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The effect of age of acquisition and imageability on reading words aloud

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The effect of age of acquisition and imageability on reading words aloud

ABSTRACT

The age at which words are learned appears to affect the speed at which they can be accessed in various tasks. This age of acquisition (AoA) effect is argued by some to be a semantic one; however, more explicitly semantic variables such as imageability are rarely found to have an effect on reading words aloud, and only under particular circumstances. This study explores the potential interaction between the two variables. AoA estimates by adult readers were found to be reliable for different word sets with different levels of imageability. Words varying on AoA and imageability but matched on other variables in a factorial design were then read aloud by skilled adult readers in either mixed blocks, or in pure blocks of high or low imageability. An AoA effect was found when words were presented in the mixed blocks, but no imageability effect was found. By contrast, an imageability effect was found across the pure blocks, and the AoA effect was significant within the high imageability block. The results are discussed in terms of two hypotheses relating to strategic control of processing in pure and mixed blocks, the route emphasis account and input gain.

KEY WORDS:	**AGE OF ACQUISITION**	**IMAGEABILITY**	**STRATEGIC CONTROL**	**NAMING LATENCY**	**EGNLISH**

Introduction

The study of the processes which support reading is informed by simulating observed behaviours within computational models. Assumptions about the structure of the reading system are therefore constrained by observations. Much experimental research has focused on the effects on reading performance of variables such as a word's frequency of occurrence in the language or its orthographic neighbourhood. One of the more controversial variables is the effect of the age at which a word is learned. Words which are learned earlier in life appear to be faster to access than later acquired words. This age of acquisition (AoA) effect has been shown to influence performance in a number of different tasks, including object recognition (Brown and Watson, 1987), eye fixation in reading (Juhasz and Rayner, 2003), lexical decision and naming latencies (see Juhasz, 2005 for a comprehensive review). The purpose of the investigation reported in this dissertation was to examine the conditions under which the AoA effect is observed in oral reading and the role of another variable, imageability, in setting the condition for the appearance of AoA.

One proposed explanation of the AoA effect is that it reflects the influence of the organization of semantic knowledge on reading performance. It is hypothesised that the earlier a word is acquired, the more semantic information will be associated with it, allowing faster access. This could be because later acquired words have to build on the information associated with early acquired words (van Loon-Vervoorn, 1989, as cited in Brysbaert, van Wijinendaele & de Deyne, 2000). Alternatively, semantic AoA effects could reflect greater ease of access due to an increased number of associated links with other words. Work on the organisation of semantic systems by Steyvers and Tenenbaum (2005) suggests a small-world structure in which a minority of nodes are highly connected to other nodes while most only have small numbers of links. They argue that the earlier a node - where a node represents a concept - is established in a semantic network, the more connections to other nodes it will have at any given time compared to later arrivals. Thus, later learned words are "less richly connected" to other words in the network (Steyvers & Tenenbaum, 2005, p.71). Converging evidence is provided by a neuroimaging study of the effect of AoA on picture naming. Ellis, Burani, Izura, Bromiley and Venneri, (2006) found that earlier-acquired words were associated with greater activation in the occipital and left temporal poles. This is argued to be related to the increased interconnectivity of early-acquired words.

The difficulty with evaluating the age of acquisition (AoA) effect is that AoA tends to be correlated with frequency. However, Brysbaert and Ghyselinck (2006) distinguish between a frequency-dependent and frequency-independent AoA effect. The latter effect is hypothesized to be semantic as the effect of AoA is significantly larger than frequency in picture naming, a task which is dependent on semantic information. This is consistent with Zevin and Seidenberg's (2002) contention that the AoA effect should properly be described as a frequency trajectory effect, where it reflects increased exposure to a given word over the course of time. Zevin and Seidenberg, however, do also allow for an AoA effect when the mappings between spelling and sound are arbitrary; in these cases, semantic information needs to be recruited. According to this explanation, AoA effects should be largest in tasks which depend more heavily on semantics; comparisons of word naming and lexical decision tasks do suggest that this is the case (Balota, Cortese, Sergent-Marshall, Spieler, &Yap, 2004).

The two main models of reading, the dual-route cascaded model (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001; DRC) and the triangle connectionist model (Plaut, McClelland, Seidenberg & Patterson, 1996) account for many of the factors which affect word access, but the AoA presents a challenge, particularly if it is understood to be a semantic variable. The DRC is conceptually dependent on the division between regular words with a consistent spelling to sound mapping, and irregular, exception words with an inconsistent mapping. The model proposes that there are two routes: either words are read using a grapheme to phoneme (GPC) conversion, possible if the word is regular or a pronounceable nonword; or words are read using a lexical route in which the whole word is accessed. The lexical route depends on access to phonology either via semantics or via non-semantic lexical information. Coltheart and colleagues argue that the non-semantic reading pathway is the most commonly used route for both regular and irregular words. They do not expand on how the semantic pathway might function, leaving it as an unimplemented part of their model (Coltheart et al., 2001). Its presence, however, is justified by patient data relating to deep dyslexia in which naming appears to be heavily reliant on semantics (Coltheart, Patterson & Marshall, 1980).

