Does The Face Fit The Facts? Testing Three Accounts Of Age Of Acquisition Effects

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Abstract

Naming and perception tasks show robust effects of age of acquisition (AoA), with faster processing of stimuli learnt earlier in life compared to stimuli acquired later. That AoA effects prove to be more elusive on semantic processing tasks is of importance in attempting to determine the mechanism and locus (or loci) of AoA effects. Three accounts of AoA effects were tested empirically using perceptual familiarity decision tasks to record response latency and accuracy to the faces and names of famous people, with the quantity of semantic knowledge being manipulated. The results do not support the semantic 'hub' network or arbitrary mapping explanations of AoA but are consistent with the Set-up of a Specialized Processing System hypothesis.

Introduction

The ability to recognize and name objects, words, and faces is fundamentally important to our understanding of, and ability to interact with, the environment. However, the ubiquity, ease, and speed of such processing contrasts with the complexity of the cognitive processes involved. In addressing these complexities, it has been common to select a set of variables and to decide which variable from this set has the most influential effect on processing. Age of acquisition (AoA) has been found to be one such important predictor of processing speed. Using tasks that require responses to the names and faces of well known figures in popular culture, the differences between three accounts of the AoA phenomenon are examined in this paper, namely the arbitrary mapping hypothesis (Ellis & Lambon Ralph, 2000), the semantic 'hub' network model (Steyvers & Tenenbaum, 2005), and the Set-up of a Specialised Processing System hypothesis (SSPS; e.g., Moore, 2003).

All things being equal, individuals are faster to process items that are learnt earlier in life than items acquired later. This processing advantage for early-acquired stimuli, the AoA effect, has been reported across many tasks and domains (e.g., Brysbaert, Lange, & van Wijnendaele, 2000; Moore, Smith-Spark, & Valentine, 2004; Morrison & Ellis, 1995). Early theories attributed AoA effects to a single locus, the phonological output lexicon (e.g., Brown & Watson, 1987), arguing that the phonological representations of early-acquired words are stored in a more complete form than those of words acquired later. The advantage for early-acquired items was thus proposed to result from the phonological reassembly of late-acquired items for production. Morrison and Ellis attributed AoA effects on lexical decision tasks to the automatic activation of phonology in the output lexicon. A locus at speech output suggests that the AoA effect arises during spoken language acquisition. However, children learn to read long after they have learnt to speak so this account cannot readily explain AoA effects on the decoding of *written* words.

Reports of AoA effects on proper name and face processing (Moore & Valentine, 1998, 1999) are also problematic for the phonological output lexicon explanation, because early-acquired items in this domain are acquired subsequent to any period of critical language development. Furthermore, evidence indicates that names are not automatically activated when seeing a face; firstly, the difficulty of naming familiar faces argues against any automatic process (e.g., Brédart, 1996) and, secondly, no direct links from face perception to naming have been found to exist (Valentine, Hollis, & Moore, 1998). Performance on face familiarity decision tasks has been argued to be based on activation of PINs (Person Identity Nodes, which act as a gateway to semantic information) rather than phonology (Burton, Bruce, & Johnson, 1990). As a consequence, Moore and Valentine (1998, 1999; also Brysbaert, van Wijnendaele, & De Deyne, 2000) propose that because knowledge of famous people is acquired after the language learning period, AoA effects reflect the *order of acquiring* information in a specific stimulus domain rather than the *age* at which items were acquired.

