Age of Acquisition effects in recognition without identification tasks

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Abstract

The Age of Acquisition (AoA) effect results in early-acquired words being processed more quickly and accurately than later-acquired words. This effect is argued to result from a gradual development of semantic representations and a changing neural network throughout development (Chang et al., 2019). Some forms of the Recognition Without Identification (RWI) effects have been observed at a perceptual level. The present study used the RWI paradigm to examine whether the AoA effect is located at the perceptual loci. A total of 174 participants were presented a list of pictures (Experiment 1) or words (Experiment 2) followed by a list of mixed early- and late-acquired picture or word fragments that participants had to identify; half of which corresponded to studied words and half of which to unstudied words. Irrespective of whether the item was identified, participants then rated the likelihood that the item appeared in the study phase. In both experiments, results showed that studied items were recognised more accurately than unstudied items, even when they could not be identified and late-acquired items were recognised more than early-acquired items, even when they were not identified. Finally, RWI interacted with the AoA effect only in pictorial stimuli, indicating that the RWI and AoA effects are located at the perceptual level.

All things being equal, the age at which a word or object is first encountered and learned has a significant effect on the efficiency of recall later in life. This Age of Acquisition (AoA) effect is such that, in most cases, early acquired words are advantaged compared to later acquired words. These effects have been demonstrated within a large number of different tasks, including object naming (e.g., Barry et al., 2001; Barry et al., 1997; Gerhand & Barry, 1999; Gilhooly & Gilhooly, 1979; Morrison et al., 1997; Morrison et al., 2002; Morrison et al., 1992; Snodgrass & Yuditsky, 1996), face naming (Lewis, 1999; Moore & Valentine, 1998), semantic classification (e.g., Johnston & Barry, 2005; Catling & Johnston, 2006), word naming (Morrison & Ellis, 1995; Ellis & Morrison, 1998; Elsherif et al., 2020) and lexical decision tasks (Morrison & Ellis, 1995; Gerhand & Barry, 1999). Reviews by Johnston and Barry (2006) and Juhasz (2005) further discuss the AoA effect using different methodologies, populations and languages.

Theories of the AoA effect

There are three predominant theories that seek to explain how and why AoA effects occur: The semantic theory, originally presented by van Loon-Vervoon (1989, cited in Brysbaert, van Wijnendaele & De Deyne, 2000), posits that AoA effects could result from the incremental construction of semantic representations. Early-acquired words are placed at the hub of the network (i.e. the centre) and from the hub, early-acquired words have a greater number of semantic connections to other concepts that allow early-acquired words to be easily accessible and processed (Brysbaert & Ghyselinck, 2006; Steyvers & Tenebaum, 2005). Put simply, early-acquired words have richer semantic representations and are immune to cognitive impairments (Brysbaert & Ellis, 2016; Catling et al., 2013; Marful et al., 2012). Supporting evidence has shown that the effect size of the AoA effect depends on the degree of semantic involvement of the task, thus the more semantic involvement, the larger the AoA effects (e.g.

AoA effects are larger for picture naming than for lexical decision, followed by progressive demasking and finally, word naming; Catling & Johnston, 2009; see review by Juhasz, 2005). An alternative, but not mutually exclusive, theory to the semantic theory is the arbitrary mapping (AM) account of AoA (Chang et al., 2019; Ellis & Lambon Ralph, 2000; Lambon Ralph & Ehsan, 2006; Monaghan & Ellis, 2010). According to the AM hypothesis, prior to early-acquired items entering the mental lexicon, the neural network has a high level of plasticity. Early-acquired words benefit from the rich resources available in the system, leading to rich and stable representations being better consolidated in the mental lexicon. As a result, early-acquired items modify the connections between input and output representations, causing the network to lose plasticity and the resources needed to lead to the strong and robust consolidation of a representation. Put simply, early-acquired items have a large effect on the final structure of the network. Late-acquired items need to be fitted to the network's structure formed by early-acquired words. However, there is a processing cost as late-acquired words, especially those with an arbitrary relationship (i.e. between orthography/phonology and semantics, as in picture naming), do not benefit from this structure formed by early-acquired words (Lambon-Ralph & Ehsan, 2006; Zevin & Seidenberg, 2002). Supporting evidence has demonstrated that AoA effects are stronger for items with arbitrary mappings between input and output (e.g. picture naming) than for items with more systematic and regular mapping between input and output (e.g. word naming; . Catling & Elsherif, 2020; Lambon Ralph & Ehsan, 2006).

It has recently been argued that the AoA effect is the resulting combination of the formation of representations and the changing plasticity in the neural network over development (Brysbaert & Ellis, 2016; Catling & Elsherif, 2020; Chang et al., 2019; Chang & Lee, 2020; Cortese et al., 2020; Dirix & Duyck, 2017; Menenti & Burani, 2007). Chang et al. (2019) used a computational model of reading across development and observed that there was a

stronger AoA effect for the lexical decision task than for word naming and that the AoA effect was stronger in inconsistent words than consistent words. This supports the AM hypothesis, as the AoA effect is the result of gradual development of the neural network. These results align with the integrated account of the AoA effect, indicating that early-acquired words benefit from more connections and accessibility than late-acquired words, such that lexical processing is shaped by the experience of learning during development in a gradual manner (Brysbaert & Ellis, 2016; Dirix & Duyck, 2017). To sum up, the AoA effect arises from both the connections between and within these representations in lexical processing (Chang et al., 2019). This argument has been limited to semantic representations, but the AoA effect has been observed in tasks that do not necessitate access to semantic representations but to perceptual and orthographic representations (Catling et al., 2008; Chen et al., 2009; Dent et al., 2007). Using the recognition without identification (RWI) paradigm, would allow the current study to determine precisely whether the AoA effect originates at the semantic or perceptual level.