Although the DRC does not explicitly explain the AoA effect, the latter could be explained if AoA, as Brysbaert and Ghyselinck (2006) argue, is principally understood to be related to frequency. High frequency words are activated more swiftly, and this sensitivity could also be related to the AoA effect (Coltheart et al., 2001). However, this view cannot account for the evidence which suggests a strong role for semantics in the AoA effect (Burani, Arduino & Barca, 2007), indeed, it does not explain what Brysbaert and Ghyselinck (2006) term the frequency-independent AoA effect. Without an implementation of the semantic lexical pathway, it is difficult to assess whether the both the frequency-dependent and the frequency-independent AoA effects could be reconciled within this model.

The connectionist triangle model (Plaut et al., 1996; PMSP) does not rely on making a rule-based distinction between words. Instead, the reading system is conceived of as an interactive network, in which the different elements co-operate and compete in the process of translating a written word to a spoken one. In the PMSP model, all words are read with the involvement of orthography (O), phonology (P) and semantics (S); information passes through connections between O, P and S representations. The most common activation is the O-P mapping, used for example in the case of high frequency, consistent words. The authors suggest that the O-S-P mapping is initially recruited in harder circumstances, such as low frequency, exception words; the use of semantic mappings then becomes the typical response of the model to these types of words. In the PMSP model, such words can eventually be read if the semantic pathway is absent from the beginning of the simulation, but if the system has been trained using it, a ‘lesion’ will cause a high degree of errors in exception words. Therefore, the semantic pathway is useful but not essential to a learning system that must divide its labour between frequent or consistent O-P mappings and rare or exceptional mappings.

As it has been argued that AoA effects should mainly be seen when spelling-sound mappings are arbitrary (Zevin & Seidenberg, 2002; Lambon Ralph & Ellis, 2000; Lambon Ralph & Ehsan, 2006), it may be that the connections using semantics to read low frequency, exception words would show stronger AoA effects in reading aloud (compared to the O-P mappings used for high frequency consistent words). In the former cases, knowledge about early-acquired words could not be generalised to later-acquired words and so an AoA effect would be expected. By contrast, later-acquired words with a predictable mapping from spelling to sound can be read by drawing on knowledge of similar spelling-sound mappings for early-acquired words, reducing any additional benefit associated with earlier AoA.

Previous research suggests that semantic variables also play a role in naming words. Work by Strain and colleagues (Strain, Patterson & Seidenberg, 1995, Strain & Herdman, 1999) suggests that the naming of low frequency, irregular words can be positively affected by the word's imageability. However, Monaghan and Ellis (2002) criticised that study because it failed to control for AoA, instead finding a significant effect of AoA but no effect of imageability when imageability was manipulated while AoA was controlled (although see the reply by Strain, Patterson & Seidenberg, 2002). Furthermore, whereas Balota et al. (2004) found imageability effects in word naming and lexical decision tasks, Cortese and Khanna (2007) demonstrated that if AoA was taken into account, this imageability effect was no longer significant. These contrasting perspectives imply that the relationship between reading, AoA and explicitly semantic factors such as imageability is not a simple one. Given the high levels of correlation between the two factors (Brysbaert, Lange & van Wijnendaele, 2000), it could be argued that they may to some extent be the same.

Further evidence suggests that concrete and abstract words (often words of high and low imageability) could be represented differently. Concrete words, which are associated with perceptual information (de Groot, 1989), may have more links than abstract words which allows them to be responded to faster (see also Steyvers and Tenenbaum, 2005). Paivio (1971) argues that concrete words are associated with distinct image-based processing units, or 'imagens' and Jones (1985) suggests that highly imageable words are associated with more semantic features or predicates. There is converging neural evidence for these different kinds of representation. Neuropsychological case studies suggests a dissociation between processing of abstract and concrete words (Newton and Barry, 1997, Plaut & Shallice, 1993). This is supported by work by Papagno, Fogliata, Catricala & Miniussi, (2009) who used transcranial magnetic stimulation to demonstrate a dissociation between the cortical areas involved in lexical decision-making relating to abstract and concrete words.

Thus prior research has suggested that either AoA affects word naming times, or imageability, but not both. However, if both concrete words of high imageability and early acquired words have more semantically based links within the system, an interaction should be seen between the two. Boulenger, Decoppet, Roy, Paulignan,

& Nazir (2007) found an AoA effect in a lexical-decision task for concrete nouns, but not for action verbs, suggesting that the type of word employed in studies of AoA may also affect the outcome. Studies by Morrison and Ellis on AoA for example (1995, 2000) have focused on concrete words (based on pictures selected by Snodgrass and Vanderwart, 1980). Furthermore, while Cuetos and Barbon (2006) found an effect of AoA in reading Spanish words, Barca, Burani and Arduino (2002) found no effect of AoA in their study of Italian words, an orthographically similar language. This may be as a result of the stimuli used, as the Cuetos and Barbon set included more concrete nouns (Davies, Wilson, Cuetos & Burani, in preparation).

This may mean that, by chance, AoA effects have been observed for the kinds of words that, by chance, are most likely to present the opportunity to detect the effect. No studies have directly addressed the interaction between AoA and imageability with a factorial design. One reason an AoA x imageability interaction is worth considering is that if the AoA effect is a semantic effect, the chances of observing it might be boosted if semantic processing is emphasised in reading by presenting words in blocks of high imageability words.

