

Imageability, age of acquisition, and frequency factors in acronym comprehension

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Imageability, age of acquisition and frequency factors in acronym comprehension

Quarterly Journal of Experimental Psychology

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Abstract

In spite of their unusual orthographic and phonological form, acronyms (BBC, HIV, NATO) can become familiar to the reader, and their meaning can be accessed well enough that they are understood. The factors in semantic access for acronym stimuli were assessed using a word association task. Two analyses examined the time taken to generate a word association response to acronym cues. Responses were recorded more quickly to cues which elicited a large proportion of semantic responses, and those which were high in associative strength. Participants were shown to be faster to respond to cues which were imageable or early acquired. Frequency was not a significant predictor of word association responses. Implications for theories of lexical organisation are discussed.

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3 The present study is concerned with acronyms, a significant part of our vocabulary that has
4 been largely neglected in word processing research. Acronyms are abbreviations of long
5 terms or cumbersome phrases commonly formed by selecting key letters within a term or
6 sentence (e.g., DNA from deoxyribonucleic acid, WWW from World Wide Web). As a result
7 of this process, acronyms can have very peculiar orthographies in conjunction with unusual
8 pronunciation patterns. Originally the term ‘acronym’ was coined to designate
9 pronounceable abbreviations (e.g., NATO, RADAR) while ‘initialism’ was the name selected
10 for unpronounceable abbreviations (e.g., PC, TV). However, despite this distinction acronym
11 is the word more commonly used to refer to all abbreviations, pronounceable or not, formed
12 as a combination of the initial letters of a term or sentence. It is in this more general sense
13 that the word acronym is used in the present study. In addition, only acronyms constituted by
14 a string of consonants, or vowels or a combination of vowels and consonants (e.g., BBC, EU,
15 HIV), will be discussed here.

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18 The formation of acronyms is not new or unique to the English language. RIP (*Requiescat in*
19 *pace* – Rest in peace), for example, is an early acronym from the Latin. However, despite
20 their historical presence in all languages, acronym formation was never prolific in the distant
21 past. This changed dramatically a few decades ago when an increase in literacy and wealth,
22 and advances in science and technology popularised the generation of acronyms. The latest
23 emergence of Short Message Systems (SMS) has boosted the creation and use of acronyms at
24 a rate never experienced before.

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27 Research on how acronyms are processed is scarce. The few studies that have looked at
28 acronym reading and recognition processes have been mainly interested in the lexicality
29 status of acronyms, the question of interest being whether acronyms storage and processing is
30 similar to that of mainstream words (Besner et al., 1984; Brysbaert, Speybroeck and
31 Vanderelst, 2009; Carr, Posner, Pollatsek & Snyder, 1979; Coltheart, 1978; Laszlo &
32 Federmeier, 2007a; 2007b; 2008; Noice & Hock, 1987; Prinzmetal & Millis-Wright, 1984).
33 The evidence accumulated so far indicates that despite the orthographic and phonological
34 peculiarities of acronyms they are cognitively similar to mainstream words and that are
35 processed in a similar manner, at least in the lexical tasks in which acronyms have been
36 tested so far.

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39 The letter identification task and letter string matching task are some of the tasks used to look
40 at acronym processing. The identification of a given letter is commonly reported to be more
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3 successful when it is embedded in a mainstream word than when the letter appears in an
4 illegal non-word (Reicher, 1969). Similarly, participants are faster to decide that two
5 simultaneously presented strings of letters are the same if the stimuli are words than if they
6 are illegal non-words (Carr et al., 1979). This is known as the word superiority effect (WSE).
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8 An acronym superiority effect has also been observed in both tasks with faster identification
9 of letters within acronyms than within non-words and faster detection of similarities between
10 two letter strings when these are acronyms than when they are non-words (Besner et al.,
11 1984; Carr et al., 1979; Laszlo & Federmeier, 2007a; Noice & Hock, 1987). Prinzmetal and
12 Millis-Wright (1984) used a version of the Stroop task to compare acronyms, mainstream
13 words and non-words processes. Acronyms, words and non-words had each of their letters
14 printed in a different colour ink. Participants were asked to name the colour of specific letters
15 within the string. A greater number of errors were made in acronym and word trials than
16 when the letters were embedded within non-words. More recently acronyms have been
17 included in studies of word reading using the ERP technique (Laszlo & Federmeier, 2007b;
18 2008). The N400 component is a negative going deflection which is observed around 400ms
19 after the presentation of a stimulus. The amplitude of the N400 elicited by a word is larger
20 when it is first presented than when the same word is presented again. This repetition effect
21 is shown in response to words but not when the stimuli are non-words. Laszlo and
22 Federmeier (2007b; 2008) showed that a significant reduction in N400 amplitude was
23 observable for acronyms. Importantly, closer examination of their data revealed that the
24 repetition effect for acronyms was restricted to those items that the participants knew. That is
25 to say that known acronyms showed word-like N400 repetition effects, while unknown
26 acronyms elicited activity similar to non-words. In another recent study of acronyms, Izura
27 and Playfoot (in press) investigated whether acronym naming times were not just similar to
28 that of mainstream words but whether acronyms could be comparable to the way in which
29 regular or irregular words are processed in the English language. The study assessed the
30 influence of a number of variables on acronym naming using hierarchical regression
31 techniques. The analyses showed a combined influence of variables commonly associated to
32 regular and irregular word processing (e.g., number of letters, orthographic familiarity,
33 printed frequency, age of acquisition, imageability, etc.). The authors conclude that acronym
34 processing is not directly comparable to regular or irregular word processing but a complex
35 mixture of both.
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3 The studies reviewed so far indicate that the way in which acronyms and mainstream words
4 are processed is similar overall but also that acronym recognition and naming has its own
5 processing peculiarities, as reflected in the type of factors influencing their processing. Since
6 the main motivation to study acronyms has been to determine whether the mental lexicon
7 accommodates the distinctive orthographic and phonological configuration of acronyms, no
8 research has examined the potential semantic singularity of acronyms. Thus, the present study
9 is the first effort to fill this gap. Here, individuals were encouraged to process acronyms
10 semantically using an acronym association task.