Most studies assessing the AM hypothesis and the integrated view of the AoA effect (excluding Catling & Elsherif, 2020; and Lambon-Ralph, 2006) have used only one type of stimuli (i.e. words/characters or pictures). It is important to note that the mechanisms underlying word and picture processing differ in respect to perceptual input and linguistic representation of a name (see Figure 1). The processing of pictorial stimuli is primarily driven by semantic processing, as the speaker needs to identify the concept that instantiates the picture, choose a suitable lexical unit and retrieve its corresponding phonological representations (e.g. Indefrey & Levelt, 2004; Levelt et al., 1999), while the processing of words entails the mapping of orthography on to phonological representations (see review by Ellis, 1984). Word processing can involve semantic and conceptual representation but does not depend on these processes in the same way as picture naming, as shown in skilled readers

who can readily read and discriminate nonwords in lexical decision tasks (Rosson, 1983; Theios & Muise, 1977; see review by Ellis, 1984). The processing of picture and word stimuli therefore depend on different cognitive mechanisms and these processes have differential outcomes on the AoA effect. For instance, name-picture verification depends more on semantic processing and has more arbitrary mapping between perceptual and semantic processing than picture-name verification (Catling & Elsherif, 2020). In addition, picture naming leads to larger AoA effects than word naming (Lambon-Ralph & Ehsan, 2006). By using word stimuli and pictorial stimuli, we can disentangle the role of whether the AoA effect resides in the perceptual and/or post-perceptual loci.

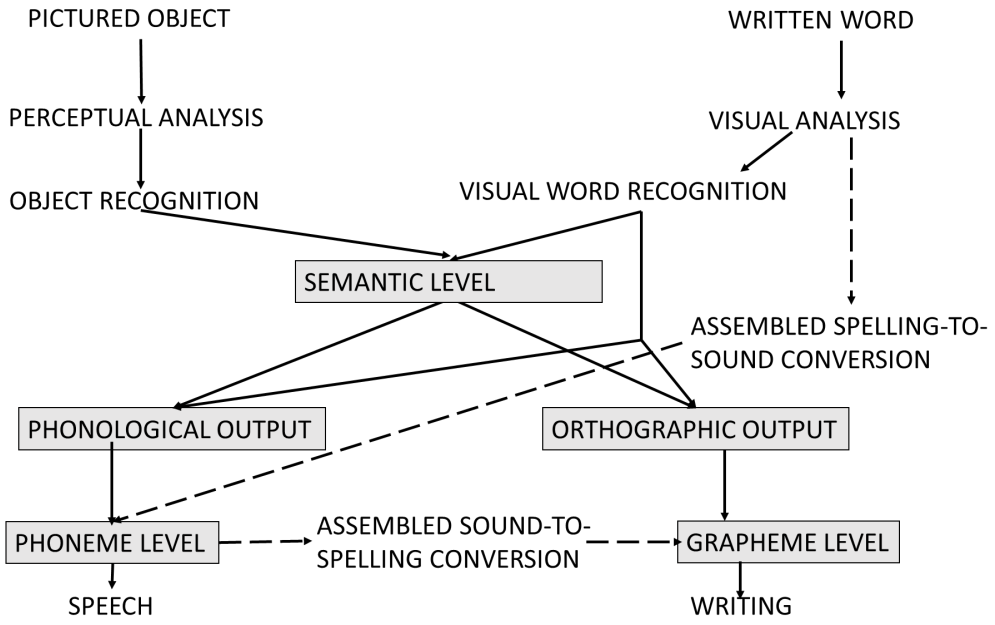

Figure 1. A general model of the processes underlying spoken and written object naming. The components belonging to the direct lexical pathway are presented against a light grey background and the components linked to the indirect sublexical pathway are illustrated in bold dotted lines. From "The hunt for the age of acquisition effect: It's in the links!" by Catling and Elsherif, 2020, *Acta Psychologica*, *209*, p.3. Copyright 2020 by Elsevier. Reprinted with permission.

Recognition Without Identification

One way of investigating where the effects of AoA reside in the processing of visual stimuli is to assess which other known psycholinguistic effects (that have a well-established locus of effect) might interact with AoA. Research has demonstrated that the locus of some forms of Recognition Without Identification (RWI) is known to be located at the perceptual level of processing (e.g. Langley et al., 2008). RWI is experienced by people in everyday life, as a person can maintain the ability to recognise a situation as familiar (e.g. recognising someone's face), whereas the details of that specific memory are unidentified or unretrieved (e.g. the name of an individual). In this paradigm, familiarity detection during the retrieval halt is tested, as the retrieval process occurs prior to stimulus identification (Arndt et al., 2008; Cleary et al., 2004; Langley et al., 2008; Peynircioglu, 1990).

Initially, RWI was investigated by Peynircioglu (1990) who presented participants with a list of words to study, followed by a test comprised of a list of word fragments to identify. Half of the fragments corresponded to words from the studied list, and half corresponded to words that had not been studied. Regardless of whether the word fragment could be identified, participants were asked to rate how likely it was that the word fragment corresponded to a word seen in the studied list. For instance, Peynircioglu (1990) presented participants with a list of words (e.g. amethyst) in a study phase, while in the test phase, word fragments were presented . Half of the word fragments were related to studied words (e.g., a----y--), while the other half were unstudied words. The authors observed that although some of the words could not be identified, participants were significantly more able to recognise them as studied than unstudied words This discrimination is usually demonstrated in the form of higher familiarity ratings for unidentified fragments from studied words than for unidentified fragments from unstudied words.

The RWI paradigm has been generalised to several stimuli and situations. In addition to visual word RWI (Cleary, 2004, Cleary & Greene, 2001; Ryals & Cleary, 2012), stimuli have been demonstrated but not limited to: spoken words (Cleary et al., 2007; Cleary et al., 2007), songs (Kostic & Cleary, 2009; McNeely-White & Cleary, 2019), faces (Cleary, 2011; Cleary & Specker, 2007), scenes (Cleary & Claxton, 2018; Cleary et al., 2012; Cleary & Reyes, 2009), odours (Cleary et al., 2010) and pictures (Cleary et al., 2004; Langley et al., 2008).