It is also possible, however, that there are differences in reliability in the ratings for AoA for high compared to low imageability words. Funnell, Hughes and Woodcock (2006) argue that words learned by younger children tend to have strong links to visual experience, whereas words learned later are more conceptually based. Thus it is may be that it is more difficult for adults to estimate the AoA for low imageability words, limiting reliability of AoA ratings for such words. Vul and colleagues have emphasized that an upper limit on the potential extent of correlations between two measures is set by the product of the coefficients of reliability of the two measures (Vul, Harris, Winkielman &Pashler, 2009). Therefore if the AoA estimates are more reliable in concrete than abstract words, any correlation between AoA and reading reaction time must be lowered by the lower reliability for the abstract words compared to the high reliability of AoA ratings for concrete words. AoA and imageability effects on reading might interact because AoA is more reliably estimated for high imageability words so that effects would seem to be larger - the correlation between AoA and RT would be higher - for these kinds of words. Differences in the reliability of AoA ratings for high versus low imageability words would invalidate any AoA x imageability interaction.

Alternatively, AoA and imageability effects on reading might interact because high imageability words are read more semantically. Kello and Plaut (2000, 2003) have emphasised that extra-stimulus factors need to be taken into account when examining what affects naming latencies. In a study comparing nonwords and irregular words, Monsell and colleagues (Monsell, Graham, Hughes, Patterson & Milroy, 1992) found that organizing the presentation of irregular words into ‘pure’ blocks of just irregular words resulted in faster naming times than when the stimuli were ‘mixed’ with nonwords. This effect is explained by Monsell et al. (1992) in the route emphasis hypothesis, in which particular words are read by emphasising or de-emphasising one of the routes in the DRC (Coltheart et al., 2001). Irregular words are named fastest when the non-semantic lexical route is used exclusively, as in pure blocks. In contrast, in mixed blocks, the presence of nonwords requires the

GPC route to be active as well, which slows down responses to exception words because of competition between regular and irregular pronunciations for those words.

An alternative explanation for this blocking effect is provided by the input gain account (Kello and Plaut, 2000, 2003). In this account, levels of input gain can change how quickly a network processes information. The results of Monsell et al. (1992) could therefore be explained by supposing that irregular words are read more quickly in pure blocks because they are read under a high input gain strategy emphasizing speed. When reading mixed blocks, a more conservative low gain strategy is required to ensure nonwords are not accidentally read as words, resulting in slower responses to irregular words. Thus the reader allows high input gain when she recognizes that she is reading words that can be read quickly.

If high imageability words should tend to be read more quickly (due to increased links), then presenting pure blocks of high or low imageability words may result in different reading strategies, compared to when readers see low and high imageability words together in mixed blocks. High imageability words could be read under a high input gain strategy in pure high imageability blocks but the same words could be read under a lower gain strategy in mixed blocks. This should result in differences in reading speed in different block type conditions, but it could also result in larger semantic effects in pure high imageability blocks. Concrete words, as noted, may be associated with more available information. If changes in input gain strategy are encouraged through blocking then increased input gain in the pure blocks condition should also increase the influence of the semantic information associated with high imageability.

The present study

Evidence suggests a difference in the AoA effect for high and low imageability items, potentially because the words are associated with different kinds of knowledge (Funnell et al., 2006). Thus it was hypothesised that AoA would be less reliably estimated for words of lower imageability. In Experiment 1, the reliability of ratings for a series of words selected to vary on rated AoA was investigated by asking skilled readers to rate the AoA of low and high imageability words. The reliability of AoA ratings for different types of words was compared.

It was also hypothesised, however, that the AoA effect would be greater for words of high imageability because the AoA effect is associated with semantics/arbitrary mappings. This was tested in Experiment 2 in an oral reading experiment using the same stimuli in a factorial design, comparing early and late acquired words, and high and low imageability words, to establish whether imageability interacted with the rated AoA. It was predicted that the AoA effect would be greater in the case of high imageability words.

Furthermore, it was hypothesised that the use of semantics is driven by strategic processes. This was tested by presenting the stimuli in either mixed (high and low imageability) blocks, or in pure (high or low imageability) blocks. It was predicted that by placing items in pure and mixed blocks, the effect of imageability would be accentuated, such that the imageability effect would be most significant when in pure blocks of high imageability items.

Method

Experiment 1 – Ratings Study

Participants

30 participants (12 males, 18 females) volunteered for this study. The mean age was 30.5 years (S.D. = 5.80 years), range 19 to 44 years. All participants were native English Speakers.

Materials

212 stimuli were selected for a 2x2 factorial design from a database of 3000 monosyllabic words subjectively rated for AoA and imageability (Cortese &Khanna, 2008, Cortese & Fugett, 2004). Words were selected for inclusion into one of four word-groups; early acquired, high imageability (EAHI), early acquired, low imageability (EALI), late acquired, high imageability (LAHI) and late acquired, low imageability (LALI). See Appendix 1 for the full word set. Using data from the N-watch database (Davis, 2005), the words were matched on CELEX frequency, length and neighbourhood (Coltheart's *N*, Coltheart, Davelaar, Jonasson & Besner, 1977), p> 0.1 for all (t-test) comparisons between word sets. The early acquired words (EAHI v. EALI) differed significantly only on imageability, t(68.24)=11.74, p< .001, *r*=-.81, as did the late acquired words (LAHI v. LALI), t(93.89)=13.73, p< .001, *r*=.56. Finally, all the early acquired words compared to all of the late acquired words were significantly different only on age of acquisition, t(151.42)=-16.63, p< .001, *r*= .80. All effect sizes were large (Cohen, 1988, 1992).

