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The effects of polysemy for Japanese katakana words

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Abstract. In these experiments, the effects of polysemy were examined as a function of word frequency for Japanese katakana words, words which have consistent character-to-sound correspondences. In the lexical decision task, an additive relationship was observed between polysemy and frequency (i.e., polysemy effects were identical for high and low frequency katakana words). In the naming task, although no word frequency effect was observed, there was a significant polysemy effect which, as in the lexical decision task, was identical for high and low frequency words. The implications of these results for conclusions about the loci of polysemy and frequency effects in lexical decision and naming tasks are discussed.

Key words: Lexical decision and naming of katakana words, Polysemy and frequency effects, Lexical-selection accounts, Dual-route and PDP framework

Introduction

In reading research, much attention has been paid to the issue of how word meanings are derived from the processing of visual input. For example, one of the main questions that this research has addressed is whether the retrieval of word meanings is accomplished directly from orthography or is mediated by phonology (or both). A second question, and one that is more central to the present investigation, is how semantic factors might guide reading processes, for example, whether semantic variables affect the process of selecting a lexical representation or whether semantic variables guide the process of phonological coding. To address these issues, the effects of semantic variables have been examined in a number of studies using isolated word recognition tasks.

In fact, significant effects of semantic variables have been reported in a variety of word recognition tasks (e.g., Fera, Joordens, Balota, Ferraro & Besner 1992; Hino & Lupker 1996; James 1975; Jastrzembski 1981; Jastrzembski & Stanners 1975; Kellas, Ferraro & Simpson 1988; Millis & Buttons 1989; Rubenstein, Garfield & Millikan 1970; Rubenstein, Lewis & Rubenstein 1971; Strain, Patterson & Seidenberg 1995; for a review see also

Balota, Ferraro & Connor 1991). For example, imageability effects have been found in both lexical decision (e.g., James 1975) and naming tasks (Strain et al. 1995) due to the fact that more imageable words (e.g., COMB, PEAR) are responded to faster than less imageable words (e.g., CASTE, WARN). More relevant to the present discussion, there are now a number of studies showing that polysemy (number of meanings) affects lexical decision performance. In particular, the typical result has been that lexical decision latencies are shorter for words with multiple meanings (e.g., LEAN, RIGHT) than for words with fewer meanings (e.g., TENT, SMALL) (e.g., Borowsky & Masson 1996; Hino & Lupker 1996; Jastrzembski 1981; Jastrzembski & Stanners 1975; Kellas et al. 1988; Millis & Buttons 1989; Rubenstein et al. 1970; Rubenstein et al. 1971; but for criticisms see Clark 1973; Forster & Bednall 1976; Gernsbacher 1984). More recently, some researchers have also reported significant polysemy effects in naming tasks (e.g., Fera et al. 1992; Hino & Lupker 1996), although others have failed to observe these effects (e.g., Borowsky & Masson 1996; Chumbley & Balota 1984).

On the basis of these results, Balota et al. (1991) suggested that semantic variables such as polysemy and imageability do affect the lexical-selection process which is common to these word recognition tasks. Balota et al.'s specific account was based on the interactive-activation model (McClelland & Rumelhart 1981; Rumelhart & McClelland 1982). According to this model, each word-level unit has a resting activation level that is a direct function of word frequency. When a stimulus is presented, each unit's activation increases in direct proportion to how similar the stimulus is to the word for that unit. A lexical unit is ultimately selected when that unit is activated over its threshold. Since the word-level units are also connected to meaning-level units via bi-directional links, Balota et al. assumed that the partial activation of word-level units sends activation signals up to meaning-level units before a word-level unit reaches the threshold. The activated meaning-level units would then send activation signals back down to the word-level units. As a consequence, the lexical-selection process would be facilitated due to the feedback of activation from meaning-level units.

In addition, Balota et al. also assumed that polysemous words correspond to multiple units at the meaning-level, whereas nonpolysemous words correspond to a single meaning-level unit. Since polysemous words activate multiple meaning-level units, the feedback of activation from meaning-level to word-level units would be greater for polysemous words than for nonpolysemous words. Thus, lexical selection would be facilitated by semantic feedback more for polysemous words than for nonpolysemous words, producing the observed polysemy effects.

According to Balota et al.'s model, then, polysemous words are assumed to be represented by a single lexical-level unit which is connected to multiple meaning-level units. As Balota and Paul (1996) have suggested, however, it would also be possible to assume that a polysemous word is represented by multiple lexical-level units. In fact, in order to account for the polysemy effects in their lexical decision experiments, Rubenstein and colleagues (1970, 1971) and Jastrzembski (1981) assumed that there were multiple lexical units for polysemous words.

Rubenstein and colleagues (1970, 1971) assumed that lexical selection consists of two sub-processes. The first is a marking process in which a set of lexical units is marked based on the nature of the visual input. In this process, lexical units are assumed to have a higher probability of being marked if those units correspond to higher frequency words. Since the marked units are evaluated first, the word frequency effect can be explained as being due to this marking process. The marked units are then randomly compared with visual inputs in the second sub-process. A single lexical unit is finally selected when a match is found during the comparison process. Since Rubenstein and colleagues assumed that each meaning corresponds to a lexical unit, polysemous words are represented by more lexical units than nonpolysemous words. Thus, when the comparison process randomly selects from among the marked units, the probability of selecting any one of the units for polysemous words should be greater than that for words with fewer units. As a consequence, this comparison process would, on average, be completed more rapidly for polysemous words.