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13 Although none of the research published so far has explored the semantic organization of
14 acronyms, Brysbaert et al.'s (2009) study is the only one to date that when examining the
15 potential similarity between acronyms and words emphasised meaning rather than form.
16 They used acronyms in an associative priming paradigm which specifically relies on semantic
17 links between the target and the prime. The common finding in priming tasks is that a
18 response to a target word is affected by the characteristics of an item that precedes it (the
19 prime), even if the prime disappears so quickly that it is not consciously detected. In
20 Brysbaert et al.'s (2009) study, participants were presented with a lexical decision task in
21 which word targets were preceded by briefly presented primes. In half of the 96 prime-target
22 pairs the prime was an acronym, and in half the prime was a word. Each of the targets was
23 presented twice, once preceded by a semantically related prime that could be an acronym
24 (e.g., BLT-SANDWICH) or a word (e.g., FIB-LIE), and once with an unrelated prime (SNT-
25 SANDWICH; HIM-LIE). Associative priming effects followed acronym primes as well as
26 word primes. The facilitation resulting from acronym primes was observed irrespective of
27 letter case. Thus, BLT, blt and bLt increased the speed of the response to the target by the
28 same amount. Brysbaert et al. (2009) concluded that this finding was "particularly
29 convincing for the lexical processing of acronyms" (pp. 1838).

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32 As discussed above, the prevailing evidence indicates that acronyms are integrated in the
33 mental lexicon along with mainstream words. However, their lexicality does not resemble
34 that of regular or irregular words since processing differences have been detected (Izura &
35 Playfoot, in press). No study so far has explored the semantic configuration of acronyms and
36 assuming that it is the same as for mainstream words might be risky. In the present study we
37 investigated the factors that might affect the speed with which acronyms are understood in an
38 attempt to break the ice in the investigation of the semantics of acronyms.

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3 The finding that associative priming effects are observed with acronym primes suggests that
4 their meaning is accessed quickly. Semantic network models posit that words (and possibly
5 acronyms) are stored as interconnected nodes (e.g. Steyvers & Tenenbaum, 2005). Each
6 node has a number of other nodes linked to it and connections between nodes gain in strength
7 every time they are used. Strong links are easy to access, and result in rapid activation. One
8 technique used to examine semantic or lexico-semantic connections is the discrete word
9 association task, in which participants are presented with a single word and required to
10 produce the first word that comes to their minds. In order to achieve this, participants are
11 forced to activate a second lexical representation which normally is semantically connected to
12 the target word. It is argued that the participant's response is the word that has been activated
13 quickest, and represents the strongest link between nodes (i.e., words) in the participant's
14 lexicon. By asking a large number of participants to provide associations to the same cues,
15 the way in which words might be semantically interconnected is inferred.
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Word association data is rich in nature. Among other things it provides a measure of the
strength of the link between cue and associate. Associative strength refers to the proportion
of participants who produce the same response. For example, if 58 out of 100 participants
said WHITE to the cue word BLACK, the associative strength between BLACK and WHITE
is 0.58. Research suggests that associative strength is a reliable indication of the
predominance of a particular response in the population (Nelson & Schreiber, 1992), and a
good predictor of priming effects (Canas, 1990). Another common measure used in word
association tasks is the number of different associative responses that are provided by more
than one participant. This has been called '*meaning set size*' (Nelson & Schreiber, 1992).
These two measures of associative response (i.e., associative strength and meaning set size)
will be considered in the present study along with the following lexico-semantic
characteristics of the cue words: word frequency, imageability, age of acquisition and letter
length. The findings related to these variables and predictions are discussed in turn below.