Few studies have investigated the RWI in pictorial stimuli. Cleary et al. (2004) used a fragmentation technique to isolate specific stimulus features on a recognition test. They provided the participants with a list of pictures of objects (e.g. stool). In the study phase, participants were given a recognition test containing picture fragments that appeared or did not appear in the study list. In addition, the fragments contained isolated geometric shapes from their relating pictures, while other fragments had only line-segments without the component-shape information. The authors observed RWI when picture fragments contained geometric shapes from their original pictures but not when they only contained line-segment information. They concluded that this form of RWI is perceptual in nature. Further evidence supporting this argument is provided by Langley et al. (2008) who demonstrated that the RWI could be extended to masked picture recognition. Participants viewed a list of pictures of common animals and objects (i.e. Experiment 1) and names of the picture (i.e. Experiment 2), followed by a test list comprised of both studied and unstudied pictures. The pictures in the test condition were masked and unidentifiable to subjects. Langley et al. found that subjects could correctly discriminate between previously presented pictures and new ones, while when names of the pictures, as opposed to pictorial stimuli, were used as a list of study items, the RWI effect disappeared. Following these experiments, the authors argued that if the RWI is at the perceptual level, there must be a perceptual match in terms of the pictorial

stimuli between the study items and the test items, but if the RWI is at the conceptual level, the RWI should be shown irrespective of perceptual match or mismatch. The authors observed the former finding, concluding that this specific form of RWI in pictures is recognised at a perceptual level.

Importantly, whereas the locus of the AoA effect is still subject to debate, the locus of effect for some specific forms of RWI is thought to involve perceptual-level processing (Cleary et al., 2004). Furthermore, it is apparent that the RWI effect can be found in the recognition of written words (e.g. Arndt et al., 2008; Peynircioglu, 1990) as well as pictorial stimuli (e.g. Cleary et al., 2004; Langley et al., 2008). Interestingly, in a similar study to RWI, Dewhurst et al. (1998) used a recognition memory task with mixed lists (i.e. early-acquired words and late-acquired words were placed in one list). The authors found that performance was better for late-acquired than early-acquired words, but only on remember, not on know, judgments. They concluded that the difference in processing between early-acquired and late-acquired word may result from more distinctive episodic traces for the latter than the former. In addition, the authors concluded that the greater distinctiveness of late-acquired words would increase the amount of conscious recollection linked with late-acquired words, as the recognition advantage was in the recollection component of recognition memory. However, recognition memory can be influenced by later processes, while specific forms of RWI will allow us to assess whether the AoA effect in recognition occurs in the early stages.

Until now, RWI and AoA effects have not been assessed together. This creates an opportunity to investigate possible interactions between the two effects to assess (through additive factors logic) for a possible AoA locus of effect at the perceptual level of processing. If AoA does indeed interact with perceptual forms of RWI effects, then it would suggest that AoA does have a locus of effect at the perceptual level of processing.

EXPERIMENT 1: What do we predict for pictorial stimuli and AoA effects?

METHOD

Design

The present study encompassed two independent variables and was therefore based on a 2 (AoA: early-acquired, late-acquired) x 2 (study status: studied, unstudied) within-participants design. The dependent variable was the mean rating of likelihood of recognising unidentified items as having been previously studied.

Participants

We first conducted a power analysis based on the effect size of the RWI (d = 2.6)[1] of Langley et al.'s (2008) experiment, calculated using Brysbaert and Stevens (2018) equation for Cohen's d to detect a similar effect. Our power analysis was performed using G*Power (Faul et al., 2009) with a Cohen's d calculated, a power level of 95% and a significance level of 5% (two-sided). This power analysis produced a minimum number of five participants. Note that the sample size in our experiments (n = 97 in Experiment 1 and n = 77 in Experiment 2) was considerably higher. It was important to test a larger sample size than suggested by the power analysis, as larger sample sizes in the individual experiments enabled us to better assess the interaction of AoA and RWI. Participants were students at the University of Birmingham recruited on a voluntary basis through the Research Participation Scheme in exchange for course credits. 97 participants took part in the experiment. All participants were monolingual and had English as their first language. Participants were aged from 18-40.

[1] The effect size of d is calculated by the mean difference of the proportion identified of old pictures (M = 0.59) and new pictures (M = 0.20) divided by the average standard deviation of old pictures (0.18) and new pictures (0.12).

Materials

The critical stimuli set were 48 black and white line drawings from Barry et al., (2001; originally taken from Snodgrass and Vanderwart 1980), 24 of which had early-acquired labels and 24 had late-acquired labels. The two sets of items were matched for the mean word frequency of their names, using Celex written frequency, Celex spoken frequency, and Kucera and Francis (1967) and the object's rated familiarity and percentage name agreement (Barry et al., 1997) and phoneme length and did not differ on ratings of image agreement or visual complexity (Snodgrass & Vanderwart,1980). The "early" items were selected such that their names had AoA ratings (Barry et al., 1997) of less than 2.25 and the "late" items had AoA ratings of greater than 2.90 See Table 1 and Appendices). These two lists were created such that they were matched on all variables. These were then split into four blocks of equal length (all lists were mixed for AoA).

Table 1. Mean (standard deviations in parentheses) of the critical psycholinguistic stimuli properties.

Property	Early Acquired	Late Acquired
AoA		
Subjective	1.95 (0.19)	3.36 (0.35)
Objective (months)	35.7 (28.5)	61.8 (21.5)
Word frequency		
Celex written	10.7 (11.3)	8.7 (11.4)
Celex spoken	4.0 (3.8)	3.8 (4.8)
Kucera and Francis	9.0 (9.3)	9.9 (9.2)
Object familiarity	2.93 (0.77)	2.82 (0.80)
% Name agreement	95.5 (8.4)	94.5 (6.4)
Image agreement	3.71 (0.58)	3.68 (0.76)
Visual complexity	3.01 (0.92)	2.76 (0.94)
No. of phonemes	4.2 (1.4)	5.0 (1.7)

To create the picture fragments, 80% of the pixels were deleted to resemble the 'recoverable' or geon fragments used by Cleary et al. (2004). This meant that the fragments contained the contact points of the basic components that make up the picture, which was necessary as RWI does not occur without them (Cleary et al., 2004; see Figure 2).