Jastrzembski's (1981) account of polysemy effects was based on the logogen model (Morton 1969). Like Rubenstein and colleagues, Jastrzembski also assumed that polysemous words are represented by multiple lexical units (i.e., logogens), with different logogens corresponding to different meanings. According to this model, a word is recognized whenever a logogen's activation threshold is exceeded. Because polysemous words would activate more logogens than nonpolysemous words, the probability of any one of these logogens reaching threshold by a given point in time would be greater than the probability of a single logogen reaching threshold by that same point in time. Thus, polysemous words should be responded to more rapidly than nonpolysemous words.

Since lexical decision tasks specifically require that participants determine whether a presented letter string has a lexical unit, it has been assumed that 'word' decisions are made when a lexical unit (logogen) is selected (e.g., Coltheart 1978; Coltheart, Curtis, Atkins & Haller 1993). Working on this assumption, therefore, these models predict different relationships between word frequency and polysemy in a lexical decision task. That is, according to the model of Rubenstein and colleagues, the word frequency effect is assumed to be due to the marking process, whereas the polysemy effect is assumed to be due to the comparison process. Consequently, because different sub-processes are responsible for producing word frequency and polysemy effects, this model would predict an additive relationship between word frequency and polysemy in lexical decision tasks (which is what Rubenstein et al. observed). On the other hand, Balota et al.'s model and Jastrzembski's model both assume that word frequency and polysemy effects are due to the process of selecting a lexical unit and that lexical selection is a unitary process. Thus, according to additive factors' logic (Sternberg 1969), these models would instead predict an interactive relationship between word frequency and polysemy (which is what Jastrzembski observed).

Note also that all these models share the assumption that both word frequency and polysemy effects are due to the lexical-selection process. Thus, word frequency and polysemy are both assumed to affect task performance whenever the task involves the lexical-selection process. Further, as Balota and Chumbley (1984) noted, the size of the effects that either of these variables produce should be identical across tasks if two things are true (a) the variable does not affect any process other than lexical selection, and (b) the lexical-selection process is a necessary component of the tasks. Therefore, based on the fact that, in their experiments, the word frequency effect was larger in lexical decision than in naming, Balota and Chumbley concluded that the frequency effect in lexical decision was not only due to lexical selection but was also due to postlexical decision-making processes.

As pointed out by other researchers working within the dual-route framework (e.g., Monsell 1991; Monsell, Doyle & Haggard 1989; Paap, McDonald, Schvaneveldt & Noel 1987), however, a prediction of equal size effects in the naming and lexical decision tasks would not necessarily follow since it is not the case that the lexical-selection process is a necessary component in the naming task. According to dual-route models (e.g., Coltheart 1978; Monsell 1991; Monsell et al. 1989; Paap et al. 1987), there are at least two independent parallel phonological coding pathways or 'routes' used in naming. The first does involve selection of the appropriate lexical unit (based on an analysis of the word's orthographic representation), which is then followed by the essentially holistic retrieval of a phonological code (the 'lexical route'). The second pathway, however, does not involve the lexical-selection process. Here, phonological codes are generated from subword-level orthographic codes by applying spelling-to-sound correspondence rules. That is, phonological coding is accomplished based on graphemic codes (or larger orthographic units) by computing the corresponding phonemes and then assembling them to produce a phonological code (the 'nonlexical route').

To the extent that the nonlexical route rather than the lexical route drives responding in a naming task, lexical-selection effects should be smaller in that task. More specifically, as Paap et al. (1987) and Monsell and colleagues (Monsell 1991; Monsell et al. 1989) suggest, one place where the nonlexical route will have a major impact is in naming low frequency regular words. That is, these words are presumed to be processed slowly enough on the lexical route that the phonological code resulting from processing on the nonlexical route should often become available first. As such, for low frequency regular words, the nonlexical route rather than the lexical route will drive responding on a reasonable proportion of trials. High frequency regular words, on the other hand, are presumed to be processed rapidly enough on the lexical route that the lexical-selection process will nearly always be involved in producing a phonological code. In contrast, in the lexical decision task, it is assumed that the lexical-selection process will be involved in all trials for all types of words because, in order to ensure that the stimulus truly is a word, it is essential that a corresponding lexical unit be located (e.g., Coltheart 1978; Coltheart et al. 1993).

In essence then, Balota and Chumbley's (1984) suggestion about equal size effects in naming and lexical decision tasks would apply only to words which cannot be pronounced via the nonlexical route (i.e., irregular words). Words that can be named via the nonlexical route (i.e., regular words) would be expected to show a smaller frequency effect in the naming task which is, in fact, what is typically reported (e.g., Balota & Chumbley 1984; Brown, Lupker & Colombo 1994; Frost, Katz & Bentin 1987; Forster & Chambers 1973; Hino & Lupker (in press); Monsell 1991; Monsell et al. 1989).

More importantly for present purposes, what this analysis also suggests is that the sizes of other lexical-selection effects (e.g., the effects of semantic variables) in naming tasks should be modulated by word frequency. That is, according to Monsell and colleagues, the naming of higher frequency words would be mainly controlled by the lexical route because that route will produce a phonological code quite rapidly for those words. Consequently, any semantic effects for higher frequency words (regular or irregular) should be similar in naming and lexical decision tasks. On the other hand, because the contribution of the nonlexical route to the naming of lower frequency regular words is substantial, any semantic effects for these words would be diluted and, thus, semantic effect sizes should be smaller in naming than in lexical decision.