Originally devised to explain the empirical effects of preserved memory in organic amnesia (Mayes, Poole, & Gooding, 1991), the SSPS hypothesis can account for empirically reported AoA effects on lexical, object, and face processing tasks, as well as second language learning (e.g., Moore, 2003; Moore & Valentine, 1999). Under this account, exposure to novel exemplars will instantiate a new system (or reconfigure an existing one) to process them. The *interaction* between novel exemplars and a lack of mediation from the semantic system will stimulate a physiological orienting response (Lang, Bradley, & Cuthbert, 1997). This bi-directional influence would create a vehicle for greater attention to be given to subsequent, similar examples. Such a situation would effectively initiate an SSPS by pegging out, or 'hard clamping', the parameters of distinction between the earliest observed examples. Thus, a different pattern of activity between representations would create a discrete state space for that type of information, producing a gateway into the semantic system for processing. Moore argues that learning at this stage is explicit and effortful. Once a gateway is created, a more automatised form of processing takes over to facilitate the learning of similar exemplars (Langer, 2000). The performance of any perceptual or motor task for which specialised representations are established should therefore be influenced by AoA. Moore proposed that only this can explain the empirically measured effects of AoA on face processing. Children can process faces from a very early age (e.g., Barrera & Maurer, 1981), but ratings taken from adults show that individuals typically start to become aware of celebrity status at around 6 years of age (Moore & Valentine, 1999). This awareness requires the recruitment of a new processing strategy or the reconfiguration of the specific state-space to process similar items.

Historically, connectionist back-propagation models were considered to be unable to implement AoA effects (e.g., Morrison & Ellis, 1995) due to catastrophic interference. However, it has since been demonstrated that AoA is, in fact, a natural and emergent property of such networks (Anderson & Cottrell, 2001; Ellis & Lambon Ralph, 2000). Models trained on interleaved early- and late-learned patterns produced a processing advantage for items introduced in earlier training epochs, thereby replicating human empirical data. Ellis and Lambon Ralph attributed the effect to a gradual reduction in network plasticity, with neural plasticity being hard clamped by exposure to early exemplars. Accordingly, AoA effects should occur in the binary mappings between two sets of representations and especially in the case of arbitrary mappings, such as those between the name or face of a person and semantic knowledge about that individual (also Zevin & Seidenberg, 2002). One of the major differences between object and person processing lies in the fact that recognition of an individual requires a *unique identifier*. Naming a face requires the identification of a unique concept (unlike in the case of a ball or a chair). Very strong physical similarities exist between identical twins, but they are still distinguishable to people who know them. Equally, there are many people with the name ''John Smith' (both first and family names are highly frequent in the UK), but each John Smith is a unique individual and uniquely separable from all of the other John Smiths in the world. According to various connectionist (and, indeed, many cognitive) models, the distinction between pictures and labels (or written words) is that text follows certain rules. Therefore, input and output have a 'linear' relationship. On the other hand, input and output for pictorial information is much more arbitrary. For example, a linear relationship between the label 'balloon' and the image of a balloon is not evident.

To date, there is no compelling evidence in favour of an unambiguous effect of AoA on semantic processing tasks. An initial report by Rubin (1980) argued that semantic classifications were significantly affected by AoA. However, more recent research (Moore, 2003) has failed to uncover any effects of AoA on a battery of semantic processing tasks, despite robust AoA effects on perceptual and naming tasks involving the same stimuli. Other reports of AoA influencing semantic processing (e.g., Lewis, 1999) may be premature, as complications exist with tasks and stimuli (see Moore, Valentine, & Turner, 1999). In those studies, participants were typically aged between 18 and 25 years, so there was only a short age distance between early- and late-acquired stimuli. Early-acquired stimuli were classed as those learnt before the age of 12 and late-acquired stimuli were considered to be those learnt after 18 years old. To obviate this criticism, the present study was conducted on adults aged over 40 years.

The SSPS view is that it *should* be possible to elicit AoA effects on semantic face processing tasks. However, Moore (2003) has argued that such effects may be elusive since the processing framework would be clamped by the *individual's* exposure to novel items. Whilst words and objects learnt early in vocabulary development are likely to be shared by children within the same culture and educational system, a child's early exposure to the individual as a celebrity will be highly dependent on parental interests (be they in film, sport, music, politics, etc.). Thus, selecting a set of stimuli that share universal semantic properties is far more difficult than finding stimuli for other types of experiments that manipulate AoA.