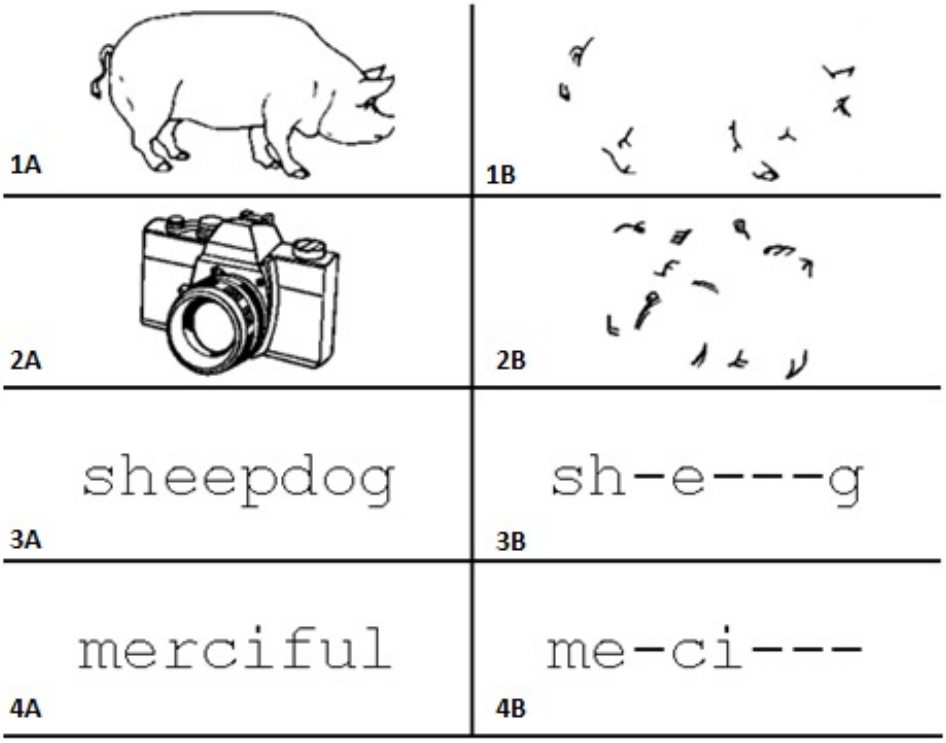

Figure 2. Sample stimuli from the present study. Items 1A and 2A are pictures that were used in the study for Exp 1. 3A and 4A are words that have been used in a study list for Exp. 2. Items 1B and 2B (Exp. 1), 3B and 4B (exp. 2) are the corresponding picture and words fragments that have been used in the test list. Items 1A and 3A with their corresponding fragments are early-acquired items, whilst items 2A and 4A with their corresponding fragments are late-acquired items.

Procedure

Prior to each block, each participant was given written instructions on the computer screen detailing the requirements for that block. The picture experiment was made up of four picture blocks consisting of 6 pictures each, half had early-acquired labels and half had late-acquired labels. This was followed by the presentation of the test list, containing 48 picture

fragments; half had been seen in the study list and half had not (all lists were mixed for AoA).

Within the testing phase of the study each stimulus was presented on the screen for 2 seconds at a time. Participants pressed the space bar if they could not identify the picture, or typed in the name of the original picture if they could identify it. Regardless of whether they could identify the picture, participants rated 0 (definitely not in the original list) to 10 (definitely in the original list) how likely they thought the item was in the original list of items. Both experiments were presented using E-Prime version 2.0, run on a desktop computer.

RESULTS[2]

Three participants' data in the picture condition were excluded from the analysis. This was due to participants misunderstanding the experiments requirements as some participants only provided 'recognition' ratings for the items they could identify, as opposed to providing a rating for each item regardless. A 2 X 2 (study status: studied, unstudied) X (AoA: early-acquired, late-acquired) analysis of variance (ANOVA) was carried out. For this fully orthogonal design, we report the results of analysis by participants only (following Clark, 1973; Raaijmakers et al., 1999). The main interest lay in the items that could not be identified as opposed to the identified items, as this determines the RWI effect.

Study Status

There was a significant main effect of study status on recognition ratings for unidentified pictures. Participants gave significantly higher ratings for unidentified studied

[2] An item-analysis was conducted for each participant on the pictures they were able to recognise but failed to identify. We found that the 'early' and 'late' groups of words were still significantly different in respect to their AoA ratings (t = 10.90, p = .001) but remained matched for all other variables (all ps > .05).

pictures (M = 3.39) compared to unidentified unstudied pictures (M =2.75; $F(1, 93) = 30.71$; $p < .001$, $\eta p^2 = 0.25$, 90%CI[0.13, 0.36]). (See Figure 3 for the mean ratings of pictures).

Age of Acquisition

There was a significant main effect of AoA on recognition ratings of unidentified pictures; $F(1, 93) = 4.122$; $p = .045$, $\eta p^2 = 0.04$, 90%CI[0.0005, 0.13]. Participants gave significantly higher ratings for late-acquired pictures ($M = 3.61$) than early-acquired pictures ($M = 3.17$). Whereas for the unstudied pictures, participants gave higher recognition ratings for early-acquired pictures (M = 2.78) than late-acquired pictures (M = 2.72). With regards to studied words, participants also gave significantly higher ratings for unidentified studied late-acquired words (M = 3.22) than unidentified studied early-acquired words (M = 3.03). Similarly, for the unstudied words, participants gave higher recognition ratings for late-acquired words (M = 2.77) than early-acquired words (M = 2.64).

There was a significant interaction of study status and AoA in the picture condition ($F(1, 93) = 7.6$; $p = .007$, $\eta p^2 = 0.08$, 95%CI[0.01, 0.17]). Figure 3 represent the mean recognition ratings for pictures. To examine this significant interaction between study status and AoA for the picture condition, post hoc t-tests were conducted to compare mean ratings in studied early-acquired pictures and studied late-acquired pictures. There was a significant difference in the studied condition in the ratings for early-acquired (M = 3.17, SD = 1.57) and late-acquired (M = 3.61, SD = 1.80) conditions ($t(93) = 2.594$, $p = .011$). No other comparisons were significant.

