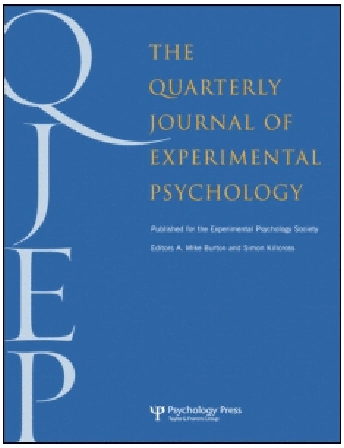

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Size matters: Bigger is faster

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Short article

Size matters: Bigger is faster

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A largely unexplored aspect of lexical access in visual word recognition is "semantic size"—namely, the real-world size of an object to which a word refers. A total of 42 participants performed a lexical decision task on concrete nouns denoting either big or small objects (e.g., *bookcase* or *teaspoon*). Items were matched pairwise on relevant lexical dimensions. Participants' reaction times were reliably faster to semantically "big" versus "small" words. The results are discussed in terms of possible mechanisms, including more active representations for "big" words, due to the ecological importance attributed to large objects in the environment and the relative speed of neural responses to large objects.

Keywords: Semantic size; Visual word recognition; Lexical decision.

Over the past four decades, research in visual word recognition has sought to identify the variables affecting the speed with which we access the meaning of words. These have been classified as intraword, word, and extraword variables, based on the lexical level at which they are expressed (Rayner & Sereno, 1994). For example, intraword or sublexical variables include word-initial letter combinations (bigrams, trigrams), morphological information (affixes, stems, inflections), orthographic–phonological correspondence (spelling–sound regularity), and the size and consistency of a word's orthographic neighbourhood (i.e., words of a given length that differ by a single letter). Word or lexical variables include length, frequency, age of acquisition, semantic ambiguity, the size and density of a word's semantic neighbourhood, and other forms of lexical complexity, such as syntactic class, imageability (concreteness) of meaning, and affective tone. Extraword or supralexical variables include the prior discourse context and how it relates to a target word. One key variable is the predictive strength of a prior context. Others include whether the target is

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temporarily syntactically ambiguous, whether it is in discourse focus, whether it has a relevant antecedent, or whether it requires an elaborative inference.

While these variables have all been shown to influence word recognition processes (e.g., Rayner, 1998), it is less clear precisely when and how such mechanisms operate. Different measures provide complementary means for pursuing these issues (Sereno & Rayner, 2003). For example, standard behavioural paradigms, such as lexical decision and naming, have proven effective in establishing the lexical features of interest. The briefer response time associated with eye fixation duration measures sets temporal limits for these processes in the context of normal reading. Electrophysiological measures can index associated changes in real time. Haemodynamic brain imaging techniques, while temporally coarse, indicate localized differences of activity. Together with behavioural and neuropsychological results, such measures can begin to formulate the neural circuitry of word reading (e.g., Posner, Abdullaev, McCandliss, & Sereno, 1999; Salmelin & Kujala, 2006).

The focus of our current experiment was to establish a new lexical variable—namely, semantic size. Object size is one of the few dimensions that generates iconic gestures during spontaneous speech (Beattie & Shovelton, 1999). We hypothesized that responses to words representing big items (e.g., *ocean*, *dinosaur*, *cathedral*) would be faster than responses to words representing small ones (e.g., *apple*, *parasite*, *cigarette*), for several reasons. The first concerns the concept of linguistic markedness (Greenberg, 1966; Jakobson & Halle, 1956). At an abstract level, a word that is unmarked is usual or dominant, characterized as a basic or default form. In English, for example, feminine forms can be gender-marked, whereas both the general and male forms are unmarked (e.g., *lioness* vs. *lion*, *actress* vs. *actor*). In terms of size, bigness is the unmarked form—one asks how *tall* someone is, or how *big* or *wide* something is. The corresponding marked forms (*short*, *small*, *narrow*) are generally used only for effect, occurring in specialized contexts.