Brysbaert and Ghyselinck (2006) state that when frequency is controlled in lexical processing, there is no speed advantage for early-acquired words on either naming or classification tasks, but there is a significant influence of AoA on object processing. Brysbaert and Ghyselinck argue that this dual-AoA effect is caused by letter strings being *yoked* to frequency, whereas picture formats are frequency-independent (see also Lambon Ralph & Ehsan, 2006). They relate their findings to the Steyvers and Tenenbaum (2005) semantic 'hub' network model. From this perspective, the organisation of the semantic system can explain AoA effects; as a novel concept is perceived, it becomes represented in the semantic system and interconnects with pre-established concepts. Early-acquired concepts form a central hub with a far richer interconnectivity than later-acquired concepts, resulting in more efficient retrieval. According to this account, AoA can be equated with (if not be superseded by) the richness of interconnections between concepts. However, it cannot account for robust AoA effects on naming and familiarity tasks in the absence of a semantic effect for identical stimuli (Moore, 2003).

Brédart, Valentine, Calder, and Gassi (1995) found that participants were faster to name celebrity faces about whom many pieces of semantic information were known than those belonging to celebrities about whom little was known. However, their stimuli were controlled for familiarity, but not for AoA. This paper adopts a similar approach but incorporates AoA into the experimental design and probes familiarity decisions rather than naming responses.

The theories outlined above allow distinguishable predictions to be made about the outcome of the experiment. The work of Ellis and Lambon Ralph (2000) would suggest that there will be an AoA effect based on arbitrary mappings, such that there will be an early-acquired processing advantage in classifying both pictures of faces and printed names of the same celebrities. However, an interaction between AoA and format of presentation (faces or names) should occur. The magnitude of the AoA effect will not be so strong in the case of the responses to written names as it will be in response to faces. The arbitrary mapping hypothesis predicts that early-acquired faces should receive a greater processing advantage than names of the same celebrities, as a consequence of the more arbitrary connection between a face and an individual rather than between a name and the same individual. The semantic 'hub' network model (Steyvers & Tenenbaum, 2005) would predict that faster processing will occur for items possessing the most semantic connections. That is to say, there will be faster and more efficient processing of celebrities about whom many pieces of semantic information are known than for those about whom relatively little information is known. Furthermore, while an AoA effect is predicted by the model, the effects will be secondary to the processing advantage conferred by the rich interconnectivity of nodes for celebrities about whom many facts are known. Finally, the SSPS model (Moore, 2003) makes the prediction that there will be faster processing of early-acquired items regardless of the amount of information known about each celebrity. Furthermore, the *magnitude* of the difference will be the same for *both* the printed names and the faces.

Method

Participants

Forty-eight adults (32 female, 16 male) took part in the experiment (mean age = 66.92 years, SD = 8.59). All the participants had lived their whole lives in the UK. They were randomly allocated to one of two conditions, such that half were presented with faces (15 female, 9 male; mean age = 69.38 years, SD = 8.59) and half saw names (17 female, 7 male; mean age = 64.46 years, SD = 6.71).

Materials

Participants (N =105, mean age = 60.44 years, SD = 11.80) wrote down all the facts they knew about highly familiar celebrities (previously rated by 182 participants, see Smith-Spark, Moore, Valentine, & Sherman, 2006). Participants were informed of the type of factual information required: nationality, family details (e.g., marital status, famous parents, siblings, or children), the titles of films or television programmes in which s/he had appeared, and any other information (such as anecdotes) known to them (see Brédart et al., 1995). The responses were cross-checked for their veracity using several internet-based biographical sources.

From the above data, 40 famous people were selected on the basis of having either few or many facts known about them. These stimuli had been rated as either early- or late-acquired (Smith-Spark et al., 2006) and were chosen as being amongst those most easily recognised by participants aged over 40 years. It is difficult to remove all individual differences in 'world knowledge' from the experimental design, but a priori and post hoc ratings were employed to ensure that the stimuli were very well known to the participants[1]. The stimulus selection procedure allowed AoA and the number of facts known (NoF) to be manipulated orthogonally, creating four stimulus groups of 10 items. The groups were i) early-AoA, few-NoF, ii) early-AoA, many-NoF, iii) late-AoA, few-NoF, and iv) late-AoA, many-NoF. The groups were matched for familiarity, facial distinctiveness, and the number of syllables in the celebrities' names (see Smith-Spark et al.). The critical items were subjected to one-way ANOVAs (see Table 1) to verify that there were significant differences between the levels of the independent variables and that there were no differences across the control variables (e.g., familiarity).

Table 1: Means and *p*-values for each stimulus grouping.

