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Age of Acquisition, Lexical Processing and Ageing: Changes Across the Lifespan

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Abstract

An important determinant of picture and word naming speed is the age at which the words were learned, that is, their age of acquisition (AoA). Two possible interpretations of these effects are that they reflect differences between words in their cumulative frequency of use, or that they reflect differences in the amount of time early- and late-acquired words have spent in lexical memory. Both theories predict that differences between early- and late-acquired words will be smaller in older than younger adults. We report three experiments in which younger and older adults read words varying in AoA or frequency, or named objects varying in AoA. There was no effect of word frequency when AoA was controlled. In contrast, strong AoA effects which did not diminish with age were found. The implications of these results for theories of how AoA affects lexical processing are discussed.

Introduction

Recent evidence suggests that AoA, and not word frequency, is the most important determinant of lexical processing speed (e.g., Morrison, Ellis & Quinlan, 1992; Morrison & Ellis, 1995). High frequency words tend to be learned earlier in life than low frequency words, so frequency and word learning age correlate highly (typically, around $r = .6$). The consequence of this natural correlation is that word sets matched for frequency are likely to be confounded on AoA. We argue this confounding of frequency with AoA has resulted in an overestimation of the role of frequency in determining word naming speed. Effects of word frequency in object naming have been claimed by a number of authors who have failed to control for differences in AoA (e.g., Oldfield & Wingfield, 1965; Jescheniak & Levelt, 1994), yet when the two variables are controlled statistically the effect of AoA appears robust while the independent effect of frequency fails to achieve significance in most studies (e.g., Morrison et al., 1992; Vitkovitch & Tyrell, 1995).

Cumulative Frequency and Residence Time Accounts of AoA Effects

How could the age at which a word is learned come to affect the speed with which it can be produced in response to a written word or a picture? Gilhooly and Watson (1981) proposed an explanation based on Morton's (1979) logogen model of word recognition and production. According to that model, the spoken forms of words that are produced in word and picture naming tasks are stored in, and retrieved from, the speech output logogen system. They suggested that the thresholds of individual logogens might be determined by AoA, with early-learned words having lower thresholds, and hence being easier to access, than later-learned words. Brown and Watson (1987) and Morrison and Ellis (1995) have proposed somewhat different accounts which nevertheless share Gilhooly and Watson's belief that AoA effects lie in the speed with which spoken word-forms can be accessed.

These proposals all share in common the idea that word learning age is the factor underlying the AoA effect: the accessibility of a word is determined at the time it is acquired and remains more or less unchanged thereafter. Previous studies have tentatively suggested AoA effects are not reducible to cumulative frequency (Carroll and White, 1973) or residence time (Gilhooly, 1984) and have led to the conclusion that whatever determined the accessibility of words in the mental lexicon is more or less fixed at the time the word is learned.

The present experiments take a different approach to evaluating the rival accounts of AoA effects. Imagine two words, one of which is acquired early in childhood at the age of 2 years while the other is acquired later at the age of 10. By the time a person is 20 years old the early-acquired word will have been resident in memory for 18 years while the late-acquired word will have been resident for 10 years. By the time that person has reached the age of 70, the early-acquired word will have been resident in memory for 68 years while the late-acquired word will have been resident for 60 years. The absolute difference is still 8 years, but in proportional terms the difference is residence time between the two words is greater for the 20-year-old that for the 70-year-old. Hence, if AoA effects are due to differences in residence time, then differences between early- and late- acquired words should gradually diminish as a person grows older. Cumulative frequency is just residence time multiplied by the number of times a word is encountered or used each year. If we make the simplifying assumption that the two words are matched in terms of the frequency, then the same prediction holds for the cumulative frequency hypothesis of AoA as for the residence time hypothesis: differences in cumulative frequency which are substantial when a person is young will become less significant as the person grows older. That is, the cumulative frequency hypothesis, like the residence time hypothesis, predicts that AoA effects will diminish with age. In contrast, the theory that word learning age *per se* predicts that AoA effects will be as large in old people as in young people. The present Experiments 1 employs the word naming task to discover whether or not the effect of AoA varies in younger and older participants. Experiment 2 looks for effects of frequency in the two groups. Experiment 3 examines the effect of AoA on object naming speed in groups of participants of different ages.

Experiments 1 and 2

In Experiments 1 and 2, we compared word naming performance in a group of young adult participants and a group of older adults. The word sets used either varied on AoA with word frequency controlled (Experiment 1) or varied on word frequency with AoA controlled (Experiment 2).