Further evidence supporting a "bigger is better" view comes from other research traditions. For example, Bruner and Goodman (1947) demonstrated a size-value effect, in which objects of greater value were judged as being larger. In the ethology literature, there is often a biological preference towards more extreme stimuli, including larger size, as seen from the evolution of the "supernormal" stimulus (e.g., Tinbergen & Perdeck, 1950). A larger exemplar of a category activates more neurons in early visual pathways, attracts attention more easily, and may hold attention longer. In many habitats, size confers a reproductive advantage, particularly in sexually dimorphic species. Finally, Fischer (2001) demonstrated that lines flanked by a digit on either side were bisected in the direction of the larger-magnitude digit (e.g., 9 vs. 1), regardless of its relative position. Such a bias could indicate that the larger number attracts more attentional resources.

In our experiment, words denoting big and small entities were presented in a standard lexical decision task. Other lexical variables known to robustly affect response time, such as word length, frequency, and imageability, were controlled. If words representing large objects are processed faster, then reaction times should likewise be speeded up, indicating that the semantic size of a word influences some aspect of lexical processing.

Method

Participants

Twenty-eight (14 female, 14 male) native English-speaking University of Glasgow undergraduate and graduate students (mean age 26 years) voluntarily participated. All had normal or corrected-to-normal vision, were right-handed, were not diagnosed as dyslexic, and were naive as to the purpose of the experiment.

Apparatus

The experiment was run on a Mac G4 (OS 9.0.4) computer using PsyScope 1.2.5 PPC software (Cohen, MacWhinney, Flatt, & Provost, 1993). Stimuli were presented in 24-point Courier font (black characters on a white background) on a Hansol 2100A 19″ colour monitor (85 Hz, 1,024 × 768 resolution). At a viewing distance of approximately 86 cm, 3 characters subtended 1° of visual angle. Responses were made via a PsyScope Button Box, and reaction times (RTs) were recorded with millisecond accuracy.

Materials

The 90 experimental words are presented in the Appendix. Half were "Big" words denoting a large entity (e.g., *jungle*), and half were "Small" words, denoting a little entity (e.g., *needle*). Operationally, we defined Big and Small in relation to the size of a human. Items were matched pairwise on length, number of syllables, and word frequency. Word frequencies were obtained from the British National Corpus (BNC), a database of 90 million written words (http://www.natcorp.ox.ac.uk). Imageability norms were obtained from three sources—the MRC Psycholinguistic Database (Wilson, 1988; http://www.psych.rl.ac.uk/), the Bristol Norms (Stadthagen-Gonzalez & Davis, 2006; http://language.psy.bris.ac.uk/ bristol_norms.html), and Cortese and Fugett's (2004) imageability norms. These norms reflect participants' ratings of words on a scale of 1 (low imageability) to 7 (high imageability). Norms were available for 35 of the 45 Big words and 35 of the 45 Small words. The average values (and standard deviations) of the stimulus variables for each condition are presented in Table 1. Nonword stimuli comprised pronounceable, orthographically legal psuedowords (e.g., *blimble*). For each word pair, two length-matched pseudowords were generated, resulting in a total of 90 pseudowords.

Procedure

Participants were tested individually. They were given a consent form and written instructions. They were told that half of the stimuli were words and half were nonwords and that they should respond as quickly, but as accurately, as possible. They were also instructed that the words represented a selection of several different categories of objects (e.g., animals, plants, vehicles, fruits, buildings, household items, and terrestrial entities). Participants were then presented with 16 practice items (8 words, 8 nonwords) to become accustomed to the task. Word responses were made using the right forefinger on the right (green) key of the Button Box, labelled "W," and nonword responses with the left forefinger on the left (red) key, labelled "NW." Participants were then presented with the 180 experimental items (90 words, 90 nonwords), with a programmed break roughly halfway through the trials.

Each trial consisted of the following events. A blank screen was initially presented for 1,000 ms. A fixation cross (+) then appeared in the centre of the screen for 200 ms, replaced by another blank screen for 500 ms. A letter string was then presented centrally until the participant responded. Experimental trials were presented in a different random order for each participant.