	Early-acquired		Late-acquired		
NoF	Few	Many	Few	Many	*p*
Syll.	3.30	4.20	4.10	3.90	.196
Gen.	69.10	69.30	71.40	76.30	.941
AP Fam.	4.37	4.66	4.48	4.65	.421
AP Dist.	4.51	4.46	4.27	4.58	.667
AP AoA	3.31	3.59	6.03	6.31	< .001
AP Facts	3.14	5.45	2.97	6.15	< .001
PH Fam.	4.30	4.51	4.32	4.55	.583
PH Dist.	4.28	4.32	4.15	4.32	.898
PH AoA	3.58	3.93	6.57	6.69	< .001
PH Facts	3.88	5.71	3.19	5.36	< .001

Key: AP = a priori ratings; PH = post hoc ratings; Syll. = number of syllables in the name; Gen. = number of times a name was generated; Fam. = rated familiarity (7-point scale); Dist. = rated distinctiveness (7-point scale); AoA = rated AoA (10-point scale); Facts = NoF.

The celebrity stimuli were supplemented with 40 unfamiliar faces and names. Unfamiliar faces were selected from a collection of photographs of university staff and students and faces from the Psychological Image Collection at Stirling (PICS) database. The unfamiliar names were

[1] Space constraints mean it is not possible to list the stimuli and indicate areas of fame; this information is available on request.

constructed by recombining the first and family names of other famous people recorded by Smith-Spark et al. (2006); for example, Rosemary West and Stephen Hawking produced 'Stephen West' and 'Rosemary Hawking'.

Testing was conducted using an IBM-compatible computer running the E-Prime experiment generator package (Psychology Software Tools, Inc.). The faces were presented as 256x256 pixel 16-bit greyscale images and the names were presented in reverse video 12-point Courier New font. A two-button response box connected to the PC was used to log reaction time (RT) and accuracy.

Design

A 2x2x2 mixed-measures ANOVA design was employed. Stimulus format (faces vs. names) was the between-subjects factor. The two within-subjects factors were AoA (early vs. late) and NoF (few vs. many). Since the same celebrities were used in the names and faces conditions, it was not possible to perform a purely repeated measures design without priming participants' responses and increasing the impact of individual differences in world knowledge. Participant group was taken as the random factor. This provides an appropriate test because stimuli have been matched on other variables, making an analysis with items as the random factor unnecessary (Raaijmakers, 2003). The dependent variables were RT and percent accuracy. Responses were deemed to be correct when participants correctly identified famous people as being familiar or when unfamiliar stimuli were correctly identified as unfamiliar.

Procedure

A 12-item practice session preceded the main experiment. Each trial began with a central fixation point appearing on the VDU for 700ms, followed by a warning tone (2000 Hz for 250 ms). The stimulus then immediately appeared on the screen and remained until the participant made a response by pressing the 'YES' button on the response box if the stimulus was familiar to them or the 'NO' button if it was unfamiliar. This response extinguished the display and the next trial was initiated. The participants were asked to respond as quickly and accurately as possible.

Post hoc ratings The participants were then requested to rate the critical items for their familiarity, facial distinctiveness, and AoA, using Moore and Valentine's (1998) method. Rating scores are also shown in Table 1.

Post hoc NoF scores Finally, the participants were asked to report verbally all the facts they knew about each celebrity (Brédart et al., 1995). These reports were again checked with internet biographical sources (see Table 1).

Results

The mean response rate to unfamiliar items was 1291 ms (SD = 452.96). Distractor names were responded to at a mean latency of 1502 ms (SD = 476.36), whilst the mean RT to distractor faces was 1079 ms (SD = 314.57). A mean percentage accuracy of response was also derived for the distractor items (mean = 93.70, SD = 6.50). The participants were less accurate in their responses to names (mean = 90.94, SD = 6.83) than to faces (mean = 96.46, SD = 4.89).

Analysis of the post hoc ratings indicated that there were no significant differences between the groups of critical items in their familiarity and facial distinctiveness, indicating that the items were well matched on these variables. Post hoc AoA and NoF scores differed significantly, thereby confirming the a priori allocation of items to the 4 stimulus groupings. The results of the post hoc ratings analyses are shown in Table 1. Having thus ensured the validity of the groupings, mixed-measures ANOVAs were carried out on RT and percent accuracy.