Table 1
Summary of item characteristics of early acquired words

Word group						
	Early acquired, high imageability			**Early acquired, low imageability**		
Variable	*mean (SD)*	min	max	*mean (SD)*	min	max
AoA	3.05 (0.37)	2.1	3.5	3.05 (0.34)	1.8	3.5
Imageability	4.73 (0.97)	3.6	6.9	3.04 (0.39)	2	3.5
Frequency	1.61 (0.58)	0.22	2.60	1.77 (0.55)	0.16	2.44
Letters	3.53 (0.50)	3	4	3.66 (0.48)	3	4
N-size	12.06 (4.01)	5	24	12.03 (3.97)	4	22

N=53 per group

Table 2
Summary of item characteristics of late acquired words

Word group						
	Late acquired, high imageability			**Late acquired, low imageability**		
Variable	*mean (SD)*	min	max	*mean (SD)*	min	max
AoA	4.26 (0.63)	3.6	6.0	4.48 (0.82)	3.6	6.3
Imageability	4.59 (0.80)	3.6	6.6	2.73 (0.57)	1.6	3.5
Frequency	1.53 (0.48)	0.20	2.58	1.59 (0.53)	0.14	2.44
Letters	3.54 (0.50)	3	4	3.66 (0.47)	3	4
N-size	12.17 (4.10)	4	21	11.74 (3.73)	3	19

N=53 per group

Table 3
Summary of item characteristics of early and late acquired words.

Word group						
	Early acquired			**Late acquired**		
Variable	*mean (SD)*	min	max	*mean (SD)*	min	max
AoA	3.05 (0.35)	1.8	3.5	4.37 (0.73)	3.6	6.3
Imageability	3.89 (1.13)	2	6.9	3.66 (1.16)	1.6	6.6
Frequency	1.69 (0.57)	0.16	2.60	1.56 (0.50)	0.14	2.58
Letters	3.59 (0.49)	3	4	3.6 (0.43)	3	4
N-size	12.05 (3.97)	4	24	11.95 (3.91)	3	21

N=53 per group

Each word group was randomly divided into two; from this two lists of 106 words were created and randomly ordered. Both lists were an equal mixture of high and low imageability and early and late acquired items. One set of words were presented in Questionnaire 1, the other set in Questionnaire 2 (see Appendix 2).

Procedure

15 participants were sent an Excel document containing Questionnaire 1 and 15 participants were sent Questionnaire 2 in the same format. AoA ratings were collected using a 7 point scale developed by Gilhooly and Logie (1980). Participants were asked to rate the age at which they estimated that they first learned a word and its meaning, in spoken and written form.

Results

Analyses of reliability were conducted on both Questionnaire 1 and 2, and reliability was found to be high in both cases (respectively, Cronbach's Alpha =.95, Cronbach's Alpha = .96). Reliability was also found to be high for both high and low imageability items. In Questionnaire 1, Cronbach's Alpha was .95 for high imageability items, and .96 for low imageability items. Questionnaire 2 produced similar results, with both high and low imageability items having a Cronbach's Alpha of .96.

Discussion

The high reliability of the estimation of the age of acquisition of the items regardless of their imageability suggests that there is no difference between estimates for high and low imageability items. This would suggest that the imageability of words does not influence the reliability of AoA estimation. Therefore, if there is a difference in AoA effects in reading low versus high imageability words, reliability can be excluded as a possible explanation.

Experiment 2 – Reading Study

Participants

40 participants (11 males, 29 females) volunteered for this study. The mean age was 29.13 years (S.D. = 10.64 years), range 18 to 59 years. All participants were native English speakers. Participants were assigned at random to one of two conditions, relating to word block type ('pure' or 'mixed').

Task Descriptions

All participants were presented with three tasks, a test of reading experience (Author Recognition Test), a test of reading skill (TOWRE), and the critical oral reading task. The reading experience and reading skill tests were administered to allow a check that participants assigned to different block conditions (a between-subjects manipulation) did not differ as readers. The order of task administration was counterbalanced to control for order effects.

Author Recognition Task (ART)

The ART was designed to measure print exposure (Stanovich &West, 1989) by asking adults to indicate which published authors they recognised. Masterton & Hayes (2007) adapted the test to reflect British authors (selecting 80 real authors and constructing 80 fake author names), and their version was used in this experiment as a proxy for reading history. Participants were asked to distinguish real from foil authors using a computer-based questionnaire. An ART score was calculated by subtracting false positives (recognizing fake authors) from true positives (recognizing true authors) to correct for guessing.

TOWRE

Developed by Torgesen, Wagner, & Rashotte (1999), the Test of Word Reading Efficiency (TOWRE) is designed to measure the accuracy and fluency of reading, using one list of 104 words and one list of 63 pronounceable nonwords. Participants were asked to read items, presented in the lists in increasing difficulty, as quickly and as accurately as possible. A 45 second interval was allowed for both tests.