High frequency words are recognised, produced, and recalled faster and with greater accuracy
than low frequency words (Connine, Mullinex, Shernoff, & Yelen, 1990; Yonelinas, 2002).
As studies have shown that most of the associative responses are semantically linked to the
cue word (e.g., *computer* → *screen*), it is logical to think that word association requires word
recognition, a process influenced by word frequency. It would be expected, therefore, that an

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3 influence of word frequency on word association responses would be observed. The
4 literature seems to indicate that the frequency of the cue does have some impact on the
5 strength and number of associations generated, but it is far from clear what this influence is.
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8 Early investigations indicated that high frequency cues elicited a stronger dominant response
9 (i.e., produced by many individuals) than low frequency items, and fewer different responses
10 overall (Postman, 1964; 1970). However, de Groot (1989) found no significant effects of the
11 frequency of the cue word on the speed with which an associated word was produced,
12 contradicting the predictions of semantic network models. Furthermore, both de Groot
13 (1989, Experiment 7) and Brysbaert, Van Wijnendaele and De Deyne (2000) reported that
14 high frequency cues elicited more diverse responses than low frequency cues. Interestingly,
15 this was the inverse of the frequency effects reported by Postman (1964; 1970).
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24 One major tenet of semantic network models is that the link between two concepts should be
25 strengthened by its retrieval, thus the connections stemming from high frequency words
26 should be particularly well-travelled. De Groot's study instead demonstrated that the
27 imageability of a word was more important in the distribution and speed of word association
28 responses. Imageability refers to the ease with which a word evokes a mental image (Paivio,
29 Yuille, & Madigan, 1968). In discrete word association tasks, a smaller number of different
30 responses are elicited by words which are highly imageable. Correspondingly, the dominant
31 response to a high imageability cue word has a greater associative strength than that for a less
32 imageable cue, and in addition, the responses are generated more quickly (Altarriba, Bauer,
33 & Benvenuto, 1999; Brysbaert et al., 2000; de Groot, 1989). These findings were interpreted
34 as evidence that the links between highly imageable nodes and related concepts were stronger
35 than the links stemming from low imageable nodes.
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48 Age of acquisition (AoA) refers to the moment in time in which words, objects and faces are
49 first learned. The common finding is that objects, faces and words learned early in life are
50 processed more quickly than those learned later (e.g. Brysbaert & Ghyselinck, 2006; Izura,
51 Pérez, Agallou, Wright, Marín, Stadthagen-González, & Ellis, 2011; Morrison & Ellis, 2000;
52 Pérez, 2007; Richards & Ellis, 2009). A current explanation for the AoA effect is the
53 arbitrary mappings hypothesis (Ellis & Lambon Ralph, 2000). It states that the AoA effect is
54 a product of the connections created during learning. When the relationship between input
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3 and output is predictable, a late acquired word can draw on existing knowledge to facilitate
4 processing. In regular words, for example, the relationship of spelling to sound is consistent
5 with other similarly spelled words (e.g., *sweet, feet*). Thus, a newly learned word can map on
6 to existing representations (e.g., *tweet*). However, in irregular words the pronunciation is less
7 predictable and the mapping is arbitrary (e.g., *yacht*). Under these circumstances late
8 acquired words do not benefit from existing word knowledge and processing is relatively
9 slow. The mapping between the written representation of a word and its meaning is even less
10 predictable than the relationship between spelling and sound. Retrieving semantic
11 information is, according to the mapping hypothesis, likely to be influenced by age of
12 acquisition, and effects ought to be observed in the generating words in response to a cue as
13 in Catling and Johnson's (2005) study. Catling and Johnson (2005) asked participants to
14 produce a word from a semantic category (e.g. vegetables) that began with a particular letter
15 (e.g. 'c'). They reported that participants were significantly faster to provide early acquired
16 words than late acquired words. Word association responses have also been shown to be
17 affected by age of acquisition. Van Loon-Vervorm (1989, cited by Brysbaert et al., 2000)
18 showed that responses in a discrete association task were recorded reliably faster (240 ms)
19 when the cue was early-acquired. Brysbaert et al. (2000) replicated Van Loon-Vervorm's
20 (1989) findings. They reported that early-acquired words elicited association responses 279
21 ms faster than late acquired words. Further, Brysbaert et al. (2000) provided evidence that
22 there is greater agreement among participants in the associations generated for early-acquired
23 words. Brysbaert et al (2000) pointed to the interpretation that the strength of the semantic
24 connections from early-acquired word nodes is greater than from nodes for late-acquired
25 words.
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45 In sum, the study of the influence of the characteristics of the cue words on word association
46 response times has the potential to inform about the strength and diversity of the semantic
47 connections and with that shed some light on the structure of the semantic configuration of
48 acronyms. It is important to note, however, that associative responses are not always semantic
49 in nature. In fact a number of studies have devoted their attention to the nature of the
50 relationship between a cue-word and its associate. Thus, word association responses have
51 been grouped into three major categories depending on the relationship between cue-word
52 and associative response (Fitzpatrick, 2006; 2007; 2009). These three groups are: *meaning-*
53 *based associations* which have a semantic relationship with the cue-word (e.g., *bird-robin*);
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3 *position-based associations* whose relation to the cue word is based in their frequency of co-
4 occurrence in everyday language (e.g., *blue-moon*); and *form-based associations* are those
5 that have an orthographic and/or phonological similarity (e.g., *plug-plum*; *chair-choir*; *air-*
6 *heir*). Evidence shows that when individuals provide associative responses in their first
7 language the majority of links between the cue word and a response are meaning based, while
8 only very few associations responses tend to be based on the orthographic or phonological
9 form (Fitzpatrick, 2006; Meara 2009). Importantly, when bilingual speakers are asked to
10 provide associations in their second language (L2) the percentage of associative responses
11 related in form to the cue word is higher than that produced in their first language, suggesting
12 either weaker semantic connections for their L2 words or stronger form based relationships
13 among their L2 words (Fitzpatrick & Izura, 2011).
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24 The present study collected word association responses for the 146 acronyms described by
25 Izura and Playfoot (in press) and examined the influence of associative strength, meaning set
26 size, response category, word frequency, age of acquisition and imageability on the speed
27 with which an associative response was generated. According to Steyvers and Tenenbaum's
28 (2005) model, acronyms with high associative strength values will elicit faster responses
29 because the connection between cue and response is strong in a large proportion of
30 participants. It can also be predicted that responses will be quick for acronyms which elicit a
31 large proportion of semantically related words. Finally, it is expected that the age of
32 acquisition, imageability and frequency of an acronym cue will influence response latencies
33 such that response times will be shorter for early acquired, high imageability and high
34 frequency acronyms acting as cues.
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46 **Method**