Results

RT and error percentages

The mean RT and percent error (%Error) data (with standard deviations) for Big and Small words are presented in Table 2. The RT data were subjected to two trimming procedures. Items with RTs <250 ms or >1,500 ms were

Table 1. *Specifications of words*

	N	*Length*	*Syllables*	*Frequency*	*Imageability*
Small words	45	6.20 (2.13)	2.00 (.85)	23.74 (31.28)	6.07 (.39)
Big words	45	6.20 (2.13)	2.00 (.95)	24.40 (34.41)	6.08 (.30)

Note: Mean values; standard deviations in parentheses. Units of measurement: Length in number of letters; Syllables in number of syllables; Frequency in occurrences per million; Imageability in units on a scale of 1 (low) to 7 (high).

Table 2. *Mean RT and error percentages for Small and Big words*

	RT	*%Error*
Small words	528 (9.31)	2.30 (.54)
Big words	513 (8.64)	1.59 (.34)

Note: Mean values; standard deviations in parentheses. RT in ms.

excluded from further analysis. For each participant in each condition, items with RTs beyond two standard deviations of the mean were also excluded. These procedures resulted in an average data loss of 4.72% per participant. Paired-sample, two-tailed t tests were performed on the data both by participants (t_1) and by items (t_2).

For RT, responses to Big words (513 ms) were significantly faster than those to Small words (528 ms): $t_1(27) = 5.22$, $p < .001$, $d = 0.32$; $t_2(44) = 3.29$, $p < .01$, $d = 0.52$. The %Error (1.94%) was quite low across participants. Although %Error across conditions correlated positively (numerically) with RT, there was no statistical difference in %Error for Big and Small words (ts < 1.15, ps $> .25$).

Possible confounds

There were three possible confounds within the materials that may have given rise to the pattern of results. The first concern was that, although a visual lexical decision task was used, if participants "sounded out" the words in their heads and if vowels in one word category were longer, on average, then controlling for word length (in characters) and number of syllables would not capture potential differences associated with an internalized naming duration. To address this concern, we measured the spoken duration of all Big and Small words. Four native English-speaking Scottish volunteers (2 female, 2 male) read a randomized list of all target words aloud, pausing between words, and the spoken duration of each word was measured. Paired-sampled, two-tailed t tests were performed on the data by participants and by items. No difference was found between the duration of Big (562 ms) and Small (564 ms) words (all ts < 1).

The second concern was that RT differences may have arisen from age of acquisition (AoA) differences between Big and Small words, in which developmentally earlier-acquired words demonstrate a processing advantage (see Johnston & Barry, 2006, and Juhasz, 2005, for recent reviews). AoA norms were obtained from four sources (Bird, Franklin, & Howard, 2001; Gilhooly & Logie, 1980; Morrison, Chappell, & Ellis, 1997; Stadthagen-Gonzalez & Davis, 2006) and were available for 31 of the Big words and 32 of the Small words. The average AoA ratings (and standard deviations) on a scale of 1 (early) to 7 (late) were 2.95 (0.89) for Big words and 2.66 (0.66) for Small words. Although the magnitude of the difference is slight, the direction of the difference would favour faster responses to Small words.

The final concern was that several items on the Small word list can be conceptually linked to the hand, and this may facilitate a button press made by the hand for lexical decision. We conducted two separate items analyses on the data. In the first analysis, we examined RT on Small words having hand associations versus Big words that were matched for length and frequency. There were 17 Small words that were categorized as such (*cup, pin, ring, tape, glass, phone, apple, thumb, peach, glove, button, needle, apricot, teaspoon, cigarette, fingernail, handkerchief*). Similar to the overall pattern of results, hand-related Small words (515 ms) had slower RTs than matched Big words (503 ms), although this difference was marginal, $t_2(16) = 1.90$, $p = .075$. In the second analysis, we examined the remaining 28 Small words without hand associations. These items also showed the same overall pattern of effects, with slower RTs to Small (539 ms) than Big (520 ms) words, which was significant, $t_2(16) = 2.71$, $p < .05$. Although the size effect (RT difference of Small−Big) for hand-related words (12 ms) was numerically smaller than that for the hand-unrelated words (19 ms), we do not think it prudent to draw strong conclusions from this, particularly as we are dealing with unequal-sized subsets of items and both effects were minimally marginally significant.