The purpose of the present studies was to provide another evaluation of whether semantic variables really do affect the lexical-selection process and to evaluate those predictions made by the dual-route framework. In particular, we examined the effects of polysemy, as a function of word frequency, using a very regular orthography (Japanese katakana) in a lexical decision task (Experiment 1) and in a naming task (Experiment 2).

Because each katakana character corresponds to a single syllable (mora), katakana is considered to be a shallow orthography which has virtually no spelling-to-sound irregularities. Thus, in terms of the dual-route model, the nonlexical route would be able to produce correct phonological codes for all these words. As noted, according to Balota and Chumbley's arguments, if both word frequency and polysemy effects are due to lexical selection, both of these effects should not vary in size across tasks in which lexical selection is fully involved. Our use of a completely regular orthography, however, changes those predictions. First of all, with respect to word frequency effects, the cross-task equivalence would not be expected because, as noted, a dual-route analysis suggests that low frequency words often do not require lexical selection. Thus, the expectation is that there would be a smaller frequency effect in naming than in lexical decision. More importantly, with respect to polysemy effects, the cross-task equivalence should hold for high frequency words because, for these words, the lexical route generates phonological codes much faster than the nonlexical route, meaning that the contribution of the nonlexical route to performance in the naming task would be minimal. For low frequency katakana words, however, the expectation would be that the polysemy effect should be smaller in naming than in lexical decision because of the large contribution of the nonlexical route in naming.

Experiment 1

Participants. Twenty-four undergraduate students from Chukyo University participated in this experiment for course credit. All were native Japanese speakers and had normal or corrected-to-normal vision.

Stimuli. One hundred and eighty katakana words, all between two and four characters in length, were selected from the 'table of loan words listed in order of their frequencies' in National Language Research Institute (1971). Half of these words were of high frequency, with frequency counts greater than 10 per three million. The remainder of the stimuli were low frequency words, with frequency counts of less than 10 per three million.

Experiential familiarity ratings were obtained to further quantify the normative frequency differences between the high and low frequency words. A separate group of twenty-eight participants was asked to rate the familiarity of each of the 180 words. The 180 words were randomly ordered and listed in a questionnaire, and each word was accompanied by a seven-point scale with labels ranging from 'very unfamiliar' (1) to 'very familiar' (7). Participants were asked to rate their experiential familiarity with the word by circling the appropriate number on the scale.

A different group of twenty-eight participants was asked to rate the number of meanings associated with these words. The procedure used for collecting these ratings was identical to that used by Kellas et al. (1988) and Hino and Lupker (1996). The 180 katakana words were randomly ordered and listed in a questionnaire together with 45 katakana nonwords. Each item was accompanied by a three-point scale ranging from 0 to 2. The participants were asked to decide whether the item had 'no meaning' (0), 'one meaning' (1), or 'more than one meaning' (2), by circling the appropriate number on the scale.

Based on the number-of-meanings ratings, 32 polysemous and 32 nonpolysemous words were selected for use in this experiment. Each of the 32 polysemous words had a mean number-of-meanings rating of 1.5 or greater. The ratings for the 32 nonpolysemous words were all less than 1.25. Half of the polysemous and nonpolysemous words were high frequency words, and the remainder were low frequency words. Thus, four word conditions were created by crossing two factors, Polysemy (polysemous vs nonpolysemous) and Frequency (high vs low). Word frequency and familiarity ratings were matched closely between the two high frequency word conditions and between the two low frequency word conditions. Word length, the number of syllables (moras), and orthographic neighborhood size (Coltheart, Davelaar, Jonasson & Besner 1977)[1] were also matched as closely as possible across the four conditions.

In order to assure that the four word conditions had been created properly, 2 (Polysemy) $\times$ 2 (Frequency) analyses of variance (ANOVAs) were conducted on the relevant measures: word frequency, familiarity ratings, the number-of-meanings ratings, word length, syllabic length, and orthographic neighborhood size. For word frequency, the main effect of Frequency was the only significant effect [$F(1, 60) = 30.22$; $MSe = 666.12$; $p < 0.001$]. Neither the main effect of Polysemy [$F(1, 60) = 0.11$, $MSe = 666.12$] nor the interaction between Frequency and Polysemy [$F(1, 60) = 0.13$, $MSe = 666.12$] was significant. Similar results were observed for the familiarity ratings [Frequency: $F(1, 60) = 6.33$; $MSe = 0.547$; $p < 0.025$; Polysemy: $F(1, 60) = 0.00$; $MSe = 0.547$; Interaction: $F(1, 60) = 0.08$; $MSe = 0.547$]. For the number-of-meanings ratings, the main effect of Polysemy was significant [$F(1, 60) = 860.36$; $MSe = 0.01$, $p < 0.001$], however, neither the main effect of Frequency [$F(1, 60) = 1.29$; $MSe = 0.01$] and the interaction between Frequency and Polysemy [$F(1, 60) = 0.12$, $MSe = 0.01$] was significant. No significant effects were detected in the analyses of word length, syllabic length, and orthographic neighborhood size (all $Fs < 0.08$).

Table 1. Mean word frequency, word length, syllabic length, orthographic neighborhood size (ONS), experiential familiarity rating (FAM), and number-of-meanings rating (NOM) for the word stimuli used in Experiments 1, 2 and 3

Condition Frequency/Polysemy	Word frequency	Word length	Syllabic length	N ONS	FAM	NOM
Low/Polysemous	3.00	3.25	3.25	3.88	4.44	1.74
Low/Nonpolysemous	3.25	3.19	3.19	3.56	4.37	1.05
High/Polysemous	40.81	3.19	3.19	3.69	4.85	1.77
High/Nonpolysemous	36.38	3.19	3.19	3.50	4.89	1.07

Note: The Mean NOM Rating for the 45 nonwords was 0.018.