47 *Participants*

48 Fifty participants, 18 male and 32 female, were recruited for this study. The participants
49 were students at Swansea University with a mean age of 22 years (range 19 - 29), and all
50 were native speakers of English without reading deficits and normal or corrected to normal
51 vision.
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Materials

The 146 acronyms described in Izura and Playfoot (in press) were presented as cues in a discrete word association task. Values for imageability, age of acquisition, printed and rated frequency were selected from that database. There, imageability estimates were collected using the procedure outlined by Paivio, Yuille and Madigan (1969) by which participants were asked to indicate how easily each acronym evoked a mental image on a 7 point scale. Age of acquisition ratings were gathered following Izura, Hernandez-Muñoz and Ellis' (2005) procedure where participants wrote the age they were when they first learned the acronym presented. Rated frequency was assessed using a 7 point scale ranging from "rarely or never encountered" (1) to "encountered more than twice a day" (7). Printed frequencies were estimated on the basis of the number of hits returned by advanced internet search queries using the AltaVista search engine. This procedure has been shown to provide reliable estimates of frequency (Blair, Urland & Ma, 2002). The printed frequency values were transformed into their logarithm, base 10, plus one value.

Procedure

Stimulus presentation and randomization was achieved using E Prime software (Schneider, Eschman, & Zuccolotto, 2002). Acronyms were presented centrally in black ink on a white background and with Times New Roman font, size 12 points. Participants were informed that they would be seeing a list of acronyms, individually, and that they should say the first thing that came to their mind in response to each acronym. The instructions indicated that there were no right or wrong answers, and that it was important that responses reflected the first word they associated with the stimulus. Each acronym was presented individually in the middle of the computer screen and remained there until the participant responded. The verbal response from the participant was detected by a microphone placed approximately 10 centimetres in front of the mouth. This triggered the program to show a blank screen for 500ms and to record the time that had elapsed between the onset of the presentation of the stimulus and the detection of the response. Then a screen with a horizontal line in the middle appeared to signal participants to type in the response that they had just given. Participants could type their response in their own time and they were allowed to correct spelling

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3 mistakes if the wished to do so. Participants signalled that they had completed typing the
4 word by pressing the return key. Then an asterisk appeared for 500 ms to indicate that the
5 next trial was about to commence. All 146 acronyms were presented to every participant in a
6 random order. The task took between 20 and 25 minutes to complete.
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10 11 12 13 **Results**