A test of spatial markedness

One aspect of the experimental procedure that we did not manipulate was the mapping of responses—the "word" (W) response being made with the right (dominant) hand and the "nonword" (NW) response with the left hand (all participants were right-handed). In terms of spatial markedness, right is unmarked and left is marked. Thus, the consistency in the markedness of the response could have given rise to the pattern of results. That is, pressing the right key for W may have conferred an advantage for Big words (consistent markedness) and a disadvantage for Small words (inconsistent markedness). In a similar vein, the "spatial numerical association of response codes" (SNARC) effect favours faster right-sided responses to larger numbers and faster left-sided responses to smaller numbers (e.g., Dehaene, Bossini, & Giraux, 1993; see also Nuerk, Iversen, & Willmes, 2004, who find congruency effects of linguistic markedness of response codes [MARC] with number words in parity decisions).

To address these concerns, we ran a new set of 14 right-handed participants (7 female, 7 male; mean age 23 years) in the same experiment, but we reversed the response mapping (with left for W, right for NW). The average data loss from trimming procedures was 5% per participant. An identical pattern of results emerged, with faster responses to Big (514 ms) versus Small (527 ms) words: $t_1(13) = 2.71$, $p < .05$, $d = 0.22$; $t_2(44) = 2.08$, $p < .05$, $d = 0.39$. RTs differed only by 1 ms from RTs in the main experiment. As before, there were no differences in %Error for Big (2.38%) and Small (3.14%) words, ts < 1.05, ps $> .30$. To verify the lack of a difference between the left–right response mapping groups of NW–W ($N = 28$) and W–NW ($N = 14$), a two-way ANOVA was performed (Size × Group). The main effect of size was significant, with faster responses to Big words (513 ms) versus Small words (528 ms), $F_1(1, 40) = 28.12$, $p < .001$, $d = 0.28$; $F_2(1, 88) = 12.72$, $p < .001$; $d = 0.45$. There was no effect of group, nor an interaction between size and group (all Fs < 1).

Discussion

In this experiment, we examined whether the semantic size of a word affected the speed of response to that word. Words denoting Big and Small objects were matched for word length, frequency, and imageability. Results indicated that Big words were processed significantly faster than Small words.

The question remains, however, as to whether size information is coded in lexical representations. It is clear that size is an essential feature of some words (e.g., size words themselves, and others, like *dwarf* or *giant*). Is size, however, an integral feature of concrete nouns? Prior studies have demonstrated that at least some aspects of the semantic size of a word are incorporated in its meaning and are automatically accessed (Pavio, 1975; Rubinsten & Henik, 2002). These studies typically use a size comparison task in which participants judge which of two stimuli are larger, either in physical (stimulus) or in semantic (real-world) terms. Pavio (1975) suggested that an underlying analog representation, indexing both size and viewing distance, is accessed by images and words. Pavio, however, only showed a size-congruity effect for pictures (with faster responses to congruent versus incongruent stimuli). More recently, Rubinsten and Henik (2002) did show a size-congruity effect for words (*ANT–LION* faster than *ANT–LION*), using both physical and semantic judgements. They suggested that the difference between their results and Pavio's was due to a greater variability in terms of word length in Pavio's words. Using animal words, Shoben and Wilson (1998) showed that entities having extreme magnitudes were easier to discriminate. They suggested that measuring categorization speed in a size task could reveal how closely linked magnitude information is to the retrieval of a word's semantics.

From a broader, conceptual perspective, there is much evidence suggesting that various aspects of word meanings are coded in their representations. Models of conceptual structure generally posit that concepts are composed of features. A given concept can be defined by the number of its features, their distinctiveness, their interrelationships, their perceptual or functional derivations, and their centrality to the concept (Moss, Tyler, & Taylor, 2007). For example, Bright, Moss, Longe, Stamatakis, and Tyler (2007) demonstrated that visually based attributes of animals (presented as written words) activated anteromedial temporal cortex, an area that, they suggest, processes multimodal conceptual information. In any event, the reliance of concepts on their features points to the central role of perceptual and functional processing of objects, whether they are presented in pictorial or written form.