The 64 katakana words are listed in the Appendix. The statistical characteristics of these words are given in Table 1.

In addition to the 64 katakana words, 16 filler katakana words and 80 katakana nonwords were also included in the stimulus list. The katakana nonwords were created by replacing one katakana character from actual katakana words. The string lengths and syllabic lengths for the katakana nonwords were matched with those for the 80 (64 experimental + 16 filler) katakana words. The mean string length and syllabic length were both 3.2, ranging from 2 to 4.

Procedure. Participants were tested individually in a normally-lit room. Participants were asked to make word/nonword discriminations to stimuli appearing on a video monitor (NEC, PC–TV455) by pressing either the 'word' or 'nonword' key on the computer keyboard. The two keys which flank the space-bar were used as the 'word' and 'nonword' keys ('XFER' and 'NFER' keys on the NEC Japanese keyboard). Participants were encouraged to respond as quickly and as accurately as possible. Lexical decision latencies and errors were automatically recorded by the computer (NEC, PC–9801FA).

Each trial was initiated with a 50 msec 400 Hz beep signal. Following the beep, a fixation point appeared at the center of the video monitor. One second after the onset of the fixation point, a stimulus was presented above it. The fixation point and the stimulus were presented in white on a black background. Participants were seated in front of the video monitor at a distance of about 50 cm and were asked to respond to the stimulus by pressing either the word or nonword key on the keyboard. The 'word' response was made using the participant's dominant hand. The participant's response terminated the presentation of the stimulus and the fixation point.

Sixteen practice trials (involving stimuli not used in the experiment proper) were given prior to the 160 experimental trials. During the practice

Table 2. Mean lexical decision latencies in milliseconds and error rates in percent in Experiment 1

Polysemy	Word frequency				RT difference
	Low		High		
Polysemous	573	(3.65)	538	(0.52)	+35
Nonpolysemous	598	(11.20)	567	(5.99)	+31
RT difference	+25		+29		

Note: Error rates appear in parentheses. Mean lexical decision latency and error rate for nonwords were 662 ms and 7.55% respectively.

trials, participants were informed about their lexical decision latency and accuracy after each trial. No feedback was given during the experimental trials. The order of stimulus presentation for the experimental trials was randomized separately for each participant. The intertrial interval was two seconds.

Results

Lexical decision latencies of less than 250 msec or greater than 1600 msec were classified as errors and excluded from the latency analyses. A total of 11 data points (0.29%) was excluded in this fashion. Mean lexical decision latencies for correct responses and mean error rates (based on the 64 experimental word trials) were calculated across individuals and across items and these means were submitted to separate subjects' and items' ANOVAs, respectively. The mean lexical decision latencies and error rates from the subjects' analysis are listed in Table 2.

In the analyses of lexical decision latencies, the main effect of Frequency was significant both in the subjects' and items' analyses [$F_s(1, 23) = 28.16$; MSe = 910.25; $p < 0.001$; $F_i(1, 60) = 6.63$; MSe = 2916.46; $p < 0.025$]. Response latencies to high frequency words were an average of 33 msec faster than response latencies to low frequency words. The main effect of Polysemy was also significant in both analyses [$F_s(1, 23) = 54.55$; MSe = 313.41; $p < 0.001$; $F_i(1, 60) = 5.05$; MSe = 2916.46; $p < 0.05$], as response latencies to polysemous words were an average of 27 msec faster than response latencies to nonpolysemous words. The interaction between Polysemy and Frequency was not significant [$F_s(1, 23) = 0.19$; MSe = 851.12; $F_i = 0.07$, MSe = 2916.46].

In the analyses of error rates, the main effect of Frequency was significant in both analyses [$F_s(1, 23) = 14.15$; MSe = 29.44; $p < 0.001$; $F_i(1, 60) = 7.45$; MSe = 37.29; $p < 0.001$], reflecting the fact that responses were more accurate to high frequency words than to low frequency words. The main effect of Polysemy was also significant in both analyses [$F_s(1, 23) = 54.66$; MSe = 18.61; $p < 0.001$; $F_i(1, 60) = 18.18$; MSe = 37.29; $p < 0.001$], as responses to polysemous words were more accurate than responses to nonpolysemous words. The interaction between Polysemy and Frequency was not significant [$F_s(1, 23) = 1.84$; MSe = 14.15; $p > 0.10$; $F_i(1, 60) = 0.46$; MSe = 37.29; $p > 0.10$].

Discussion

Significant polysemy and frequency effects were obtained for both lexical decision latencies and error rates in the subjects' and in the items' analyses. Thus, both of these variables clearly affect lexical decisions for katakana words. In addition, the lack of an interaction between polysemy and frequency suggests that there is an additive relation between these two variables. That is, polysemy appears to affect high and low frequency words to the same extent.

The lack of the interaction between Polysemy and Frequency is consistent with the results of Hino and Lupker (1996) and Rubenstein et al. (1970). On the other hand, Jastrzembski (1981), who also used a lexical decision task, reported that polysemy effects were larger for low frequency words than for high frequency words. As noted by Gernsbacher (1984), however, Jastrzembski (1981) did not equate his polysemous and nonpolysemous words on experiential familiarity. Because a familiarity difference would produce a larger effect on lexical decision latencies for low frequency words than for high frequency words, it is quite possible that Jastrezembski's (1981) results were due to a lack of control of experiential familiarity.