Participant scores on the tests of reading skill and experience are reported in Table 4.

There was no significant difference between the participants tested in the pure blocks versus the mixed blocks conditions on any variable.

Table 4
Summary of participants' demographics and scores on ART and TOWRE in pure and mixed conditions.

	Pure		**Mix**	
	Mean	*SD*	*Mean*	*SD*
ART	25.35	12.40	26.85	13.67
Towre word score	95.60	7.02	94.60	12.31
Towre word time	44.60	0.82	43.75	2.29
Towre nonword score	57.85	3.31	56.65	5.65
Towre nonword time	41.75	4.08	42.10	4.49
Age	30.00	11.81	28.25	9.55
Years of Education	17.00	2.05	17.10	2.27

N=20 per condition

Oral Reading

Materials

The stimuli used in this experiment were the same as Experiment 1. For the pure blocks condition, the items were divided into two blocks of high and low imageability (106 words in each block) and placed in a randomised, single fixed order. In the mixed blocks condition, the items were placed in a randomised, single fixed order, and divided into two sets of 106 words. Within blocks of words, words were randomly assigned to one of five smaller blocks, and within these blocks, stimuli were ordered randomly initially, and then organised so that there was no alliterative, rhyming or semantic association within 3 trials.

Design

This was a mixed design; all participants saw all of the words, but the blocks conditions were between subjects. Half were randomly assigned to the pure blocks condition and the other half to the mixed blocks condition.

Procedure

The experiment was carried out using an Asus 901 computer operating Windows XP. The task was run using the DMDX application (Forster & Forster, 2003). Participants sat in front of the computer screen which was approximately 2 feet away from them. Participants were asked to read words as quickly and as accurately as possible. They were given 6 practice trials to familiarise them with the task. DMDX times events in multiples of screen refresh intervals (16.8ms for the ASUS computer). A fixation asterisk was presented for 504ms, followed by the stimulus which remained on screen for 1999.2ms, this was followed by a blank screen for 504ms. The words were presented using 32 size Times New Roman font. Naming responses were recorded directly to the hard-disk drive.

Data Analysis

Spectrograms of the sound patterns of each wav. file were examined to extract response latencies, using the CheckVocal application (Protopapas, 2007). This method offers accurate response time recording because it is not vulnerable to background noise effects. Stuttering, failing to finish the word within the time-limit and incorrect responses were all coded as errors.

Results

Accuracy rates were high; only 82 errors were made overall. Mean reaction times to each word group are reported in Table 5.

Table 5
Summary of mean reaction times and standard deviations (sd) to word group, by block condition

	Pure		**Mixed**	
Word group	*Mean*	*SD*	*Mean*	*SD*
Early acquired, high imageability	484.64	33.3	487.78	35
Early acquired, low imageability	498.75	48.69	489.77	49.35
Late acquired, high imageability	492.18	23.9	498.31	29.38
Late acquired, low imageability	507.78	36.74	496.06	47.39

It was hypothesised that the age of acquisition effect would be greater for words of higher imageability. The AoA effect was estimated using regression analysis.

Although the data were selected to a 2x2 factorial design, Cohen (1990) has emphasised that by simplifying data into a nominal dichotomy, up to 35% of variance potentially explained by relationships with other variables (i.e. by experimental effects) is lost by dividing continuous variables. Following Lorch & Myers (1990) and Balota et al. (2004), two steps were taken to establish both by-item and by-subject tests of effects. Initially, regression analyses were performed on average RTs per item. Regression analyses were then performed for each person individually and the Beta standardized coefficients used as the dependent variable in an analysis of the effect of block type on the size of effects of AoA, imageability and other variables.

Correlations between the predictor variables were examined, as these have an impact on the interpretation of regression analyses (Field, 2009). AoA was found to correlate significantly with imageability [$r(210)=-.196$, $p=0.004$] and frequency [$r(210)=-.321$, $p<.001$], in line with previous findings (Brysbaert et al., 2000). Examination of VIF and tolerance statistics in subsequent regression analyses demonstrated that this multicollinearity did not distort regression coefficient estimates, however.

Table 6
Summary of correlations for predictor variables in the by-items regression analysis.

		IMG	Frequency	regularity	letters	Nsize
AOA	Pearson Correlation	-.196**	-.321**	-0.025	-0.003	-0.043
	Sig. (2-tailed)	0.004	0	0.721	0.962	0.537
IMG	Pearson Correlation	1	-.183**	.204**	-.171*	0.102
	Sig. (2-tailed)		0.008	0.003	0.013	0.139
Frequency	Pearson Correlation		1	-.213**	.427**	-0.049
	Sig. (2-tailed)			0.002	0	0.478
regularity	Pearson Correlation			1	-.243**	0.071
	Sig. (2-tailed)				0	0.301
letters	Pearson Correlation				1	-.186**
	Sig. (2-tailed)					0.006

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

N=212

By- items means regression analyses

Firstly, naming latencies were averaged by item for all participants irrespective of block condition. A linear regression model using AoA, imageability, frequency, regularity, number of letters and neighbourhood size to predict the naming latency was found to have significant predictive power, F(6, 205)= 4.60, p <.001. 12% of the variance is explained by these variables. Coefficient estimates of effects are reported in Table 7.