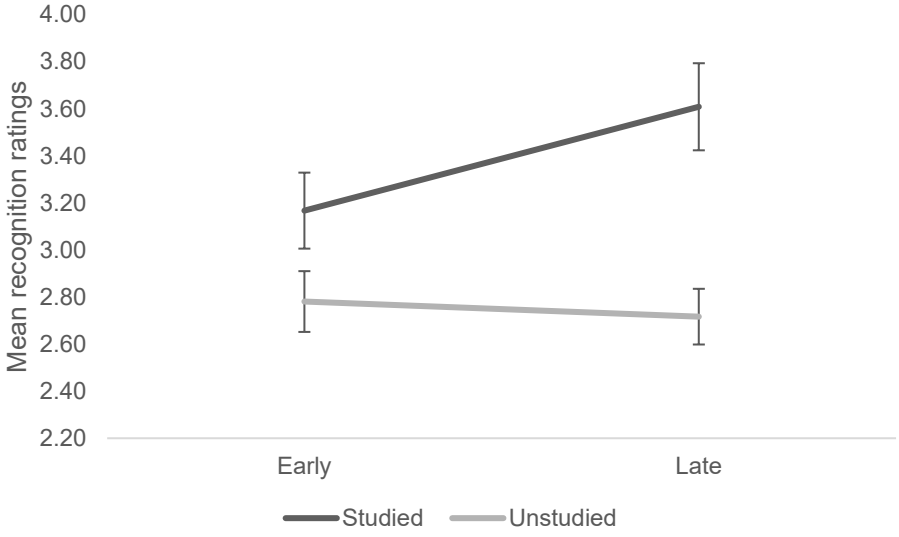

Figure 3. Mean likelihood ratings for unidentified pictures as a function of study status and Age of Acquisition. Error bars represent standard error.

Identification Accuracy

There was a trend to significance for the main effect of AoA in the picture conditions for identification accuracy. Participants failed to identify significantly more late-acquired items (M = 16.33%) than early-acquired items (M = 15.34%); $F(1, 93) = 2.88$; $p = .09$, $\eta p^2 = 0.03$, 90%CI[0.00, 0.11]. To further assess whether the non-significant effect indeed supports the null hypothesis (i.e. early-acquired words and late-acquired words do not differ in identification accuracy), we calculated the Bayes factor (= 0.44), using 'BayesFactor' package in R (see Rouder et al., 2012 for details). This result provides inconclusive evidence (1/3< Bayes factor > 3) as to whether it supports the null or alternative hypothesis (Jeffreys, 1939, 1961). In particular, while frequentist statistics are framed to reject the null hypothesis (i.e. if a p value is below the alpha level), they do not offer an explicit mechanism to affirm the null hypothesis. Bayesian methods, in contrast, do.

EXPERIMENT 2: What do we predict for word stimuli and AoA effects?

METHOD

Seventy-seven British monolingual undergraduates aged 18-40 years participated in the study and were remunerated with course credits. None of the students were involved in the previous experiment. The same design and procedures from Experiment 1 were used with the following exception: the pictorial stimuli were switched for the equivalent word stimuli. A total of 192 words were used, including 96 early-acquired words and 96 late-acquired words. The words were taken from Kuperman et al. (2012) with early-acquired words rated as less than 9 years and late-acquired as above 10.5 years and were balanced for frequency, phoneme length, and letter length. These were then split into four blocks of equal length (all lists were mixed for AoA). Each word fragment was made up of four letters, which included the first letter of the word (See Fig. 2; Cleary & Greene, 2001).

RESULTS[3]

Three participants' data in the word condition were excluded from the analysis. This was due to participants misunderstanding the experiments requirements as some participants only provided 'recognition' ratings for the items they could identify, as opposed to providing a rating for each item regardless. A 2 X 2 (study status: studied, unstudied) X (AoA: early-acquired, late-acquired) analysis of variance (ANOVA) was carried out. For this fully orthogonal design, we report the results of analysis by participants only (following Clark, 1973; Raaijmakers et al., 1999). The main interest lay in the items that could not be identified as opposed to the identified items, as this determines the RWI effect.

An item-analysis was conducted for each participant on the words they were able to recognise but failed to identify. We found that the 'early' and 'late' groups of words were still significantly different in respect to their AoA ratings (t = -12.36, p = .001) but remained matched for all other variables (all ps > .05).

Study Status

There was a significant main effect of study status on recognition ratings. Participants gave significantly higher ratings for unidentified studied words (M = 3.12) compared to unidentified unstudied words (M = 2.71; $F(1, 72) = 71.780$; $p < .001$, $\eta p^2 = 0.50$, 90%CI[0.36, 0.60]; See Figure 4 for the mean ratings of words).

Age of Acquisition

There was a significant main effect of AoA on unidentified words; $F(1, 72) = 8.552$; $p < .005$, $\eta p^2 = 0.11$, 90%CI[0.02, 0.22]. Participants also gave significantly higher ratings for unidentified studied late-acquired words (M = 3.22) than unidentified studied early-acquired words (M = 3.03). Similarly, for the unstudied words, participants gave higher recognition ratings for late-acquired words (M = 2.77) than early-acquired words (M = 2.64). There was no significant interaction between AoA and study status in the word condition ($F(1, 72) = .388$; $p = .535$, $\eta p^2 = 0.01$, 90%CI[0.00, 0.06]). To further assess whether the non-significant effect indeed supports the null hypothesis (i.e. early-acquired words and late-acquired words do not differ in study status for word targets), we calculated the Bayes factor (Rouder et al., 2012) (= 0.18), using 'BayesFactor' package in R (see Rouder et al.,2012 for details). This result provides evidence in favour of the null hypothesis (BF < 1/3; Jeffreys, 1939, 1961). In particular, while frequentist statistics are framed to reject the null hypothesis (i.e. if a p value is below the alpha level), they do not offer an explicit mechanism to affirm the null hypothesis. Bayesian methods, in contrast, do.