The additive relationship between Polysemy and Frequency in the present experiment, as well as those in Hino and Lupker (1996) and Rubenstein et al. (1970), would seem to be problematic for the models of Balota et al. (1991) and Jastrzembski (1981). That is, if polysemy and word frequency both affect the lexical-selection process, as these models claim, one would have expected an interaction between these factors in a task that is assumed to require lexical selection, such as lexical decision. Nonetheless, a lexical-selection account of these two effects can be maintained by assuming either that (a) there are separate sub-processes that are independently responsible for the two effects (as suggested by Rubenstein et al. 1970), or (b) even though both factors affected the lexical-selection process, just by chance, they happened to do so in an additive fashion.

Experiment 2

The purpose of Experiment 2 was to provide a further test of the lexical-selection account by examining its predictions in a naming task. As Balota and Chumbley (1984) suggest, if a naming task also required completion of lexical selection, both frequency and polysemy effects should be identical to those in the lexical decision task. Based on the earlier discussion about the nature of the naming task, however, we would instead expect that frequency effects for katakana words would be smaller in the naming task than in the lexical decision task due to the contribution of the nonlexical route. This is because, in essence, low frequency words gain considerably from the use of the nonlexical route, whereas high frequency words are processed so rapidly on the lexical route that the nonlexical route contributes little to their processing.

More importantly, the additive relationship between Frequency and Polysemy in Experiment 1 allows us to make a clear prediction with respect to the polysemy effects that should be observed in Experiment 2. Because the nonlexical route plays a very small role in naming high frequency words, the polysemy effect for high frequency words should be very similar to that observed in Experiment 1. On the other hand, because the nonlexical route plays a large role in naming low frequency words, one would expect a much smaller polysemy effect in Experiment 2 than in Experiment 1. The result should be an interactive relationship between Polysemy and Frequency in Experiment 2, with the polysemy effect being smaller for low frequency words.

Participants. Twenty-four undergraduate students from Chukyo University participated in this experiment for course credit. All were native Japanese speakers and had normal or corrected-to-normal vision. None had participated in Experiment 1.

Stimuli. The stimuli were the 80 (64 experimental + 16 filler) katakana words used in Experiment 1.

Procedure. Word stimuli were presented in the same manner as in Experiment 1. Participants were asked to name words aloud as quickly and as accurately as possible. Participants’ vocal responses were registered by a microphone connected to a voice key interfaced to the computer. The participants’ vocal response terminated the stimulus presentation. Naming latencies were measured from the onset of a stimulus to the onset of a vocal response. An experimenter located in a different room monitored the participants’ responses through audio/video monitors and recorded errors during the exper-

Table 3. Mean naming latencies in milliseconds and error rates in percent in Experiment 2

	Word frequency				
Polysemy	Low		High		RT difference
Polysemous	487	(0.80)	484	(1.30)	+3
Nonpolysemous	501	(1.32)	503	(1.04)	−2
RT difference	+14		+19		

Note: Error rates are in parentheses.

imental trials. In all other respects the procedure was identical to that of Experiment 1.

Results

A trial was considered a mechanical error if the participant's vocal response failed to trigger the voice key, or some extraneous sound triggered the voice key. Mechanical errors were excluded from the data analyses. There were 17 (0.89%) mechanical errors in total. In addition, naming latencies of less than 250 msec or more than 1000 msec were classified as errors and excluded from the analyses of naming latencies. Four additional data points (0.21%) were excluded in this fashion. Mean naming latencies for correct responses and mean error rates (based on the 64 experimental word trials) were calculated across individuals and across items and these means were submitted to separate subjects' and items' ANOVAs, respectively. The mean naming latencies and error rates from the subjects' analysis are listed in Table 3.

In the analyses of naming latencies, the main effect of Polysemy was significant in both the subjects' [$F_s(1, 23) = 28.55$; MSe = 225.80; $p < 0.001$], and items' analyses [$F_i(1, 60) = 4.53$; MSe = 1054.44; $p < 0.05$]. Naming latencies for polysemous words were 17 msec faster than those for nonpolysemous words. The main effect of Frequency was not significant [$F_s(1, 23) = 0.09$; MSe = 315.55; $F_i(1, 60) = 0.01$; MSe = 1054.44], nor was the interaction between Polysemy and Frequency [$F_s(1, 23) = 0.86$; MSe = 141.42; $F_i(1, 60) = 0.07$; MSe = 1054.44]. No effects were significant in the analysis of error rates (all F's < 0.60).

Combined analyses (with the lexical decision data from Experiment 1)

To compare the magnitude of the polysemy and frequency effects between the lexical decision and naming tasks, combined analyses with the experimental word trial data from Experiment 1 were conducted. Subject and item means of response latencies and error rates were separately submitted to 2 (Task

Type: lexical decision task vs naming task) × 2 (Frequency: high vs low) × 2 (Polysemy: polysemous vs nonpolysemous) ANOVAs. In the subjects' analyses, Frequency and Polysemy were treated as within-subject factors, and Task Type was treated as a between-subject factor. In the items' analyses, Frequency and Polysemy were between-item factors, and Task Type was a within-item factor.

In the analyses of response latencies, the main effects of Task Type [$F_s(1, 46) = 13.33$; MSe = 20413.71; $p < 0.001$; F_i $(1, 60) = 181.87$; MSe = 1095.83; $p < 0.001$] and Polysemy [$F_s(1, 46) = 82.60$; MSe = 269.61; $p < 0.001$; $F_i(1, 60) = 6.31$; MSe = 2875.07; $p < 0.025$] were significant. The main effect of Frequency was significant in the subjects' analysis [$F_s(1, 46) = 22.29$; MSe = 612.90; $p < 0.001$] and marginally significant in the items' analysis [$F_i(1, 60) = 3.53$; MSe = 2875.07; $p < 0.07$].