Table 7
Summary of by-item means predictors using all independent variables across conditions

	Unstandardized Coefficients		**Standardized Coefficients**		
	B	Std. Error	Beta	t	Sig.
(Constant)	532.69	27.99		19.04	.000
AOA	7.00	3.01	0.17	2.33	.021
IMG	-1.90	2.22	-0.06	-0.85	.399
frequency	-12.34	5.33	-0.19	-2.32	.022
regularity	-10.87	5.91	-0.13	-1.84	.067
letters	-8.36	5.56	-0.12	-1.51	.134
Nsize	0.11	0.62	0.01	0.18	.860

Both AoA and frequency effects were significant. Earlier acquired words were named faster than later acquired words, and higher frequency words were named faster than lower frequency words. There was no significant effect of imageability.

The items were then averaged per word within the two different conditions. For the mixed blocks condition, the results were broadly similar. A regression model with the same elements was found to have predictive power, F(6, 205)=5.19, p<.001. This accounted for 13% of the variance. Coefficient estimates of effects are reported in Table 8.

Table 8
Summary of by-item means predictors using all independent variables in the mixed blocks condition

	Unstandardized Coefficients		**Standardized Coefficients**		
	B	Std. Error	Beta	t	Sig.
(Constant)	520.01	31.56		16.48	.000
AOA	9.30	3.39	0.20	2.74	.007
IMG	2.08	2.50	0.06	0.83	.407
frequency	-14.06	6.01	-0.19	-2.34	.020
regularity	-14.26	6.66	-0.15	-2.14	.034
letters	-9.25	6.27	-0.11	-1.48	.141
Nsize	-0.19	0.70	-0.02	-0.28	.784

AoA, frequency and regularity effects were significant. As in the previous regression model, earlier acquired words were named faster than later acquired words, and higher frequency words were named faster than lower frequency words. In addition, regular words were named faster than exception words. There was also no significant effect of imageability.

It was hypothesised that the age of acquisition effect would be increased by manipulating reading strategy by presenting stimuli in pure or mixed blocks of high and low imageability items. Therefore by-items mean responses to words presented in pure blocks were analyzed. This regression model was found to have significant predictive power, $F(6, 205)=3.78$, $p=.001$ and accounted for 10% of the variance. Coefficient estimates of effects are reported in Table 9.

Table 9
Summary of by-item means predictors using all independent variables in the pure blocks condition

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	545.33	29.32		18.6	0
AOA	4.75	3.15	0.11	1.51	0.134
IMG	-5.89	2.33	-0.18	-2.53	0.012
frequency	-10.69	5.58	-0.16	-1.92	0.057
regularity	-7.57	6.19	-0.09	-1.22	0.222
letters	-7.41	5.82	-0.10	-1.27	0.204
Nsize	0.41	0.65	0.04	0.64	0.522

Only the imageability effect was significant. Words of higher imageability were named faster than words of lower imageability. There was no significant effect of any other variable, including regularity, frequency and AoA. Figure 1. shows the effect of imageability on RTs between blocks.

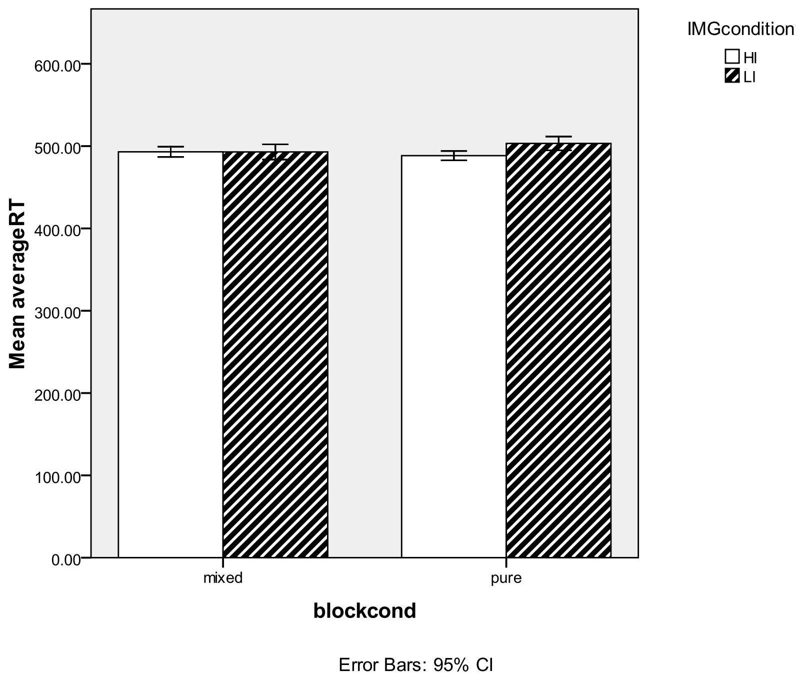

Figure 1: Mean reaction time to high and low imageability words in pure and mixed blocks.

By-subject means regression analyses

An individual regression analysis was then performed on all responses for each participant. Beta standardized coefficient estimates of effects were then analysed - as values of a dependent variable - in a series of t-tests comparing the size of the various effects (AoA, imageability etc.), estimated for each person, in the mixed and pure blocks conditions. Only imageability was significantly different between the two conditions, being larger in pure blocks, t(38, 23.12)=-2.47, p=.022, *r*=0.47. The effect size was large (Cohen, 1988, 1992). This is consistent with the by-items results.

