suffix and least impaired for nonwords combining an unfamiliar stem and unfamiliar suffix.

Conclusion

We took a novel approach to examining whether adolescents benefit from the presence of familiar suffixes when learning unfamiliar words. We found some evidence that availability of semantic and syntactic properties of suffixes corresponded to better learning of novel items. However, this effect was not evident across all tasks. We adopted an explicit instruction approach to maximise learning and provide proof of concept, but future research may take a more naturalistic approach to explore whether morphological structure supports lexical quality in the context of incidental word learning from texts. This is particularly relevant for adolescent readers, given the increasing focus on 'reading to learn' and the large proportion of morphologically complex, low-frequency, but semantically interpretable words such readers are likely to encounter (Nagy & Anderson, 1984). Nevertheless, our findings provide a first step towards identifying the mechanisms by which morphological knowledge may support the development of high-quality lexical representations that underpin efficient lexical processing.

Conflict of interest

None.

Data availability statement

Our data and R scripts are available on the Open Science Framework (https://osf.io/s897h/?view_only=6781ade268cf4744859b5a3b283e6fcc).

Acknowledgements

This research was supported by Economic and Social Research Council grants awarded to Jessie Ricketts (grant number ES/K008064/1) and Kathleen Rastle (grant number ES/P001874/1).

Note

1. We oversampled psychology undergraduates (a subsample of the older adolescent group; original *n* = 31) because it was not possible to set inclusion criteria given that all first year undergraduates were eligible to participate in studies awarding course credits. We then excluded those who spoke English as an additional language (*n* = 8) or who reported a history of special educational needs (*n* = 2) following data collection. Three further participants were excluded due to software failure during the running of the experiment, leaving a total of 18.

References

Anglin, J.M. (1993). Vocabulary development: A morphological analysis. *Monographs of the Society for Research in Child Development*, 58(10), i–186. https://doi.org/10.2307/1166112

Barr, D.J., Levy, R., Scheepers, C. & Tily, H.J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, E. & Liu, H. (1996). Cued shadowing. *Language & Cognitive Processes*, 11(6), 577–582. https://doi.org/10.1080/016909696386962

Bates, D., Maechler, M., Bolker, B. & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Boersma, P., & Weenink, D. (2017). *Praat: Doing phonetics by computer [Computer program]*. Version 6.0.31, retrieved 21 August 2017 from http://www.praat.org/

Bowers, P.N. & Kirby, J.R. (2010). Effects of morphological instruction on vocabulary acquisition. *Reading and Writing*, 23(5), 515–537. https://doi.org/10.1007/s11145-009-9172-z

Brauer, M. & Curtin, J.J. (2018). Linear mixed-effects models and the analysis of nonindependent data: A unified framework to analyze categorical and continuous independent variables that vary within-subjects and/or within-items. *Psychological Methods*, 23(3), 389–411. https://doi.org/10.1037/met0000159

Brysbaert, M., Stevens, M., Mandera, P. & Keuleers, E. (2016). How many words do we know? Practical estimates of vocabulary size dependent on word definition, the degree of language input and the participant's age. *Frontiers in Psychology*, 7(JUL), 1–11. https://doi.org/10.3389/fpsyg.2016.01116

Clark, E.V. & Cohen, S.R. (1984). Productivity and memory for newly formed words. *Journal of Child Language*, 11(3), 611–625. https://doi.org/10.1017/S0305000900005985

Coltheart, M. (2004). Are there lexicons? *Quarterly Journal of Experimental Psychology*, 57A(7), 1153–1171. https://doi.org/10.1080/02724980443000007

Davis, C.J. (2005). N-watch: A program for deriving neighbourhood size and other pyscholinguistic statistics. *Behaviour Research Methods*, 37(1), 65–70. https://doi.org/10.3758/bf03206399

Deacon, S.H., Tong, X. & Francis, K. (2017). The relationship of morphological analysis and morphological decoding to reading comprehension. *Journal of Research in Reading*, 40(1), 1–16. https://doi.org/10.1111/1467-9817.12056

Forster, K.I. & Forster, J.C. (2003). DMDX: A windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers*, 35(1), 116–124. https://doi.org/10.3758/BF03195503

Goodwin, A.P., Petscher, Y., Carlisle, J.F. & Mitchell, A.M. (2015). Exploring the dimensionality of morphological knowledge for adolescent readers. *Journal of Research in Reading*, 00(00), 1–27. https://doi.org/10.1111/1467-9817.12064

Gough, P.B. & Tunmer, W.E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education*, 7(1), 6–10. https://doi.org/10.1177/074193258600700104

Harm, M.W. & Seidenberg, M.S. (2004). Computing the meanings of words in reading: Cooperative division of labor between visual and phonological processes. *Psychological Review*, 111(3), 662–720. https://doi.org/10.1037/0033-295X.111.3.662

Henderson, L.M., Weighall, A.R., Brown, H. & Gaskell, M.G. (2012). Consolidation of vocabulary is associated with sleep in children. *Developmental Science*, 15(5), 674–687. https://doi.org/10.1111/j.1467-7687.2012.01172.x