Barsalou (1999) extended this understanding of concepts in his account of grounded cognition or embodiment, in which cognitive processing depends on internal simulations of perceptual and motor processes. Historically, embodiment emerged in psychology in William James' (1890) notion of "ideomotor action" and, more recently, in the work of Lakoff (1987) in relation to language processing. Over the past decade, much research has shown that cognition, including language comprehension, is inextricably tied to perception and action (Barsalou, 1999, 2008; Fischer & Zwaan, 2008; Glenberg & Kaschak, 2002; Pickering & Garrod, in press; Roy, 2005; Zwaan & Taylor, 2006). There is evidence, for example, that there are associations between effector-specific words and corresponding brain regions (Pulvermüller, 1999, 2005; Pulvermüller & Hauk, 2006; Tettamanti et al., 2005). Other research has demonstrated that the meaning of a word can modulate subsequent grasp aperture (Bub, Masson, & Cree, 2008; Glover, Rosenbaum, Graham, & Dixon, 2004; Tucker & Ellis, 2004). On this view, a manual button-press response should, in principle, be facilitated by object names whose meanings are related to the hand. In our study, although some of the Small items denoted parts of a hand (e.g., *thumb*, *fingernail*), or could be manipulated by (e.g., *cup*, *button*) or worn on (e.g., *ring*, *glove*) a hand, the majority did not have strong associations with the hand (e.g., *neck*, *tulip*, *vitamin*, *butterfly*). Moreover, both hand-related and hand-unrelated Small items produced slower responses compared to matched Big items.

We suggest that a reason why bigger items might generate faster responses is related to imageability. While both bigger and smaller items can be equally highly imageable (and were in our experiment), it may be that the relative speed of accessing a stored visual representation is faster when the object is bigger. When viewed at the same distance, larger objects contain more low spatial-frequency information, which is transmitted faster through the visual system via the magnocellular pathway (e.g., Sereno, 1993). It has been established that early visual areas (lateral geniculate nucleus, primary visual cortex) are activated during mental imagery (for a review, see Kosslyn & Thompson, 2003). From an embodiment perspective, it is possible that a similar mechanism comes into play during lexical access. Thus, if visual imagery accompanies word recognition, such information may become available *earlier* for words that refer to larger objects and, hence, produce a processing advantage. The fMRI studies showing early visual stream activation during imagery, however, cannot provide a time course of these activations.

In conclusion, our results suggest that semantic size is automatically activated upon reading a word, with larger semantic sizes activated more quickly. One limitation of this study is that it was based on skilled readers responding to concrete nouns where the size discrepancy between Big and Small items was substantial. It remains to be seen whether the relationship between semantic size and response time is linear in nature (i.e., whether the relationship is upheld for words denoting objects of less extreme magnitudes). Because we employed a lexical decision task, the possibility that response criteria play a role in discriminating in favour of Big versus Small words must also be considered. Big objects may have a lower response threshold than Small objects for reasons having to do with the subjective value attributed to largeness. Further investigation of this question should use measures such as eye movements during reading or event-related brain potentials during single word presentation, which are simultaneously less sensitive to response bias and more sensitive to the temporal dynamics of word recognition.

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APPENDIX

Word stimuli

Small	*Big*	*Small*	*Big*	*Small*	*Big*
cup	bed	thumb	truck	apricot	buffalo
fly	bay	peach	whale	parsley	gorilla
lip	jet	glove	camel	emerald	giraffe
pin	cow	snail	comet	magazine	mountain
rose	park	tulip	moose	bacteria	motorway
neck	tree	button	planet	molecule	elephant
ring	bear	needle	jungle	sandwich	wardrobe
nose	lake	insect	galaxy	parasite	dinosaur
tape	tank	bullet	rocket	mosquito	downtown
leaf	bull	peanut	walrus	teaspoon	bookcase
glass	river	diamond	monster	cigarette	cathedral
phone	train	battery	stadium	butterfly	submarine
video	horse	vitamin	mansion	fingernail	skyscraper
apple	ocean	sausage	tractor	handkerchief	supermarket
robin	shore	aspirin	volcano	hummingbird	hippopotamus