By-pure block regression analyses

Having found that the strategy manipulation amplifies semanticity of reading, as the imageability effect was larger in pure blocks, regression analyses were conducted to compare the effect of AoA in the high and the low imageability blocks. Using average RT per word as the dependent variable, AoA, imageability, frequency, N size, regularity, letters and word order were entered as predictor variables. This model was not found to have predictive power in the low imageability condition, although it approached significance, F(7,98)=1.99, p=.064. However, the same regression was performed for the high imageability condition, and was found to have significant predictive power, F(7,98)=2.5, p=.021 and explained 15% of the variance. Coefficient estimates of effects are reported in Table 10.

Table 10
Summary of by-item means predictors using all independent variables in the pure high imageability block

	Unstandardized Coefficients		**Standardized Coefficients**		
	B	Std. Error	Beta	t	Sig.
(Constant)	449.17	40.26		11.15	0
word_no	-0.30	0.10	-0.29	-3.02	0.003
AOA	8.49	4.01	0.21	2.20	0.037
IMG	3.26	3.65	0.09	0.89	0.374
frequency	-0.74	7.84	-0.01	-0.10	0.925
regularity	5.74	8.71	0.07	0.66	0.511
letters	-0.99	8.16	-0.02	-0.12	0.904
N_size	0.47	0.80	0.06	0.59	0.555

There was a significant effect of word order and AoA. Words that were presented later in the task were named faster than words presented earlier. In addition, earlier acquired words were named faster than later acquired words.

Discussion

The present study was conducted to explore the relationship between AoA and imageability. It was hypothesised that the AoA effect found in previous studies could be related to the use of concrete words in experiments. This study examined estimates of AoA for words of high and low imageability and found high levels of reliability for both types of words. It was also hypothesised that the AoA effect would be greater for words of high imageability. Overall and in the mixed blocks condition, the AoA effect was replicated (Cortese &Khanna, 2007), but there was no significant effect of imageability. Cortese and Khanna (2007) also found no effect of imageability once AoA had been entered into their regression model. A frequency effect was found both overall and in the mixed blocks, and an effect of regularity was also found. This finding is in line with earlier work which has found that high frequency words are named faster than lower frequency words (Forster & Chambers, 1973) and regular words faster than exception words when these are low frequency (Paap and Noel, 1991). Thus, this finding in isolation would appear to provide further supporting evidence that while the AoA effect is robust, a word's imageability only plays a limited role.

However, it was also hypothesised that if the AoA effect is due to the use of semantics/ arbitrary mappings (in which there is no predictable translation from spelling to sound), that this may have been driven by strategic control processes. No previous studies have been conducted to explore the relationship between AoA and imageability using block type manipulation to investigate the role of strategic processes. This study found that even when using the same stimuli, placing items into pure blocks of high and low imageability resulted in an imageability effect not seen in the mixed blocks conditions, suggesting block manipulation had resulted in differences in the importance of semantics in participants' reading strategies. These observations were made even after controlling statistically for the effect of the regularity of spelling-sound mappings.

In the pure blocks of high and low imageability, there was no significant effect of AoA, but when each block was considered separately, there was an effect of AoA within the high imageability block. Increasing the semanticity of reading through block manipulation brings out the AoA effect. Thus the original prediction that early acquired words with high imageability would be named significantly faster was supported by the data. However, this is only true of the condition in which these semantic elements are specifically blocked together in pure blocks. The relationship between AoA and imageability appears to be an exceptionally complex one. Other studies that have found effects of AoA or imageability (but not both) have not used this blocking technique. As Lupker, Brown and Colombo (1997) emphasise, this methodological omission raises an important issue concerning the interpretation of the results. As they note "the question could be raise as to whether the effect would have emerged (thus changing the interpretation) if the conditions had been run in pure blocks" (Lupker et al., 1997, p.585).

There are alternate hypotheses that account for evidence of strategic control processes in reading. The first was proposed by Monsell et al. (1992) and relates to the dual-route model of reading (Coltheart et al., 2001). In their experiment, irregular words were named faster when placed into pure blocks, compared to being mixed with nonwords. Their findings are consistent with a route emphasis account which argues that words are read using either one of the two routes in the DRC model, the lexical (irregular words) or the GPC (nonwords). If the stimuli are mixed, then one route cannot be deemphasised, and reaction times tend to represent a compromise to cope with the changing demands of the stimuli. The stimuli in this study represented a mixture of regular words, which might use the GPC route, and exception words, which might use the lexical route. However, the imageability of the words relates to lexical, rather than sub-lexical information; a possibility is that in the pure block condition, the high imageability words were being read via the lexical-semantic route and that this allowed for faster response times.