The interaction between Frequency and Task Type was significant in both analyses [$F_s(1, 46) = 19.58$; MSe = 612.90; $p < 0.001$; $F_i(1, 60) = 8.40$; MSe = 1095.83; $p < 0.001$], reflecting the fact that significant frequency effects were observed only in the lexical decision task. The interaction between Polysemy and Task Type was significant in the subjects' analysis [$F_s(1, 46) = 4.72$; MSe = 269.61; $p < 0.05$], although not in the items' analysis [$F_i(1, 60) = 1.25$; MSe = 1095.83; $p > 0.10$]. Overall, the pattern of data suggests that polysemy effects are smaller in the naming task than in the lexical decision task. The interaction between Frequency and Polysemy [$F_s(1, 46) = 0.57$; MSe = 496.27; $F_i(1, 60) = 0.09$; MSe = 2875.07] was not significant, nor was the three-way interaction between Frequency, Polysemy, and Task Type [$F_s(1, 46) = 0.00$; MSe = 496.27; $F_i(1, 60) = 0.01$; MSe = 1095.83].

In the analyses of error rates, the main effects of Task Type [$F_s(1, 46) = 21.58$; MSe = 39.67; $p < 0.001$; $F_i(1, 60) = 30.80$; MSe = 18.56; $p < 0.001$], Polysemy [$F_s(1, 46) = 45.26$; MSe = 11.69; $p < 0.001$; $F_i(1, 60) = 15.01$; Mse = 23.49; $p < 0.001$], and Frequency [$F_s(1, 46) = 10.98$; MSe = 17.96; $p < 0.001$; $F_i(1, 60) = 5.58$; MSe = 23.49; $p < 0.025$] were significant in both analyses.

The interactions between Frequency and Task Type [$F_s(1, 46) = 12.24$; MSe = 17.96; $p < 0.001$; $F_i(1, 60) = 7.92$; MSe = 18.56; $p < 0.001$] and between Polysemy and Task Type [$F_s(1, 46) = 41.78$; MSe = 11.69; $p < 0.001$; $F_i(1, 60) = 17.54$; MSe = 18.56; $p < 0.001$] were both significant. These effects mirror the effects in the response latencies analyses. The interaction between Polysemy and Frequency was not significant [$F_s(1, 46) = 2.22$; MSe = 11.09; $p > 0.10$; $F_i(1, 60) = 0.70$, MSe = 23.49; $p > 0.10$], nor was the three-way interaction between Polysemy, Frequency, and Task Type [$F_s(1, 46) = 0.46$, MSe = 11.09; $p > 0.10$; $F_i(1, 60) = 0.18$; MSe = 18.56; $p > 0.10$].

Discussion

There are a number of results of note in Experiment 2. First, significant polysemy effects were observed in both the subjects' and items' analyses. Thus, polysemy clearly is an important variable in naming as well as in lexical decision. If one maintains a lexical-selection account of polysemy effects, this result implies that the lexical route was significantly involved in naming the words used in Experiment 2. Second, there was no word frequency effect, which led to the significant Frequency by Task Type interaction in the combined analyses. In dual-route terms, this implies that the nonlexical route was often the dominant route for the low frequency words in the naming task, allowing them to be named as fast as high frequency words. Third, as reflected by the significant Polysemy by Task Type interaction in the combined analyses of response latencies, polysemy effects were smaller in the naming task than in the lexical decision task. This result is consistent with the general idea that the nonlexical route is used on some proportion of the trials in the naming task. However, this result must be considered within the context of the final, and most important, result which is that there was no hint that the Polysemy by Task Type interaction was modulated by Frequency. Looked at another way, it was quite clear that Polysemy did not interact with Frequency to any larger degree in naming than in the lexical decision. In both tasks, the relationship was strictly an additive one. This result is clearly in opposition to the predictions that were made based on the lexical-selection/dual-route account.

The existence of a polysemy effect that is additive with frequency in a naming task is consistent with data reported by Fera et al. (1992). In contrast, Hino and Lupker (1996) reported that polysemy effects were limited to low frequency words in their naming experiment. The explanation for this apparent discrepancy can be found in the definition of 'high frequency' words used by the different investigators. In Hino and Lupker's experiments, the high frequency words all had normative frequencies greater than 80 per million, and the low frequency words all had normative frequencies less than 30 per million, according to the Kucera and Francis (1967) word frequency norms. In contrast, in the present study, high frequency words were defined as any that surpassed a normative frequency cutoff of 10 per three million (National Language Research Institute 1971). This somewhat low cutoff had to be used because there are almost no truly high frequency polysemous katakana words. Thus, our frequency manipulation was substantially weaker than Hino and Lupker's. The same was true for Fera et al.'s materials. Their frequency manipulation was based on a high frequency cutoff of 30 per million according to the Kucera and Francis norms. Thus, the significant polysemy effect for high frequency words in the present study and in Fera et al.'s study is probably due to the fact that the high frequency words were much lower in frequency than Hino and Lupker's high frequency words.