Method

Participants. The young adult group comprised 12 undergraduates at the University of York, with a mean age of 20.2 years (range 18-25). They were paid £2 or given a course credit for their participation. The 12 members of the older adult group had a mean age of 44.1 years (range 38-55). They were mature students from the Psychology Department, attendants at an Open University Summer School or Psychology teaching staff.

Stimuli. The stimuli were word sets previously used in a word naming study by Morrison and Ellis (1995). The word sets for Experiment 1 consisted of 24 early and 24 late acquired words matched for frequency and length. Another two sets of 24 words formed the stimuli for Experiment 2. These consisted of high and low frequency words matched for AoA and length.

Procedure. The experiments were conducted using a Macintosh computer and the stimuli were presented via a Hypercard program. A fixation dot appeared in the centre of the screen for 500 milliseconds before each word was presented. Stimuli were positioned such that the initial letter of each word appeared where the fixation dot had been. There was an interstimulus interval of 1000 milliseconds before the next fixation dot appeared. When the word appeared, a square wave signal was sent from the computer to a tape recorder. Naming responses were recorded on tape via a high sensitivity microphone. Reaction times were measured from the recording of the speaker's utterance using the SoundEdit program (see Morrison & Ellis, 1995, for details).

Participants were told that the experiment was aimed at measuring the speed at which people could name words and they were asked to name the words as quickly and accurately as possible. They were instructed to say only the target word, and were warned that mispronunciations or verbal hesitations would invalidate their response. The experiment began with 20 practice items.

Results

All scores representing incorrect responses or verbal hesitations were removed from the analyses. This amounted to 34 responses in total (an error rate of 1.5%).

Experiment 1. Means were calculated for the early and late AoA words and all responses falling more than two and a half standard deviations from the mean were removed. Means were recalculated by subjects and by items and the data were analysed. The by-items data are shown in Table 1.

Two-way analyses of variance were carried out with participant age (young/old) as the between-subjects factor and AoA of the words (early/late) as the within-subjects factor. There was no significant effect of participant age either by subjects, $F_1(1,22) = .02$, $MSE = 244.8$, $p = .90$, or by items, $F_2(1,46) = .42$, $MSE = 467.3$, $p = .50$. The effect of AoA was highly significant both by subjects, $F_1(1,22) = 35.07$, MSE = 20232.7, $p < .0001$, and by items, $F_2(1,46) = 31.3$, $MSE = 41669.6$, $p < .0001$. There was no indication of a significant interaction between participant age and AoA either by subjects, $F_1(1,22) = 1.25$, $MSE = 718.58$, p = .28, or by items, $F_2(1,46) = .35$, $MSE = 465.3$, p = .5687. That is, the AoA effect was of similar magnitude for the younger and older participants.

Experiment 2. Means were calculated for the high and low frequency words and all responses falling more than two and a half standard deviations from the mean were removed. Means were recalculated by subjects and by items and the data were analysed. The by-items data are shown in Table 1.

Two-way analyses of variance were carried out with participant age (young/old) as the between-subjects factor and word frequency (high/low) as the within-subjects factor. Again there was no significant effect of participant age either by subjects, $F_1(1,22) = .003$, $MSE = 29.6$, $p = .96$, or by items, $F_2(1,46) = .05$, $MSE = 29.03$, $p = .82$. The effect of frequency was also nonsignificant in both the by-subjects analysis, $F_1(1,22) = 1.58$, $MSE = 457.6$, $p = .22$, and the by-items analysis, $F_2(1,46) = .88$, $MSE = 634.02$, $p = .35$. The interaction between age and frequency approached significance in the by-subjects analysis, $F_1(1,22) = 3.63$, $MSE = 1049$, $p = .07$, with the young adult group tending to show more of an effect of frequency than the older group, but the interaction was far from being significant in the by-items analysis, $F_2(1,46) = 1.72$, $MSE = 634.02$, $p = .20$.

Discussion

Experiment 1 found a clear effect of AoA on word naming speed which was as large in older as in younger subjects. This pattern is contrary to the prediction of cumulative frequency hypothesis that there will be a reduction in the AoA effect in the older group compared with the younger group. Experiment 2 also replicates Morrison and Ellis (1995) in finding no effect of frequency on word naming once AoA is controlled.