There was a significant main effect of AoA on RT, with the participants responding significantly faster to early-acquired stimuli, $F(1, 46) = 45.52$, $MSE = 7114.393$, $p < .001$. The mean RTs were 1061ms ($SE = 29.32$) to early-acquired and 1143ms ($SE = 32.35$) to late-acquired stimuli.

There was also a significant main effect of NoF, $F(1, 46) = 13.22$, $MSE = 3107.127$, $p = .001$. Participants were faster to respond to many-NoF (mean = 1087ms, $SE = 30.24$) than to few-NoF stimuli (mean = 1117ms, $SE = 30.82$).

Presentation format had no significant effect, $F(1, 46) = 1.73$, $MSE = 175871.120$, $p = .195$. Mean RTs were 1062ms ($SE = 42.80$) to faces and 1142ms ($SE = 42.80$) to names.

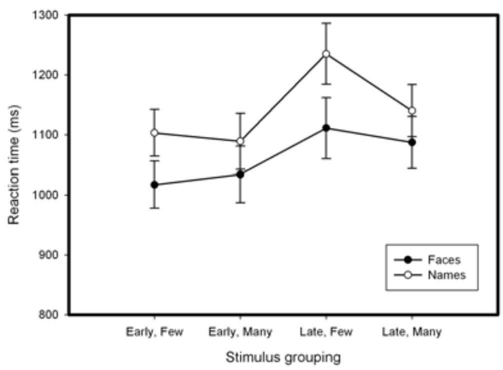

Figure 1: Mean RT

There was no significant interaction between AoA and presentation format, $F(1, 46) < 1$, $MSE = 7114.393$, $p = .457$. However, there was a significant NoF x presentation format interaction, $F(1, 46) = 10.21$, $MSE = 3107.127$, $p = .003$. Non-significant trends suggested that both early-acquired, $t(46) = 1.56$, $p = .127$, and late-acquired few-facts faces $t(46) = 1.73$, $p = .090$, were responded to faster than their few-fact name counterparts. There was also a significant interaction between AoA and NoF, $F(1, 46) = 4.30$, $MSE = 10378.203$, $p = .044$. A related-samples *t*-test indicated that there was a significant difference between responses to late-few and late-many facts stimuli, $t(47) = 31.93$, $p < .001$. The mean RTs for each stimulus grouping are shown in Figure 1. There was no evidence of a significant AoA x NoF x presentation format interaction, $F(1, 46) = 0.474$, $MSE = 10378.203$, $p = .494$.

The percentage accuracy data also indicated that there was a significant main effect of AoA on performance, $F(1, 46) = 4.38$, $MSE = 93.252$, $p = .042$. Participants produced more accurate responses to early-acquired celebrities (mean = 92.40%, $SE = 0.99$) than to those that were late-acquired (mean = 89.48%, $SE = 1.17$).

However, there was no significant effect of NoF on response accuracy, $F(1, 46) = 2.87$, $MSE = 58.832$, $p = .097$. The mean accuracy scores were 90.00 ($SE = 1.06$) for low-NoF and 91.88 ($SE = 0.93$) for high-NoF groupings.

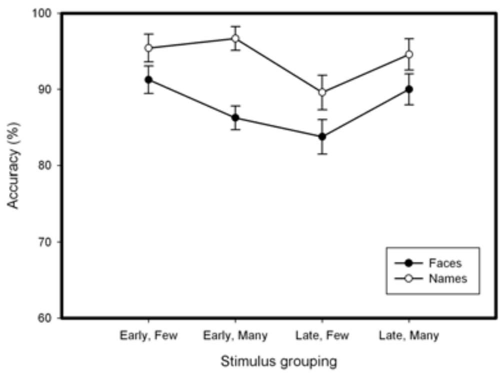

Figure 2: Mean percent accuracy

Format of presentation significantly affected accuracy, $F(1, 46) = 14.13$, $MSE = 132.745$, $p < .001$. More accurate responses were produced to names (mean = 94.06, $SE = 1.18$) than to faces (mean = 87.81, $SE = 1.18$).