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15 Omissions were removed from the assessments of word association responses. Spelling
16 mistakes and typographical errors were corrected only if the participant's intended response
17 was clear (e.g. TNT – '*dinamite*'). If the response recorded was potentially a spelling
18 mistake but made another word, this was not altered (MRI – scam) because of the difficulty
19 of being certain of the participant's intention. Although it could be argued that the intended
20 response is clear in this example, other instances were not so obvious. Therefore a consistent
21 procedure was employed for all responses to all cues. The complete set of word association
22 responses is included in the appendix.
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32 Six participants offered association responses for fewer than half of the items presented, and
33 were, therefore deleted from further analyses. Thus the analyses reported here are based on
34 the responses from 44 participants. A multilevel or hierarchical regression analysis (Miles &
35 Shevlin, 2001) was used here with RT as the outcome variable. The multilevel model is an
36 extension of linear regression to allow variation between groups to be accounted for at
37 different levels (Gelman & Hill, 2007). This offers an important advantage over classical
38 regression in that systematic variation among the participants can be accounted for before
39 assessing the variables under study. Essentially, each step of the hierarchy assesses whether
40 newly entered variables are able to add to the variance in the outcome variable that can be
41 explained by the model over and above that which was accounted for in the previous step. In
42 this case, the participants were entered in the first level of the hierarchy. Important individual
43 differences have been shown to occur in word association responses (Fitzpatrick 2007; 2009),
44 so entering participants in the first step of the analysis partialled out the potential influence of
45 individual differences on reaction times. In the second level of the analysis the proportion of
46 responses that could be classified as semantic, position-based or form-based were included.
47 The third level assessed the predictive power of associative strength and number of
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3 responses. The methods for determining these values are detailed below. The fourth and
4 final step of the regression analyses included the following acronym characteristics,
5 frequency, age of acquisition, imageability and letter length.
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10 11 *Categorisation of word association responses*

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13 Word association responses were classified into three categories according to the type of
14 relationship that was found between the cue and the response produced. These categories
15 were: form based, meaning based, and position based associates (Fitzpatrick, 2006). The
16 meaning based category included responses that had a meaning relation with the cue word.
17 Thus, synonyms (e.g. ASAP – quickly), acronym’s complete or partial forms (e.g., ASAP –
18 as soon as possible; KFC - chicken), hyponym s and co-hyponyms (e.g., RPG standing for
19 rocket propelled grenade - rifle) and others (e.g., ECG – hospital or heart) were included in
20 the meaning based category. Position based responses were those that frequently co-occur
21 with the acronym in the natural language (e.g., SCUBA – diving). Associative responses
22 were classed as form based when the response shared orthography or phonology with the cue,
23 but not meaning. These were commonly instances where letters had been transposed (FBI –
24 FIB), substituted (TFT – TNT), added (BST – best) or omitted (RNIB – nib).
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37 Examination of the responses indicated that in some instances associations may have been
38 made in two steps. For example, when presented with CCCP, eight participants responded
39 with “camera.” The participants could potentially have arrived at this response by a two
40 stage process, first transforming CCCP to the orthographically and phonologically similar
41 CCTV and then providing the constituent word “camera.” Responses of this type were
42 counted as a separate category and not included in the analyses presented here. Associations
43 for which no clear discernible link between cue and response could be found were classed as
44 erratic responses and removed from analyses. Circumstances where the participant had
45 invented a new full form for the acronym were classified as erratic responses and also
46 removed from further analyses. The total percentage of responses classified as members of
47 each category are presented in Table 1.
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(Table 1 about here)

As shown the majority of responses were meaning based, with only very few associations based on position or form alone. These response category measures were converted to proportions for inclusion in the multilevel regression. Thus, the number of semantic responses (33 for MMR) was divided by the total number of responses elicited by the acronym (37), making the proportion of semantic responses to MMR 0.89.

Associative strength and meaning set size

Associative strength refers to the proportion of participants who gave the most common response to each acronym. Singular (e.g. cat) and regular plural (created by adding an “s” as in cats) forms of a word were considered to be the same response. Irregular plurals were counted as a separate response. The frequency with which the dominant response was recorded by the participants was divided by the total number of responses to that cue to determine associative strength. For example, the most frequently given associate for BBC was “television” which was offered by 24 participants. All 44 of the participants recorded a valid associative response for BBC. Therefore the associative strength for “television” is 24 out of 44, or 0.55. The meaning set size was the total number of different responses given by two or more participants for each cue. This measure was also entered into the regression analysis.

Reaction time analyses

Response latencies for omissions (14%) were removed prior to reaction time analysis. Trials in which the voice key had malfunctioned (3%) were also deleted from these analyses. Correlations between the lexical variables (i.e., imageability, rated and printed frequency, age of acquisition and letter length), the measures indicating the type of link between cue and response (i.e., meaning, position and form based), the measures of response distribution (i.e., associative strength and meaning set size) and RTs are presented in Table 2.