The older participants responded just as quickly as the younger participants in naming the words. The average age of our older participants was over twice that of our younger participants, so the experiment constituted a fair test of the cumulative frequency hypothesis of AoA effects. However, the older participants were only aged between 38 and 55 years so may not have reached the age at which cognitive slowing becomes apparent (although we note that previous studies of the effects of age on word naming failed to find significant slowing with age despite using a wider range of ages than were employed here [Cerella & Fozard, 1984; Waugh & Barr, 1980]).

Experiment 3

Like Experiment 1, Experiment 3 is concerned with whether AoA effects change across the adult life span. It differs from Experiment 1 in three important respects: first, it involves the naming of pictures of objects rather than reading words aloud; second, the participants cover a wider range of ages than those in Experiment 1; and third, the division of words into early and late-acquired is based on normative data on children's naming rather than on adult estimates of AoA.

Because the present investigation is primarily concerned with evaluating alternative theories of AoA effects, Experiment 3 compared the naming of objects with early- and late-acquired names that were matched on frequency and other object and word properties. To the best of our knowledge there have been no previous factorial investigations of differences in object naming latency between early- and late-acquired words.

In Experiment 3, the objects were chosen to be ones which will have been equally commonplace in the childhood experience of people born in the early decades of this century and those born in the 1970s. AoA was determined using normative data from children, taken from Morrison et al. (1997), rather than using adult ratings of word learning age, as all previous studies have done. The young adults were again students. Older participants were drawn from the North East Age Research (NEAR) panel. NEAR is a longitudinal study of cognitive processing in several hundred older adults in Newcastle, England. Most panel members have been involved in research for at least 10 years so there is substantial data on various measures of their language and memory performance, allowing us to select the participants carefully.

Method

Participants. There were three groups of participants. The young adults were 17 psychology students at the University of York who varied in age between 18 and 32 years, with a mean age of 20 years 7 months. They were given a course credit for their participation. The older participants were drawn from the NEAR subject pool. There were 32 participants in each of two age groups - 60-69 year olds and 80+ year olds. They were selected on the basis that they scored highly on four measures of language ability - Mill Hill tests of synonym judgement and word definition (Raven, 1965), and the Alice Heim (AH) tests of general and spatial reasoning (Heim, 1970). All the NEAR panellists reported that they were in good health and had normal or corrected-to-normal vision. They were paid £4 for participation.

Stimuli. The experimental stimuli were 50 black-and-white drawings of objects, taken from the picture set used by Morrison et al. (1997). The AoA scores upon which picture selection was based were the objective norms data reported by Morrison et al., who obtained objective measures of AoA for the names of 220 pictured objects from children aged from 2:6 up to 10:11. Twenty five pictures were selected that were known to children below the age of 26 months; these were the early-acquired items. The late-acquired items had AoA scores of 50.5 months, or more. The two sets of pictures were matched pairwise on rated visual complexity, name agreement (the degree to which speakers give the target name in response to the picture), Cobuild combined written and spoken frequency (Centre for Lexical Information, 1993), rated imageability and phoneme length.

Procedure. The stimuli were presented on a Macintosh computer, using SuperLab software. Participants wore a set of headphones with a high sensitivity microphone attached. The microphone was linked to a voice key that detected verbal responses and relayed reaction times to the computer. A 350 ms fixation dot in the centre of the screen cued the participant for the appearance of the stimulus which immediately followed the dot. The stimulus remained on screen until the participant made a verbal response or for 4 seconds, whichever was shorter. There was then an interstimulus interval of 2500 ms before the presentation of the next fixation dot.

Participants were told that a picture would appear on the screen and that they had to name the pictured object as quickly and as accurately as possible using a single-word label. They were instructed that the experiment was a test of their reaction time and were encouraged to respond as rapidly as possible, but with an emphasis on accuracy as well as speed. The experiment began with 30 practice items.

Results

Mean naming latencies were calculated by subjects and by items for each of the three age groups. Data from three of the participants in the oldest group were omitted from the analyses because they failed to name, or misnamed, more than 25% of the pictures. Seven items had an error rate of more than 25% across all three groups and these were also removed from the analyses (*beetle*, *boot*, *camera*, *cannon*, *cowboy*, *glasses*, *rocket*) along with their corresponding paired items (*duck*, *bow*, *cake*, *frog*, *butterfly*, *chain*, *rabbit*). This left 18 pairs of early- and late-acquired items for analysis. Thus, the analyses reported here are based on responses to 18 early and 18 late acquired items from 17 young adults, 32 60-69 year olds, and 29 80+ year olds.