The weakness of our frequency manipulation also explains why we did not observe a significant frequency effect in Experiment 2. As noted, in general, frequency effects for words with regular spelling-to-sound correspondences are typically not very large in naming tasks, even when one is evaluating the difference between very high and low frequency words. For example, Frost, Katz, and Bentin (1987) examined the effects of word frequency using lexical decision and naming tasks for Hebrew, English, and Serbo-Croatian, and found that although the frequency effects were consistent in the three languages in lexical decision tasks, there was a noticeable trend for frequency effects to decrease for shallower orthographies. Monsell (1991) also pointed out that even in the English language literature, there is a noticeable trend that frequency effects are small for regular words in naming tasks, a result that has been replicated many times over the past few years (e.g., Brown et al. 1994; Paap & Noel 1991). (Note also that in all these instances, the frequency manipulation used was much stronger than the one we used.) Thus, it is likely that the lack of a frequency effect in Experiment 2 was due to the facts that Japanese katakana words possess virtually no character-to-sound irregularities and that our frequency manipulation was weak.

The complete lack of a frequency effect in the present experiment would be consistent with Morton and Sasanuma's (1984) claim that Japanese katakana strings are named only via the nonlexical route. This claim, however, seems unlikely to be true, because both Besner and Hildebrandt (1987) and Hino and Lupker (in press) have reported significant frequency/familiarity effects for katakana-written words in naming tasks. In particular, using a more substantial frequency manipulation (derived from word frequency norms that are similar to those used here, National Language Research Institute 1970),[2] Hino and Lupker reported a significant frequency effect for katakana words. Thus, it is unlikely that katakana words are all named only via a nonlexical route. Based on the present results, however, it does appear that lexical influences (and, hence, frequency effects) in naming tasks start to be evident only when the katakana words are quite high in frequency.

Experiment 3

The most important aspect of the results of Experiments 1 and 2 is the lack of a Frequency by Polysemy interaction in both lexical decision and naming tasks. This finding is quite inconsistent with the explanation of polysemy effects offered by the lexical-selection/dual-route account (e.g., Balota et al.

1991; Jastrzembski 1981; Rubenstein et al. 1970, 1971). Before considering alternative accounts, however, it is necessary to determine whether the present results are contaminated by any articulation onset differences among the word conditions. That is, because none of the word conditions were matched on first phonemes, it is possible that such differences could have contributed to or even caused the effects that we have attributed to either Frequency or Polysemy in the naming task.

To determine if these results were contaminated by articulation onset differences, in Experiment 3, a delayed naming task was employed with the identical words used in Experiments 1 and 2. Although significant frequency effects have been reported by some investigators using the delayed-naming task (e.g., Balota & Chumbley 1985; Theios & Muise 1977), given the lack of a frequency effect in Experiment 2, the expectation is that there should be no significant frequency effect in Experiment 3. The main question, however, is whether the polysemy effect will also disappear in this task. If so, this would indicate that the effect observed in the standard naming task is not due to articulation onset differences.

Participants. Twenty-four undergraduate students from Chukyo University participated in this experiment for course credit. All were native Japanese speakers and had normal or corrected-to-normal vision. None had participated in any of the previous experiments.

Stimuli. The stimuli were the same as used in Experiment 2.

Procedure. Participants were asked to name a word aloud as quickly and as accurately as possible as soon as the word was surrounded by brackets ([ ]). The brackets were presented 1500 msec after the onset of the word stimulus. The participant’s vocal response terminated the stimulus presentation and the naming latency from the onset of the brackets to the onset of the participant’s response was recorded. In all other ways, the procedure was identical to that of Experiment 2.

Results

A trial was considered a mechanical error if the participant’s vocal response failed to trigger the voice key, or an extraneous sound triggered the voice key. Mechanical errors were excluded from the data analyses. There were 11 (0.57%) mechanical errors in total. In addition, naming latencies of less than 50 msec or more than 1000 msec were classified as errors and excluded from the analyses of naming latencies. Three additional data points (0.16%) were excluded in this fashion. Mean delayed-naming latencies for correct

Table 4. Mean delayed naming latencies in milliseconds and error rates in percent in Experiment 3

Polysemy	Word frequency				RT difference
	Low		High		
Polysemous	305	(0.52)	310	(1.04)	−5
Nonpolysemous	309	(0.78)	311	(0.52)	−2
RT difference	+4		–1		

Note: Error rates are in parentheses.

responses and mean error rates (based on the 64 experimental word trials) were calculated across individuals and across items and these means were submitted to separate subjects' and items' ANOVA, respectively. The mean delayed-naming latencies and error rates from the subjects' analysis are listed in Table 4.

In the analyses of naming latencies, neither of the main effects nor the interaction approached significance in either analysis (all F's < 1.91). The same was true in the analyses of error rates (all F's < 0.95).

Discussion

Since neither Polysemy nor Frequency affected delayed naming performance, it is unlikely that the results of Experiment 2 were contaminated by articulation onset differences among word conditions.

General discussion

In the present experiments, we examined the effects of word frequency and polysemy in lexical decision and naming tasks using Japanese katakana words in order to evaluate lexical-selection accounts of these effects. As noted, Balota and Chumbley (1984) suggest that if these effects are due entirely to the lexical-selection process, then the effect sizes should not vary across different word recognition tasks if those tasks fully involve the lexical-selection process. Paap et al. (1987) and Monsell and colleagues (Monsell 1991; Monsell et al. 1989) have suggested, however, that the effect sizes should be smaller in a naming task than in a lexical decision task (at least for words with consistent spelling-to-sound correspondences), because non-lexical phonological coding would dilute lexical-selection effects in a naming task. Since each katakana character corresponds to a single syllable (mora), katakana words do have consistent character-to-sound relationships. Thus, if word frequency and polysemy effects are both due to the lexical-selection process, the sizes of these effects were expected to be smaller in a naming task than in a lexical decision task. This is, in fact, the pattern that we observed.