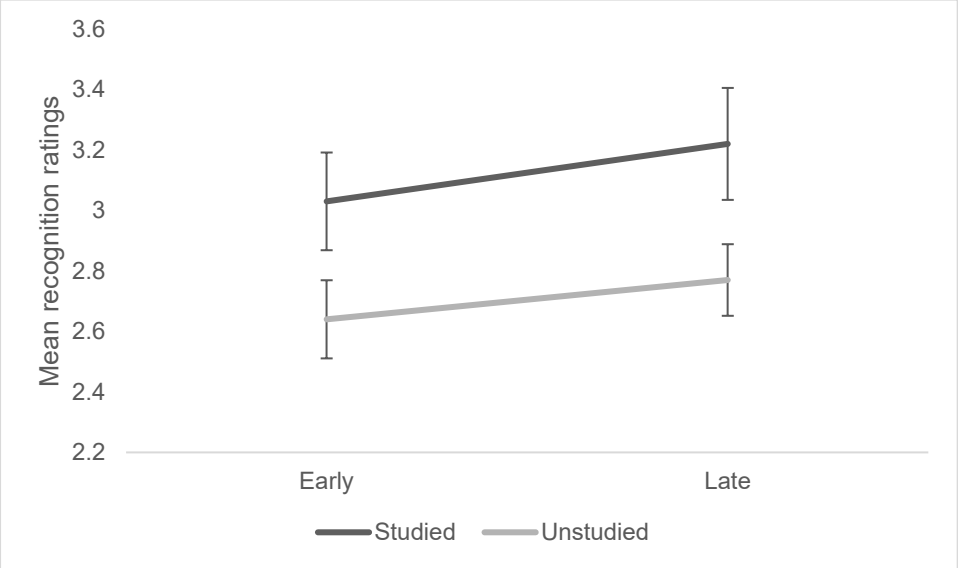

Figure 4. Mean likelihood ratings for unidentified words as a function of study status and Age of Acquisition. Error bars represent standard error.

Identification Accuracy

There was a significant main effect of AoA in the word conditions for identification accuracy. Participants failed to identify significantly more early-acquired items (M = 20.31%) than late-acquired items (M = 18.79%); $F(1, 72) = 18.157$; $p < .001$, $\eta p^2 = 0.20$, 90%CI[0.08, 0.33]. The combined differences in accuracy of word and picture identification as a function of AoA are presented in Figure 5.

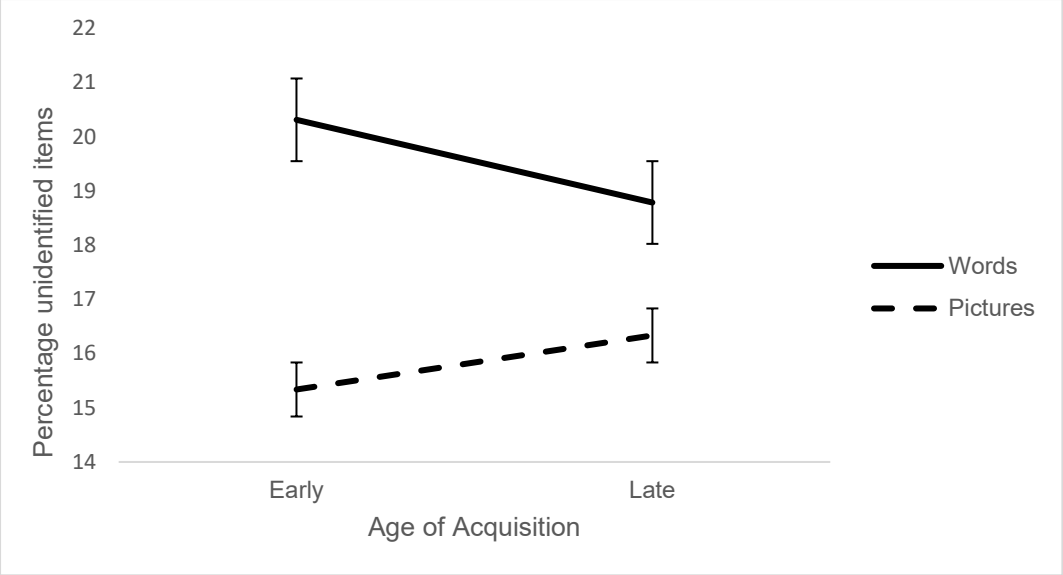

Figure 5. Mean percentage of unidentified studied items as a function of Age of Acquisition and stimulus type collapsed across Exps. 1 & 2. Error bars represent standard errors.

DISCUSSION

The current study is novel in being the first study to assess AoA effects with RWI. In those items that could not be identified, studied pictures and words were overall more recognised as having been previously studied than pictures and words which were not previously studied. Thus, there was a significant RWI effect in both pictures and words. The finding provides additional validation for previous findings of RWI in pictorial stimuli (e.g. Cleary et al., 2004; Langley et al., 2008) as well as written word stimuli (e.g. Arndt et al., 2008; Peynircioglu, 1990). RWI is primarily explained using global-matching models of recognition memory which state that RWI occurs when there is just a partial match of test items to studied items in memory. The occurrence of and positioning of some of the letters and geons relate to the mental representations of the studied items, which act as partial probes to result in recognition (Arndt et al., 2008).

Second, there was an observed significant interaction between AoA and RWI for picture stimuli, the focus was on the effect of AoA on studied items specifically, because

RWI requires an item to have been previously studied, but not identified. Furthermore, a significant difference was found between the recognition of early- and late-acquired items when they had been studied, in that late-acquired studied items were significantly more recognised than early-acquired studied items across both pictures and words. Interestingly, however, the effect of AoA did not occur in the same direction as item naming. In previous research on item naming, it has been found that early-acquired words are recalled faster and more accurately than late-acquired words, and consequently have an advantage in item naming (e.g. Barry et al., 2001; Carroll et al., 1973; Meschyan & Hernandez, 2002), whereas in the present study on item recognition, rather than naming, the late-acquired items presented an advantage over early-acquired items. This supports the findings of a different recognition task used by Dewhurst et al. (1998) who showed that when words are presented in a mixed list containing both early- and late-acquired words, late-acquired words are significantly better recognised. Hence, while early-acquired items may be more accurately named, late-acquired items may be better recognised.