The error rates for the young adults (7.9%) and the 60-69 year olds (7.4%) were comparable, though the error rate for the oldest participants was somewhat higher (11.9%). Some of this difference can be accounted for by the fact that older participants tended to make more elaborations (e.g., saying 'crescent moon' for *moon*), and that they used alternative names rarely or never used by younger participants (e.g., 'fiddle' for *violin*; 'keg' for *barrel*). However, older participants also made recognition errors never made by younger participants, (e.g., naming *cake* as 'cheese'), and occasionally gave semantic alternatives, (e.g., naming *violin* as 'banjo'), which younger participants rarely do.

The results of Experiment 3 are illustrated in Figure 1. Analyses of variance were carried out with AoA (early/late)

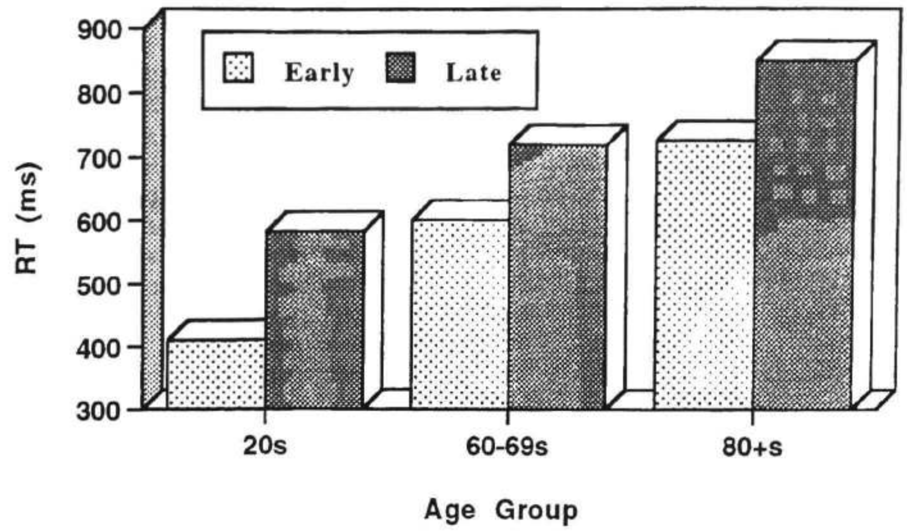

Figure 1. Results of Experiment 3. Mean picture naming RTs for early- and late-acquired items for each age-group.

as a within-subjects factor and group (young adults/60-69s/80+s) as a between-subjects factor. These revealed significant main effects of AoA, $F_1(1, 75) = 103.21$, $MSE = 691093$, $p < .0001$; $F_2(1, 51) = 24.75$, $MSE = 1056879$, $p < .0001$, with naming speeds being much faster for pictures with early-acquired names than for pictures with late-acquired names, and of group, $F_1(1, 75) = 16.51$, $MSE = 917201$, $p < .0001$; $F_2(1, 51) = 17.04$, $MSE = 684570$, $p < .0001$, with naming speeds being progressively slower as age increased. The interaction between AoA and group did not approach significance, $F_1(1, 75) = 1.17$, $MSE = 7865$, $p = .30$; $F_2(1, 51) = .41$, $MSE = 17359$, $p = .70$.

Discussion

AoA exerted a significant effect on picture naming speed in all three age groups. The effect of AoA in the young adult group replicates previous findings on picture naming speed (e.g., Morrison et al., 1992; Vitkovitch & Tyrell, 1995). Naming speed increased with age, which is in line with the results of previous studies (Mitchell, 1989; Thomas, Fozard and Waugh, 1977). Importantly, there was no indication of an interaction between participant age and AoA: indeed the AoA effect was as great in adults over 80 years of age as it was in young adults.

General Discussion

Experiments 1 and 3 found strong effects of AoA on word naming speed and object naming speed respectively using sets of items that were matched on word frequency, length, etc. In Experiment 1 the differentiation of early- from late-acquired words was based on adult ratings of AoA whereas in Experiment 3 it was based on normative data from children and adults. These results replicate the previous reports of effects of AoA on word naming (e.g., Brown & Watson, 1987; Morrison & Ellis, 1995) and object naming (Morrison et al., 1992; Vitkovitch & Tyrell, 1995).

In Experiment 2, there was no effect of word frequency on word naming speed. These results are compatible with the view that at least a substantial proportion of the so-called 'frequency' effect in word naming is, in fact, due to differences in AoA between high and low frequency words.