Given the imageability effect on RTs in the pure blocks, words of high imageability could be considered as ‘fast’ stimuli, and words of lower imageability as ‘slow.’ Lupker et al. (1997) demonstrated that response times become homogenized in mixed blocks; fast words are named slower and slow words are named faster compared RTs in pure blocks. In this study, high imageability items were named faster than low imageability items in pure blocks whereas in the mixed blocks the RTs to both high and low items did not show an effect of imageability. Taylor and Lupker (2001) found that the response time for ‘fast’ stimuli was increased if it were preceded by another ’fast’ stimulus. If it is the case that high imageability words are ’fast’, it should be possible to duplicate this effect using the stimuli from the present study by presenting other ‘fast’ items before target trials. This should result in faster response times. However, it should be emphasised that in the present study, although the average imageability rating between the two blocks was statistically significant, the mean imageability rating for the high block was only 4.66, compared to a mean rating of 2.89 for the low imageability block. It would appear unlikely that given such a relatively small difference between the blocks (compared to, for example, 2 and 5) that the two blocks truly represent ‘fast’ compared to ‘slow’ items.

Another explanation for the effects found could lie in the concept of input gain. Kello and Plaut (2000, 2003) use input gain to explain both results from the Monsell et al. (1992) experiments, and Lupker et al.’s experiments (1997). They argue that when words are presented together in pure blocks, it encourages a change in the mechanism of input gain within a connectionist model such as the PMSP. This mechanism changes the effect of input; at high levels of gain, less input to the processing unit is needed to produce a quicker response while at low values of gain, the system must have high levels of input to produce a response. Furthermore the impact of larger weights in the system will be amplified more than smaller weights for the same level of input gain. When the stimuli are ‘easy’, they encourage higher levels of input gain, as errors are unlikely to be made by speeding responses. If stimuli are ‘hard,’ a more cautious approach is needed and input gain must be decreased. Therefore, it could be the case that in pure imageability blocks, the high imageability block is perceived as easier, which increases the input gain and that the low imageability block is seen as harder, reducing the input gain (in order to preserve accuracy).

For this mechanism to explain the difference between the two blocks of high and low imageability, however, the semantic properties of imageability as a variable would also have to represent ‘larger weights’ in the system or a frequency/regularity effect might have been expected. Work by de Groot (1989) suggests that concrete words with high imagebility have greater weight in the semantic system because their referents have additional perceptual information not associated with abstract words. The proposed difference in levels of input gain in the pure blocks could also account for the AoA effect found. Steyvers and Tenenbaum (2005) suggest that early acquired words may have more connections within a system; this increase in connections could lead to larger weights within the system. Furthermore, if a specifically semantic reading style is being encouraged by access to the greater semantic weight associated with the highly imageable words, the AoA effect could be occurring in tandem with the imageability effect because they arise from similar kinds of information. Kello and Plaut (2003) emphasise that input gain can be implemented across an entire system, but that it can also occur at a particular level of representation or processing. Thus it could be argued that the input gain is applied specifically to a semantic level of representation. If this is the case, it adds further support to the argument that AoA is a semantic variable (Burani et al., 2007).

Work by Zevin and Balota (2000) also lends further credence to the idea that the mechanism of input gain can account for these results. Zevin and Balota (2000) used exception words and nonwords as primes in series of oral-reading experiments. In Experiment 4, they presented words of high or low imageability and found that when words were preceded by low-frequency exception word primes, there was a marked imageability effect. They attribute this to attention being drawn to semantic information by the primes; this demonstrates that the context of semantic information can increase semantic effects responding to other words. The low-frequency exception words put a “premium on semantic information” (Zevin &Balota, 2000, p.132). They conclude that the imageability effect is due to increased attention, or potentially ‘gain’ to the semantic system. This could provide supporting evidence for the idea that the list context of high imageability words increased the gain to the semantic system in this study, thus increasing the likelihood that the AoA effect would be seen. Here, however, semantic information was not relevant simply because the words were low frequency, exception words, highlighting the limitation of current conceptions of the involvement of semantics within the PMSP.

Future studies could explore whether blocking the early and late acquired words into pure and mixed blocks resulted in an imageability effect for the early acquired words. This would provide supporting evidence for the finding that highly imageable, early acquired words were named fastest. Furthermore, as the AoA effect has been found to be stronger on explicitly semantic tasks such as lexical decision (Balota et al., 2004), and as blocking effects have been shown to occur across task (Rastle, Kinoshita, Lupker &Coltheart, 2003), these stimuli could be explored in a lexical decision task. Within this study, although the word order was randomized, it was not different for all participants, so it is possible that the AoA effect found is due to this particular order of words. Although this is unlikely, future work would need to replicate these results with all participants naming the stimuli in different orders.

This study investigated the relationship between the age of acquisition of words and their imageability. It is possible that the role of imageability has been underestimated. Imageability effects have rarely been reported in the oral reading literature and then only under specific circumstances. The division of labour explanation within the PMSP model and work by Strain and colleagues (Strain et al., 1995, Strain and Herdman, 1999) suggest that the imageability of words is only of use to the reading system with difficult words. These results, however, suggest a wider understanding of the role of imageability in word naming.

Previous studies have found effects of AoA or imageability but none have used a factorial design to explore their interaction. When the stimuli were presented in a randomly mixed order, only the AoA effect was significant. This reflects the findings of other studies. However, through investigating the strategic control processes involved in reading words aloud, this study provided evidence that the imageability effect can be increased by being placed into pure blocks of high or low imageability, and that the AoA effect is strongest where semanticity is increased by this technique. This provides supporting evidence for the contention that the AoA effect is semantic in origin and indicates that future studies of the effect of imageability and AoA need to consider the role of extrinsic, strategic processes in reading.

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