Karpicke, J.D. & Blunt, J.R. (2011). Retrieval practices produces more learning than concept mapping. *Science*, 331(6018), 772–775. https://doi.org/10.1126/science.1199327

Law, J., Rush, R., Schoon, I. & Parsons, S. (2009). Modeling developmental language difficulties from school entry into adulthood: Literacy, mental health, and employment outcomes. *Journal of Speech Language and Hearing Research*, 52(6), 1401–1416. https://doi.org/10.1044/1092-4388(2009/08-0142

Laws, J. (2019). Profiling complex word usage in the speech of preschool children: Frequency patterns and transparency characteristics. *First Language*, 39(6), 593–617. https://doi.org/10.1177/0142723719872669

Laws, J. & Ryder, C. (2014). Getting the measure of derivational morphology in adult speech: A corpus analysis using MorphoQuantics. *Language Studies Working Papers*, 6, 3–17.

van der Loo, M.P.J. (2014). The stringdist package for approximate string matching. *R Journal*, 6(1), 111–122.

Mahony, D.L. (1994). Using sensitivity to word structure to explain variance in high school and college level reading ability. *Reading and Writing*, 6(1), 19–44. https://doi.org/10.1007/BF01027276

Marslen-Wilson, W. (1973). Linguistic structure and speech shadowing at very short latencies. *Nature*, 244(5417), 522–523. https://doi.org/10.1038/244523a0

Morgan, P.L., Farkas, G., Hillemeier, M.M., Hammer, C.S. & Maczuga, S. (2015). 24-month-old children with larger oral vocabularies display greater academic and behavioral functioning at kindergarten entry. *Child Development*, 86(5), 1351–1370. https://doi.org/10.1111/cdev.12398

Nagy, W.E. & Anderson, R.C. (1984). How many words are there in printed school English. *Reading Research Quarterly*, 19(3), 304–330. https://doi.org/10.2307/747823

Nation, K. (2017). Nurturing a lexical legacy: Reading experience is critical for the development of word reading skill. *Npj Science of Learning*, 2(1), 1–4. https://doi.org/10.1038/s41539-017-0004-7

Nation, K. & Snowling, M.J. (2004). Beyond phonological skills: Broader language skills contribute to the development of reading. *Journal of Research in Reading*, 27(4), 342–356. https://doi.org/10.1111/j.1467-9817.2004.00238.x

Nippold, M.A. & Sun, L. (2008). Knowledge of morphologically complex words: A developmental study of older children and young adolescents. *Language, Speech, and Hearing Services in Schools*, 39(July), 365–373. https://doi.org/10.1044/0161-1461(2008/034

Pacton, S., Afonso Jaco, A., Nys, M., Foulin, J.N., Treiman, R. & Peereman, R. (2018). Children benefit from morphological relatedness independently of orthographic relatedness when they learn to spell new words. *Journal of Experimental Child Psychology*, 171, 71–83. https://doi.org/10.1016/j.jecp.2018.02.003

Pacton, S., Foulin, J.N., Casalis, S. & Treiman, R. (2013). Children benefit from morphological relatedness when they learn to spell new words. *Frontiers in Psychology*, 4, 1–7. https://doi.org/10.1016/j.jecp.2018.02.003

Perfetti, C. & Hart, L. (2002). The lexical quality hypothesis. In L. Verhoeven, C. Elbro & P. Reitsma (Eds.), *Precursors of functional literacy* (pp. 189–213). Amsterdam/Philadelphia, US: John Benjamins.

Perfetti, C. & Stafura, J. (2014). Word knowledge in a theory of reading comprehension. *Scientific Studies of Reading*, 18(1), 22–37. https://doi.org/10.1080/10888438.2013.827687

Perfetti, C., Wlotko, E.W. & Hart, L.A. (2005). Word learning and individual differences in word learning reflected in event-related potentials. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, 31(6), 1281–1292. https://doi.org/10.1037/0278-7393.31.6.1281

Protopapas, A. (2007). CheckVocal: A program to facilitate checking the accuracy and response time of vocal responses from DMDX. *Behavior Research Methods*, 39(4), 859–862. https://doi.org/10.3758/BF03192979

R Core Team. (2019). *R: A language and environment for statistical computing* (3.6.2). R Foundation for Statistical Computing. https://www.r-project.org/

Rastle, K. (2019). EPS Mid-Career Prize Lecture 2017: Writing systems, reading, and language. *The Quarterly Journal of Experimental Psychology*, 72(4), 677–692. https://doi.org/10.1177/1747021819829696

Reichle, E.D. & Perfetti, C. (2003). Morphology in word identification: A word–experience model that accounts for morpheme frequency effects. *Scientific Studies of Reading*, 7(3), 219–237. https://doi.org/10.1207/S1532799XSSR0703

Schneider, W., Eschman, A. & Zuccolotto, A. (2012a). E-prime 2 reference guide. *Psychology Software Tools Inc*.

Schneider, W., Eschman, A. & Zuccolotto, A. (2012b). E-prime 2 user's guide. *Psychology Software Tools Inc*.