The central focus of the present paper is whether AoA effects change across the adult life span. It is clear from our results that AoA effects remain invariant across age for both word naming (Experiment 1) and object naming (Experiment 3). A similar lack of interaction with age has been reported for frequency effects in picture naming (Thomas et al., 1977) and lexical decision (Allen, et al., 1993) in studies which failed to control for the natural correlation between frequency and AoA, and where a proportion of the reported frequency effects is probably due to differences in AoA between the high and low frequency word sets (Morrison & Ellis, 1995).

The lack of any interaction between age and AoA is incompatible with either the cumulative frequency or the residence time hypotheses of AoA effects, both of which predict that the impact of AoA will diminish with chronological age. The results are, however, in accord with the view that AoA effects reflect intrinsic properties of lexical representations which are fixed when those words are first learned and remain unchanged thereafter.

Theoretical models of lexical processing postulate distinct stages of processing in object and word naming, and researchers have used these frameworks in an attempt to trace the locus of frequency and AoA effects in picture and word recognition tasks. Currently, architectures used in the speech production literature are a popular explanatory tool (e.g., Levelt, 1989; Jescheniak & Levelt, 1994). External information maps on to semantic nodes which in turn activate lexical nodes called lemmas - abstract representations of word forms. Lemmas then activate lexemes - phonological nodes specifying a word's spoken form. The lexeme specification maps onto phonetic articulatory units and drives the process of articulation.

Roelofs (1992) extended this framework to account for both picture and word naming. In line with many accounts of word recognition (e.g., Seidenberg & McClelland, 1989), he suggested that word naming by-passes the semantic level in one of two ways. The first is that orthographic representations (visual lexemes) activate lemmas which are involved in both the comprehension and production of words. The lemmas can then activate phonological lexemes and output processes without involving semantic representations. Another possibility is that there is a direct mapping between orthographic and phonological representations. Such mappings are widely proposed in models of word naming (e.g., Seidenberg & McClelland, 1989), and one reason for believing in their existence is to explain effects of the consistency or regularity of spelling-sound correspondences on word naming speed (e.g., Jared, McRae & Seidenberg, 1990). If abstract lemma representations were interposed between orthographic and phonological representations, then effects of sublexical consistency between spelling and sound should be lost.

Morrison et al. (1992) found no effect of AoA on semantic classification time for pictures but an effect on picture naming, and argued that AoA exerts its effect at or beyond the stage of lexical access. Morrison and Ellis (1995) found an effect of AoA on word naming in an immediate naming task when the response was produced as rapidly as possible following a word's appearance on the screen. There was no effect of AoA in a delayed naming task where the word was followed by an unpredictable delay and naming was prompted by the appearance of a visual cue to respond. Morrison and Ellis concluded that AoA did not affect post-lexical articulatory processes. If AoA does not affect semantic activation or output processes in object naming, then by a process of elimination, the effect of age of spoken acquisition on picture naming would seem to arise in the process of lexicalisation. That could be at the lemma stage, the lexeme stage, or both. But if word naming involves direct mappings between visual and phonological lexemes, and if the same locus is to be proposed for AoA effects in both object naming and word naming, then the best candidate would seem to be lexeme activation. Though the terminologies differ, that is roughly where it was placed in the theoretical accounts of Gilhooly and Watson (1981) and Brown and Watson (1987).

We suggest therefore, that the effect of the age at which a spoken word is learned on the speed with which it can be produced in object and word naming tasks have something to do with the organisation of the lexeme layer. And because AoA effects are fixed across the adult life span we suggest that they reflect differences between early- and late-acquired words which are fixed at the time when those words are learned. Few attempts have been made to simulate AoA effects using connectionist models. Morrison & Ellis (1995) suggested that one form of architecture which might provide a plausible account of how AoA effects could arise is provided by self-organising networks of the sort proposed by Kohonen (1990). Self-organising networks learn to discriminate between patterns by organising the output layer in such a way as to represent similar patterns close together and different patterns further apart. Morrison (1993) showed that patterns introduced early into the training cycle are spread across the whole of the output layer. Patterns introduced later have to be fitted in around them in such a way that fewer cells in the network are ever involved in representing them. Although only preliminary, such work indicates how AoA effects which remain invariant across the life span might begin to be understood.

In conclusion, our results indicate that AoA effects are just as strong in older participants as in younger participants for both word and picture naming. We take this as evidence that effects of AoA observed in young adults are a genuine reflection of the age at which words are learned (or the order in which they are learned). AoA effects are not reducible to cumulative frequency or residence time. We propose that AoA effects have their locus at the lexeme level and suggested that learning in a self-organising neural network architecture might provide a useful analogy for the development of the lexeme system.

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