Importantly, the significant interaction between AoA and RWI (for pictures) also suggests that AoA effects occur at the same level as RWI for the processing of pictorial stimuli, specifically at the perceptual level of processing. This is another piece of evidence for an AoA locus of effect at the level of perceptual processing and supports previous findings such as Catling et al. (2008), who demonstrated AoA effects within visual duration thresholds for naming pictures and hence claimed (among others, e.g., Moore et al., 2004) that AoA has an early, perceptual based, locus of effect. However, as stated previously, there are a limited number of studies that disagree with this account of AoA, for example, research by Urooj et al. (2014). They used magnetoencephalography (MEG) to explore the neuropsychological locus of AoA, and their results indicated that the initial analysis of object forms in the visual cortex was not influenced by AoA, and hence, that AoA does not

influence the initial visual analysis of object features. However, given that the findings from the current study would indeed appear to support the notion of a perceptual locus of effect for AoA, it is our view that these contradictory findings are best explained by the differences in the tasks and training between the two studies – notably, Urooj et al. included a training session, in which participants were shown each picture accompanied by its initial and final letters and were asked to produce the correct name (e.g. the cue V----N is presented and the participant needs to say violin in a response to its picture). The pre-exposure to the objects was to ensure participants correctly named the target under the covert naming condition (Urooj et al., 2014). This training could quite easily have an impact on the perceptual processing of an item, in that they will have been seen before, recently, and perhaps even to some extent primed, in a way that was not possible within the current study. Furthermore, in the MEG study, participants were asked to only name the item in their heads rather than articulate the name. These differences could quite easily account for the difference in findings between the two studies, and it should also be noted that the current findings do also support previous behavioural studies that also suggest an early locus of effect for AoA (e.g., Catling et al., 2008; Ghyselinck et al., 2004; Lyons et al., 1978; Moore et al., 2004).

It is important to also remember that the interaction between AoA and RWI was only observed with pictorial, not word, stimuli. This would suggest that whilst AoA effects can be found at the perceptual analysis for pictures they are not present at the level of grapheme analysis for words. Linking these findings to those of Catling et al., (2009) who advocate a multi-loci account of AoA for both words and pictures this would suggest that one of the AoA loci of effect for pictures is at the level of perceptual analysis, but does not preclude additional later AoA loci of effect (e.g., Brysbaert & Ghyselinck, 2006; Holmes & Ellis, 2006; Moore et al., 2004), whereas, any AoA effect in word naming would be at post-perceptual levels of processing. This would also be a neat explanation for the larger AoA

effects normally found in picture naming compared to word naming (e.g., Brysbaert & Ghyselinck, 2006; Chalard, 2002) and would also reinforce the Catling and Johnston's (2006) “accumulation” hypothesis, where they suggest that the greater the levels of processing necessitated to complete the task the greater the ‘accumulated’ AoA effect. Importantly, this also suggests that the perceptual encoding and processing of words is less arbitrary in nature than the encoding and processing of pictures, and it is for this reason that the AoA effects are not found there (Ellis & Lambon Ralph, 2000). In addition, this also extends the findings of Catling and Elsherif (2020) who argued that the integrated view of the AoA effect for word originates at the post-perceptual stages, whereas for pictorial stimuli it begins at the perceptual stage.

To conclude, the current study is the first to detail evidence for the interaction of AoA and RWI with pictorial stimuli. These findings provide theoretical implications for these processes, specifically the locus of effect for AoA. The current findings would suggest an AoA locus of effect resides at an early perceptual level of processing.

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Appendices

Early-acquired pictures for experiment 1

pictures	ImAg _M	Fam_M	%NA	Freq	AoA
Balloon	4.33	2.86	100	10	1.85
Banana	4.42	3.71	90.9	4	1.8
Butterfly	3.92	2.73	100	2	2.2
Cake	3.45	3.32	100	13	1.9
Carrot	4.5	4.23	100	1	2.05
Coat	2.59	3.77	100	43	1.85
Comb	3.78	3.68	100	6	2.1
Doll	2.28	2.5	72.7	10	1.6
Drum	3.71	2.41	100	11	2
Duck	3.85	2.59	81.8	9	1.95
Elephant	3.85	2.18	100	7	2.05
Frog	3.6	2.38	90.9	1	2.1
Leaf	3.88	3.41	100	12	2.05
Lion	3.88	1.91	100	17	1.75
Lorry	2.8	3.41	77.3	0	2.2
Mouse	4.22	2.59	81.8	10	2.05
Orange	4	3.73	100	23	1.85
Pear	4.62	3.23	100	6	2.16
Pig	3.62	2.36	95.5	8	1.8
Pram	3.65	2.27	100	1	1.75
Shoe	3.02	4.68	100	14	1.5
Snail	3.33	2.45	100	1	2.2
Snowman	4	2.18	100	0	1.95
Tiger	3.82	1.77	100	7	2.1
Mean	3.71	2.93	95.45	9	1.95
SD	0.58	0.77	8.37	9.31	0.19

Note. ImAg_M = mean image agreement; Fam = mean object familiarity; %NA = % name agreement; Freq = word frequency; AoA = age of acquisition.

Late-acquired pictures for experiment 1

pictures	ImAg _M	Fam_M	%NA	Freq	AoA
Anchor	4.32	1.73	100	15	4.32
Arrow	2.27	3.27	90.9	14	2.27
Ashtray	3.2	3.5	100	0	3.2
Belt	4.05	3.81	95.5	29	4.05
Bow	2.67	2.36	81.8	15	2.67
Cigar	2.75	2.23	95.5	10	2.75
Cigarette	4.65	3.86	100	25	4.65
Envelope	4.7	4.27	95.5	21	4.7
Flag	3.22	2.22	100	16	3.22
Flute	3.41	1.91	95.5	1	3.41
Guitar	4.2	3	95.5	19	4.2
Kangaroo	4.3	1.41	95.5	0	4.3
Lamp	3.26	3.73	95.5	18	3.26
Light Bulb	4.42	3.41	77.3	0	4.42
Pineapple	4.6	2.36	86.4	9	4.6
Pliers	4.22	2.24	86.4	1	4.22
Ruler	3.98	3.82	100	3	3.98
Screw	3.67	2.77	95.5	21	3.67
Screwdriver	4.3	2.73	100	0	4.3
Spanner	2.51	2.55	86.4	0	2.51
Toaster	3.92	3.86	100	0	3.92
Trumpet	2.89	2.05	95.5	7	2.89
Vase	2.72	2.5	100	4	2.72
Violin	4.18	2.14	100	11	4.18
Mean	3.68	2.82	94.53	9.96	3.68
SD	0.76	0.8	6.42	9.17	0.76

Note. ImAg_M = mean image agreement; Fam = mean object familiarity; %NA = % name agreement; Freq = word frequency; AoA = age of acquisition.