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6 Significant correlations were found between all of the predictor variables and RT, with the
7 exception of printed frequency and number of position responses. Acronyms which were
8 high in rated frequency, high imageability, early acquired or lengthy generated association
9 responses more quickly than their short, low frequency, low imageability or late acquired
10 counterparts. This supports the findings of de Groot's (1989) and Brysbaert et al.'s (2000)
11 association studies using mainstream word cues. In relation to the proportion of responses
12 which could be classified in each category, significant correlations were observed with all
13 other variables. The only exceptions to this were the non-significant correlations between
14 position and length, position and age of acquisition and form and printed frequency.
15 Associative strength was significantly correlated with all other variables, and meaning set
16 size correlated with all but printed frequency. Finally, the correlations between pairs of
17 predictor variables were all significant, and mirror the general relationships between these
18 variables in mainstream word studies (e.g. Balota et al., 2004).
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30 For the purpose of all analyses reported here, acronym naming times were log transformed to
31 reduce skew. Multicollinearity of the predictor variables was assessed in relation to the
32 variance inflation factor (VIF). VIF values were within the acceptable range (1.04 to 3.30).
33 Beta coefficients for each of the predictor variables are presented in Table 3.
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44 In step 2, the proportion of responses that were linked to the cue acronym semantically or in
45 terms of their form significantly predicted reaction times. Responses were likely to be fast
46 for cues which elicit a high proportion of semantic responses and slow in cues with high
47 proportions of form links. In step 3, both associative strength and meaning set size were
48 predictive of reaction times. Particularly strong and commonly generated links between cue
49 and response were given quickly. Responses were generally slow when a large number of
50 different associations were recorded for the same cue. Imageability, age of acquisition and
51 length emerged as significant predictors of word association response latency in step 4. As a
52 whole, the regression model was able to account for 24% of the variance in RT.
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5 Word association has traditionally been considered a semantic task (Brysbaert et al., 2000).
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7 This is clearly the case in this study given that the majority of the responses are semantically
8 related to the cue word (94%), and suggests a good level of acronym knowledge among the
9 participants in this study. However, as mentioned in the introduction, not all responses in
10 word association tasks are semantic, since some of them appear to be the result of co-
11 occurrence of cue and response, and others share only their orthographic form. In order to
12 give a purer assessment of the lexical factors affecting semantic access for acronyms, the
13 influence of the lexical variables on reaction times was reassessed, this time taking into
14 account only those responses that were semantically linked to the cue. The results of the
15 multiple regression analysis carried out are presented in Table 4. When considering only
16 semantic responses, age of acquisition and imageability were the only significant predictors
17 of reaction times. The proportion of the variance accounted for by the model increased to
18 42%.
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35 Discussion

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37 The present study investigated the influence of a number of lexico-semantic factors on
38 acronym association response times. Two analyses were carried out. The first analysis used a
39 multilevel regression technique to take into consideration the variance associated with
40 individual differences and to observe the influence of the selected predictors at three different
41 levels of analysis. Individual differences were entered in the first step of the analysis. In the
42 second step the influence of the type of link between cue and response was examined while
43 the predictive power of two response distribution measures (i.e., associative strength and
44 meaning set size) and acronym characteristics were entered into the third and fourth steps of
45 the analysis respectively. Responses were made quicker to cues that: 1) elicited a large
46 proportion of semantic responses, 2) a low proportion of form responses, 3) were high in
47 associative strength, 4) were low in meaning set size, 5) were long, early acquired and
48 imageable. The second analysis used multiple regression analysis to consider the influence of
49 lexical variables on RTs for only those responses that were semantically linked to the cue. As
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3 in previous reports, participants were shown to be faster to respond to cues which were
4 imageable and early acquired (Altarriba et al., 1999; Brysbaert et al., 2000; de Groot, 1989).
5 A higher proportion of the variance in RT was accounted for when only lexical factors and
6 semantic responses were considered, implying that the factors considered were better at
7 explaining the variance associated to semantic than to any other response. It is important to
8 note that among the factors considered, imageability and age of acquisition were the only
9 significant predictors for associative responses linked to the cue by meaning.
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15 It is worth noting that as in studies with mainstream words the majority of responses elicited
16 in a discrete association task using acronyms were related to the meaning of the cue
17 (Fitzpatrick, 2006). In contrast only a small proportion of word association responses were
18 form based and an even smaller proportion of responses were position based (i.e., responses
19 that often co-occur with the target). Interestingly, this is closer to the pattern of associative
20 responses produced to mainstream words by second language speakers of English than those
21 produced by first language speakers (Fitzpatrick & Izura, 2011). Thus, in the first language
22 there are more position than form based responses while the reverse is the case in the second
23 language. This might suggest that the semantic connections of some acronyms are weak or
24 not very stable as it also happens for some second language words. On those occasions
25 individuals used the potentially stronger lexical connections providing associative responses
26 that shared the form rather than meaning. The scarcity of position based responses might
27 reflect the fact that the use of acronyms is not as profuse as that of mainstream words.
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38 In relation to the response distribution measures, meaning set size and associative strength,
39 the present study replicate and extend on previous findings reporting semantic effects on
40 word recognition times. Associative strength and meaning set size affected response
41 association times as it has also been reported to affect word recognition times (Balota et al.,
42 2004; Buchanan, Westbury & Burgess, 2001). The fact that words with large meaning set
43 sizes generated slower responses might be related to a similar result found by Mirman and
44 Magnuson (2008) where individuals were slower at discriminating words with many near
45 neighbours (i.e., words that had a closer semantic distance with the cue word) and is
46 congruent with the finding of faster response times for words with high associative strength
47 and therefore low in meaning set size.
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One finding of particular interest is that word association responses did not correlate with or
show a significant effect of printed frequency. The nature of acronym creation and use may