Schreuder, R. & Baayen, R.H. (1995). Modeling morphological processing. In L.B. Feldman (Ed.), *Morphological aspects of language processing* (pp. 131–154). Hillsdale,New Jersey: Lawrence Erlbaum.

Slowiaczek, L.M. (1994). Semantic priming in a single-word shadowing task. *The American Journal of Psychology*, 107(2), 245–260. https://doi.org/10.2307/1423039

Taft, M. (2006). A localist-cum-distributed (LCD) framework for lexical processing. In S. Andrews (Ed.), *From inkmarks to ideas: Current issues in lexical processing* (pp. 76–94). Hove, UK: Psychology Press.

Taft, M. & Forster, K.I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior*, 14(6), 638–647. https://doi.org/10.1016/S0022-5371(75)80051-X

Tamminen, J., Davis, M.H. & Rastle, K. (2015). From specific examples to general knowledge in language learning. *Cognitive Psychology*, 79, 1–39. https://doi.org/10.1016/j.cogpsych.2015.03.003

Torgesen, J.K., Wagner, R.K. & Rashotte, C.A. (2012). *Test of Word-Reading Efficiency – Second edition (TOWRE 2)*. Austin, TX: Pro-Ed.

Tyler, A. & Nagy, W. (1989). The acquisition of English derivational morphology. *Journal of Memory and Language*, 28(6), 649–667. https://doi.org/10.1016/0749-596X(89)90002-8

Tyler, A. & Nagy, W. (1990). Use of derivational morphology during reading. *Cognition*, 36(1), 17–34. https://doi.org/10.1016/0010-0277(90)90052-l

Wechsler, D. (2013). WASI-II: Wechsler Abbreviated Scale of Intelligence – Second edition. *Journal of Psychoeducational Assessment*, 31(3), 337–341.

Appendix
Experimental stimuli

Nonword	Part of speech (congruent condition)	MLBF[a]	Congruent definition	Incongruent definition
Brintise	Verb	2.78	To make an object clean again	A person who investigates crop circles
Brontful	Adjective	2.42	Describes someone who always lies	A person who breaks open safes
Clantist	Noun	2.71	A person who investigates crop circles	To ruin the taste of something
Clernise	Verb	2.58	To shrink something in the wash	Describes someone who doesn't like spending money
Crondful	Adjective	2.42	Describes someone who doesn't like spending money	A person who is a good public speaker
Drampise	Verb	2.49	To ruin the taste of something	Describes someone who is highly confident
Drictful	Adjective	2.28	Describes someone who comes up with new ideas	To put something in fancy dress
Flendise	Verb	2.57	To strip something of paint	Describes someone who comes up with new ideas
Glaftist	Noun	2.25	A person who breaks open safes	Describes someone who always lies
Grontist	Noun	2.76	A person who collects shells	To set something on fire
Plandist	Noun	2.64	A person who is a good public speaker	To shrink something in the wash
Prentful	Adjective	2.53	Describes someone who is highly confident	To make an object clean again
Scolpise	Verb	2.17	To set something on fire	A person who interprets dreams
Scontist	Noun	2.62	A person who interprets dreams	Describes someone who easily feels embarrassed
Slintful	Adjective	2.34	Describes someone who is always calm	To strip something of paint
Trilkist	Noun	2.42	An assistant to a magician	Describes someone who is always calm
Trimpful	Adjective	2.08	Describes someone who easily feels embarrassed	An assistant to a magician
Truftise	Verb	2.27	To put something in fancy dress	A person who collects shells

[a]Mean log bigram frequency.

Dr Nicola Dawson completed her PhD in 2019 at Royal Holloway, University of London, under the supervision of Dr Jessie Ricketts and Professor Kathy Rastle. Her doctoral research examined the role of morphological knowledge in the development of lexical processing. She is currently based at the University of Oxford, working alongside Professor Kate Nation on a Nuffield Foundation-funded project examining the impact of exposure to book language on children's language and literacy skills in the early years.

Professor Kathleen Rastle completed her PhD at Macquarie University in Sydney, Australia, in 1997. She completed postdoctoral positions at the University of Cambridge and Macquarie University before accepting an academic position in the Psychology Department at Royal Holloway, University of London. Her research investigates the nature of the mental representations and computations that underlie aspects of language, literacy and learning, and she has published extensively on these topics. She is currently editor-in-chief for *Journal of Memory and Language*.

Dr Jessie Ricketts completed her PhD at the University of Oxford in 2009. She subsequently worked as a postdoctoral fellow at the Institute of Education, London, and as a senior research fellow at the University of Warwick before accepting academic positions in the Institute of Education at the University of Reading and, most recently, the Psychology Department at Royal Holloway, University of London, where she is currently a reader. Her research focuses on the role of vocabulary in reading (both word-level reading and reading comprehension) and, reciprocally, the role of reading in oral vocabulary acquisition.

Received 15 December 2019; revised version received 10 November 2020.

Address for correspondence: Nicola Dawson, Department of Experimental Psychology, University of Oxford, Anna Watts Building, Radcliffe Observatory Quarter, Woodstock Road, Oxford OX2 6GG, UK. E-mail: nicola.dawson@psy.ox.ac.uk