Early-acquired words for experiment 2

words	Freq	AoA
lifelong	1.51	8.80
outhouse	0.75	7.90
stairway	1.59	4.15
riffraff	1.02	8.26
squeezer	0.14	8.12
rigatoni	0.29	8.93
fastball	1.16	7.06
devilish	0.51	8.72
starless	0.04	8.67
bootless	0.06	8.06
bigmouth	0.53	7.00
parakeet	1.08	6.53
raincoat	1.65	5.50
disabled	3.47	7.67
diagonal	0.53	8.00
conserve	0.86	8.72
estimate	4.76	8.78
duckling	0.76	4.95
flamingo	1.18	6.32
skylight	0.84	8.60
chainsaw	1.08	7.00
ugliness	1.24	6.33
register	11.00	8.63
radiator	2.02	8.53
biblical	2.24	6.90
bookworm	0.73	5.78
stinging	0.90	6.78
impolite	1.29	7.26
eggplant	1.10	8.30
railroad	12.43	6.06
lifeboat	1.39	7.72
wrinkled	1.69	7.26
calamine	0.20	8.19
decrease	1.18	8.56
checkout	1.25	6.44
downhill	2.47	5.86
overhear	1.04	8.37
bookcase	0.94	5.63
overflow	0.96	6.44
swimsuit	1.98	5.61
congrats	1.78	8.26
predator	2.63	8.45
gardener	4.20	6.50
merciful	3.49	8.11
wasteful	0.59	7.11
goofball	0.55	7.79
doghouse	1.12	6.74
leftover	1.20	7.28

sheepdog	0.53	7.11
ancestor	1.69	8.61
hardware	6.82	8.63
steering	4.06	7.56
spaceman	1.00	7.63
wreckage	2.08	8.47
grieving	2.73	8.75
confetti	0.90	7.39
opposite	15.20	5.06
pastrami	0.96	8.42
chestnut	1.27	6.55
mythical	0.88	7.11
likeness	1.92	8.84
puncture	1.88	8.89
ladylike	0.84	7.00
christen	0.63	8.43
sporting	3.12	8.79
playroom	0.80	6.11
tinkling	0.75	8.47
motorcar	0.57	7.78
daydream	0.96	7.74
cucumber	1.98	5.72
buttocks	1.82	7.72
reminder	3.76	7.50
cheerful	3.73	7.68
recycled	0.84	8.32
hometown	3.90	7.22
purchase	6.37	8.11
hardened	1.14	6.94
unopened	0.55	7.06
flipping	2.92	7.58
shootout	1.04	8.72
disciple	1.02	8.16
dominate	1.86	8.89
shoelace	0.75	4.16
smartass	0.71	8.32
memorial	7.06	8.32
payphone	0.71	7.11
fairness	2.04	5.61
infinity	1.69	8.83
stocking	2.63	6.68
tricycle	0.53	4.05
mouthful	1.69	6.37
tailless	0.02	7.94
lecturer	0.80	8.69
treelike	0.02	8.59
marigold	0.16	8.47
evildoer	0.06	8.33
Mean	1.92	7.47
SD	2.42	1.18

Note. Freq = word frequency; AoA = age of acquisition.

Late-acquired words for experiment 2

pictures	Freq	AoA
blockade	1.53	10.55
electron	0.73	12.40
citation	1.59	12.95
elective	1.02	12.11
cohesive	0.14	12.25
dredging	0.29	14.20
uprising	1.16	11.17
bondsman	0.51	13.83
classism	0.04	15.40
resubmit	0.06	10.53
rekindle	0.53	12.79
catheter	1.08	14.37
nobility	1.65	11.39
commerce	3.47	13.44
envision	0.53	11.72
narcotic	0.86	13.11
specimen	4.75	11.72
unlawful	0.76	11.32
splendor	1.18	10.79
rigorous	0.84	11.60
anecdote	1.08	14.33
moderate	1.24	11.22
analysis	11.04	11.32
solitude	2.00	12.00
sterling	2.22	10.70
integral	0.73	14.33
travesty	0.90	12.11
overture	1.29	11.47
ensemble	1.12	12.25
producer	12.47	10.89
perverse	1.29	13.11
decipher	1.71	10.84
abridged	0.18	12.56
decadent	1.18	12.00
gullible	1.25	10.83
roulette	2.47	12.82
coherent	1.04	11.95
enduring	0.94	11.21
acoustic	0.96	12.39
manicure	1.98	10.56
disperse	1.78	12.11
hydrogen	2.67	11.00
profound	4.18	12.06
mystique	3.51	11.89
ejection	0.59	10.53
referral	0.55	10.84
punctual	1.12	10.79
chivalry	1.20	13.89

rhapsody	0.53	12.95
foremost	1.69	11.78
dispatch	6.86	11.00
discreet	4.06	11.89
exorcist	0.98	12.11
consumer	2.08	11.21
offender	2.75	10.85
chloride	0.90	12.22
homicide	15.33	12.94
unlisted	0.96	11.21
converse	1.29	12.00
maximize	0.88	10.58
adultery	1.94	11.84
sorority	1.88	14.22
doctrine	0.84	11.89
spectral	0.63	13.43
regional	3.12	10.95
symmetry	0.80	11.39
belittle	0.73	12.88
affinity	0.57	12.22
pavilion	0.96	10.58
oblivion	1.98	10.94
feminist	1.82	12.06
treasury	3.80	11.25
manifest	3.69	12.16
sanction	0.84	12.68
hangover	3.90	13.39
persuade	6.39	10.79
scrutiny	1.14	13.00
scaffold	0.55	12.11
clinical	2.92	11.84
epilepsy	1.04	12.39
eyeliner	1.02	10.63
exorcism	1.86	12.06
vigilant	0.75	13.21
senorita	0.71	11.05
compound	7.08	11.26
escalate	0.71	10.94
organism	2.04	10.61
renounce	1.69	12.72
wireless	2.65	14.05
auditory	0.53	12.79
vascular	1.69	15.11
paganism	0.02	14.59
derelict	0.78	14.38
docility	0.02	14.82
outmoded	0.16	15.80
vexation	0.06	14.80
Mean	1.93	12.20
SD	2.43	1.28

Note. Freq = word frequency; AoA = age of acquisition.