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3 be responsible for the lack of correlations with printed frequency. The correlation between
4 rated and printed frequency in the acronyms was significant, but relatively low at .34.
5 Acronyms are created to abbreviate cumbersome or technical phrases, and often come from
6 highly specialised fields. As a result acronyms with high printed frequencies may not
7 necessarily be high frequency to all the participants. It is suggested, therefore, that the non-
8 significant correlations with printed frequency indicate that printed frequency measures for
9 acronyms may not equate to individual experience. Considering the word association task is
10 mainly a semantic task, knowledge of the meaning of an acronym is integral to the successful
11 completion of the task. The fact that rated frequency correlated significantly with several
12 aspects of word association behaviour is interpreted as evidence that subjective or rated
13 frequency estimates are, for acronyms at least, a better representation of lexical knowledge
14 than the printed frequency measures. Rated frequency is more likely to reflect the level of
15 familiarity that undergraduate students have with the items. However, once entered into the
16 regression analyses neither rated nor printed frequency was a significant predictor of word
17 association RT. This finding supports the interpretation of de Groot (1989) that frequent
18 encounters with words and their assumed automatic distributed activation to related
19 representations might not be sufficient to strength those connections. It suggests, in addition,
20 that the frequency of a word is not as relevant when providing associative responses as age of
21 acquisition, letter length and imageability are.
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35 Interestingly an effect of word length was observed when all the responses were considered
36 but not when only the responses related in meaning to the cue word were analysed. This
37 seems to be the result of an interaction between word length and the type of link between the
38 cue acronym and the response, with length effects having a significant influence over form
39 based responses but not so much over semantically related responses. This might be because
40 longer acronyms are more likely to look like words and therefore generate rapid responses
41 orthographically similar.
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48 Regression analyses showed that imageability was a significant predictor in the two
49 regression models. De Groot (1989) found that imageability was an important factor in RT
50 and associative strength in a mainstream word association task. De Groot (1989) argued that
51 highly imageable words have relatively strong connections with at least one associated node
52 and that these strong links are shared by a large number of individuals. Thus, the associated
53 concept is retrieved quickly and the same associate is offered by a larger number of
54 participants. The same interpretation would appear to apply in the present study. That said
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3 the potential semantic complexity of acronyms may benefit from considering other measures
4 of semantic richness such as those discussed by Pexman, Hargreaves, Siakaluk, Bodner and
5 Pope (2008) in future studies. Pexman et al. (2008) studied three measures of semantic
6 richness; 1) number of features in a concept, 2) semantic neighbourhood or the number of
7 words that co-occur in similar contexts and, 3) contextual diversity referring to the extent to
8 which a word is distributed into nine different content areas. They highlighted that each of
9 these measures had previously been demonstrated to affect latencies in word recognition
10 tasks. Pexman et al. (2008) showed that while the three measures had an effect in lexical
11 decision times only number of features and context distribution had an effect in a semantic
12 categorization task. Unlike the present study, however, Pexman et al. (2008) did not control
13 for age of acquisition or imageability. It would therefore be worthwhile investigating the
14 predictive power of semantic neighbourhood, number of features and contextual diversity
15 would be predictive of the speed with which associative responses are generated for
16 acronyms once age of acquisition and imageability are controlled for.
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30 Another important finding is the age of acquisition effect observed when all responses were
31 taken into account (analysis 1) and when only the semantic responses were considered
32 (analysis 2). This finding echoes the age of acquisition influence previously shown in word
33 association tasks. Both van Loon-Vervoorn (1989) and Brysbaert et al. (2000) reported that
34 early acquired words were quicker to produce an association response than words acquired
35 later in life. In addition, Brysbaert et al. (2000) also found a significant effect of age of
36 acquisition on their measure of associative strength. The authors suggested that influence of
37 age of acquisition and imageability on word association had a similar source. Brysbaert et al.
38 (2000) proposed that late acquired words are learned by relating the new 'late' concept to a
39 previously existing word representation. As a result of this learning process the
40 representations for early acquired words are accessed more often, and therefore the links to
41 and from an early acquired node are stronger than for late acquired words. The age of
42 acquisition effects shown in the present study could be the result of a difference in the speed
43 with which early and late acquired acronyms are recognised and the relative strength build in
44 the intra-lexical links. However, the fact that the predictive power of age of acquisition
45 increased when only semantically linked responses were considered suggests that age of
46 acquisition may be a semantic property as suggested by van Loon-Vervoorn (1989) and
47 Brysbaert et al. (2000). Nevertheless, Izura and Ellis (2002; 2004) showed that second
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3 language speakers of English were faster at processing words that had been learned early in
4 the second language than words learnt some time later. This occurred even when the early
5 acquired word in English as L2 was a late acquired word in Spanish as L1 and vice versa
6 (e.g., *money* and *travel*, are late learned words in L1 but useful and early acquired in L2 while
7 *witch*, *fairy* are words incorporated early in the L1 vocabulary but late in L2). Considering
8 these reports we are inclined to think that the age of acquisition effect found in the word
9 association task emerges from the lexico-semantic connections that might exist between
10 representations (Ellis & Lambon-Ralph, 2000; Steyvers & Tenenbaum, 2005).
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17 This study has provided useful information concerning the concepts commonly associated
18 with acronyms. Further research using acronyms and mainstream words in a word
19 association paradigm could directly compare the similarities and differences between the two
20 types of lexical items. Here it has been shown that associative responses to acronyms in
21 English as a first language have patterns similar to those produce by English second language
22 speakers and are in addition influenced by age of acquisition and imageability.
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50 51 52 53 54 **Appendix**