A significant interaction between AoA and NoF was also found, $F(1, 46) = 8.86$, $MSE = 76.223$, $p = .005$. Differences lay between early-few and late-few, $t(47) = 3.40$, $p = .001$, early-many and late-few, $t(47) = 2.68$, $p = .010$, and between late-few and late-many items, $t(47) = -2.92$, $p = .005$. There were no further significant interactions (AoA x presentation format, $F(1, 46) = 0.56$, $MSE = 93.252$, $p = .459$; NoF x presentation format, $F(1, 46) = 1.28$, $MSE = 58.832$, $p = .265$; AoA group x NoF group x presentation format, $F(1, 46) = 2.21$, $MSE = 76.223$, $p = .144$). Figure 2 shows the percent mean accuracy scores for each grouping.

Discussion

Adults were tested on perceptual familiarity decision tasks requiring classification responses to names or faces. The participants were faster to respond to familiar stimuli than to unfamiliar items. Distractor faces were rejected more rapidly and more accurately than were unfamiliar names. As predicted, there was a significant main effect of AoA, with participants responding faster and more accurately to early-acquired than late-acquired items. In addition, the participants made significantly more rapid and accurate responses to many-NoF celebrities than to few-NoF celebrities. A significant AoA x NoF interaction revealed that knowing more facts about a celebrity reduced response latencies to late-acquired items, but not to early-acquired stimuli. A similar pattern of results was found for the accuracy data, confirming that no speed-accuracy trade-off had occurred. The data will now be discussed in relation to the three theoretical approaches set out in the Introduction.

The arbitrary mapping hypothesis (Ellis & Lambon Ralph, 2000) predicted that items presented pictorially would result in the strongest effect of AoA. However, this was not borne out by the data. There was no significant effect of presentation format on RT, even though faces were indeed responded to faster than names. In fact, the magnitude of the AoA effect on RT was very similar for faces (7%) and names (8%). The absence of an AoA x format interaction is thus problematic for this hypothesis.

According to the semantic ‘hub’ network model (Steyvers & Tenenbaum, 2005), any effect of AoA should be overridden by enhanced processing of the more richly interconnected ‘many facts’ hubs. Faster responses did occur to celebrities about whom many facts were known, but the significant AoA x NoF interaction demonstrated that this effect only influenced the processing of late-acquired items. In the case of early-acquired stimuli, neither RT nor accuracy were significantly influenced by the richness of semantic information known about a person. Furthermore, all groups were matched on a priori and post hoc familiarity ratings. If it were to be argued that these ratings represented a stronger indication of interconnectivity, no significant AoA effect should have occurred. Thus, the data do not support the predictions derived from the ‘hub’ model.

The results are, however, consistent with earlier research (e.g., Moore & Valentine, 1999) in suggesting that multiple loci of AoA effects exist; that is, at perceptual recognition (as reported here) and at motor output, such as in naming.

Only the predictions derived from the SSPS hypothesis were fully supported. The AoA x NoF interaction revealed that the amount of semantic information known did not influence the speed with which early-acquired celebrities were processed, with there being a 1ms difference between the mean RTs of the two NoF groupings (few-NoF = 1060ms vs. many-NoF = 1061ms). However, knowing many facts did facilitate responses to late-acquired stimuli, with a 60ms advantage in the processing of celebrities about whom much was known (few-NoF = 1173ms vs. many-NoF = 1113ms). The second SSPS prediction, that the magnitude of the AoA effect would be the same for both names and faces, was also supported by the lack of an AoA x presentation format interaction. The results thus support research on object processing (Brysbaert & Ghyselinck, 2006). While a picture and a letter string represent the same person or object, the pattern of recognition is defined by the associated physical properties from the pictorial format. Reading and writing printed letter strings would be acquired in a later order than the representations of the physical properties (Funnell, Hughes, & Woodcock, 2006), because the child has already learnt to identify the picture or object before learning to read the name. The same may be said for processing celebrities- knowledge of who they are and what they are famous for will usually be acquired before reading about them. If not, one would simply be reading about an unfamiliar person!

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