55 **Acronym cues used in the word association task.**

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ACDC	CCCP	FIFA	LBW	PAYE	STD
ADHD	CEO	FYI	LCD	PDA	TBA
AGM	CIA	GBH	LMAO	PDF	TCP
AOL	CJD	GCSE	LSD	PGCE	TFT
APR	CNN	GMT	MBA	PSP	TLC
ASAP	CPU	GPA	MDMA	PTA	TNT
ASBO	CSI	GPS	MGM	PTO	UCAS
ATM	DHL	HDTV	MMR	PTSD	UEFA
AWOL	DIY	HGV	MRI	PVC	UFC
BAFTA	DNA	HIV	MRSA	QVC	UFO
BBC	DOA	HMO	MSN	RAF	UHF
BHS	DOB	HMS	MTV	RBS	USA
BLT	DUI	HMV	NASA	REM	USB
BMI	DVD	HRT	NASCAR	RNIB	USSR
BMW	DVLA	HSBC	NATO	RNLI	VCR
BNP	DVT	IBM	NBA	RPG	VHS
BOGOF	ECG	IBS	NCIS	RRP	VIP
BPM	EEG	ICT	NHS	RSPB	WWF
BPS	ENT	IMDB	NSPCC	RSPCA	YMCA
BRB	ESP	IRA	NYPD	RSVP	
BSE	ESRC	ISP	OAP	SAE	
BST	ETA	ITN	OBE	SAS	
BTW	FAO	ITV	OCD	SCUBA	
BYOB	FAQ	IVF	OCR	SMS	

Table 1 – Percentage of word association responses in each cue-response category, along with mean and standard deviation of response types per cue.

	Total percentage	Mean number per cue	Standard deviation
Semantic	94	30.96	8.83
Position	< 1	.30	.89
Form	6	1.73	2.83

Table 2 – Correlations between predictor variables and reaction times

	Rated Frequency	Printed Frequency	Age of Acquisition	Imageability	Letter Length	Semantic Relation	Position Relation	Form Relation	No of ass. Responses	RTs
Ass. Strength	0.17**	0.07**	-0.25**	0.34**	0.22**	0.14**	-0.15**	-0.27**	-0.64**	-0.14**
Rated Frequency		0.34**	-0.17**	0.57**	-0.11**	0.30**	0.19**	-0.28**	-0.24**	-0.09**
Printed Frequency			-0.03*	0.11**	-0.36**	0.06**	0.06**	n.s	n.s	n.s
Age of Acquisition				-0.55**	0.03*	-0.18**	n.s.	0.18**	0.39**	0.15**
Imageability					0.10**	0.55**	0.06**	-0.44**	-0.44**	-0.18**
Letter Length						0.05**	n.s.	-0.14**	-0.07**	-0.05**
Semantic Relation							-0.14**	-0.40**	-0.24**	-0.08**
Position Relation								-0.06**	0.17**	n.s
Form Relation									0.32**	0.09**
No of ass. responses										0.20**

Note: * p < .05 ** p < .001 n.s. non-significant. RT = reaction times. Freq = frequency. Ass = Associative. No = Number

Table 3 – Beta coefficients for each predictor in the multilevel regression analysis

		β
Step 2	Semantic links	-.077**
	Position links	.019
	Form links	.056**
Adjusted R^2		.184**
Step 3	Associative Strength	-.037*
	Number of responses	.191**
Adjusted R^2		.224**
Step 4	Rated Frequency	-.024
	Printed Frequency	.000
	Age of Acquisition	.053*
	Imageability	-.091**
	Letter Length	-.036*
Adjusted R^2		.236**

* $p < .05$ ** $p < .001$

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Table 4 – Beta coefficients for predictor variables when only RTs to semantically related responses were considered

	β
Rated Frequency	.004
Printed Frequency	.132
AoA	.256*
Imageability	-.462**
Letter Length	-.100
Adjusted R^2	.416**

* $p < .05$ ** $p < .001$