This argument, however, makes an additional prediction. As stated, the reason that there is a smaller frequency effect in the naming task is because the nonlexical route contributes more to the naming of low frequency words than to the naming of high frequency words. As such, if the polysemy effect were due to the lexical-selection process, its size in a naming task should be modulated by word frequency, with there being a smaller effect for low frequency words than for high frequency words. This is not the pattern that we observed. Instead, we found that the polysemy effects for high and low frequency words were equivalent in size in both naming and lexical decision tasks.

Alternative accounts

Are polysemy effects due to the use of a 'semantic route'?

One possibility for explaining the present results would be to maintain the assumption that lexical selection was frequency-sensitive but to drop the assumption that lexical selection is sensitive to polysemy. For example, in addition to the lexical and nonlexical routes, some researchers have recently suggested that a third route, one based on semantically-mediated phonological coding (the 'semantic route') should be added to the dual-route framework (e.g., Besner in press; Coltheart et al. 1993). As with the lexical route, the semantic route also requires lexical selection. However, it differs from the lexical route in terms of what happens after the appropriate lexical unit has been selected. According to this idea, once a lexical unit has been selected, a semantic code is activated, with the phonological code then being retrieved via this activated semantic code. In this way, semantic effects in naming tasks can, in theory, be explained without postulating that lexical selection itself is influenced by semantics. The question then is whether the present results could be explained in terms of the activity of this route.

In order to explain the results of Experiment 2 in terms of a semantic route, one must start with the assumption that the reason there are polysemy effects is because on some proportion of the trials, the semantic route provides the phonological code before either of the other routes do. In particular, given the equal sizes of polysemy effects for low and high frequency words, one would have to assume that this route provided the correct phonological code more rapidly than the other routes do just as often for high frequency words as for low frequency words. The lack of a frequency effect could, as before, be explained in terms of the tradeoff between the other two routes for low and high frequency words. That is, on most of the remainder of the trials for low frequency words, the nonlexical route would be presumed to provide the correct code. For the high frequency words, the nonlexical route would play a smaller role, with a larger proportion of the trials for these stimuli involving the lexical route. Thus, in general, it appears that this type of model would explain the naming data.

Unfortunately, this type of theorizing does run into a few problems. For example, Strain et al. (1995) have recently reported that naming latencies were significantly faster for high-imageability words than for low-imageability words, but only if the words were low frequency irregular words. These results seem to suggest that the semantic route is actually quite slow in that it can affect naming latencies only when both of the other routes are inefficient. As such, it seems unlikely that it could have been fast enough in the present experiment to have had such a large influence, especially for high frequency words.

To address this problem, one could make the ad hoc assumption that the impact of imageability on word naming is weaker than that of polysemy. One could assume, for example, that the semantic route did contribute (to some extent) to the naming of high frequency words in both Strain et al.'s experiment and the present Experiment 2, but that the impact of imageability is not large enough to manifest itself in an observable way unless that route plays a major role. Thus, observable imageability effects may occur only for low frequency irregular words because only for those words would the semantic route be the most effective route on a reasonably large proportion of the trials. In contrast, if the effects of polysemy are assumed to be stronger, then it would follow that even high frequency words, which would involve the semantic route on only a small proportion of trials, could still show a polysemy effect.

What is a larger problem for this model is how it could then account for the results in the lexical decision task. That is, if 'word' decisions are essentially made on the basis of selecting a single lexical unit in the lexical decision task (e.g., Coltheart 1978; Coltheart et al. 1993), then the activity of the semantic route, which comes into play only after lexical selection, would not be expected to influence this process. If so, and if the previous assumptions are correct, there would be no reason to expect polysemy effects (or any other semantic effects) in single-word lexical decision tasks. Thus, although it might be possible that further assumptions could be added to this account to give the semantic route a role in lexical decision making, it is quite clear that this type of model does have a somewhat difficult time accounting for the pattern of results reported here.

An alternative locus of word frequency effects

A second possibility for explaining the present results would be to maintain the assumption that the lexical-selection process is sensitive to polysemy but to drop the assumption that it is frequency-sensitive. For example, given that frequency effects were limited to the lexical decision task but polysemy effects were observed in both lexical decision and naming tasks, one could argue that, although polysemy effects do arise during the common lexical-selection process, word frequency effects are limited to the decision-making process specific to the lexical decision task (e.g., Balota & Chumbley 1984; Besner 1983; Besner & McCann 1987; Seidenberg & McClelland 1989).

Although this account might seem appealing on the surface, it would immediately run into a couple of problems. First, it would predict that frequency and polysemy would never interact since they do not affect the same process. This prediction is falsified by Hino and Lupker's (1996) results showing that these two factors do interact in a naming task when the high frequency words truly are high frequency. In particular, although there was a polysemy effect for the low frequency words in Hino and Lupker's experiments, the effect vanished for the high frequency words. The second problem is that this account would predict that there would never be frequency effects in naming tasks in the first place. As noted, although such effects are not large when the words have regular spelling-to-sound correspondences, frequency effects most certainly do exist in naming, even for katakana words (Hino & Lupker in press). Thus, it does not appear that simply attributing frequency effects in lexical decision to the decision-making process will allow us to produce a viable account of the processes under investigation. Rather, the account must incorporate some way of explaining both frequency effects in naming and why those effects would interact with polysemy.

A viable way of accounting for the present data does, however, derive from assuming a frequency-sensitive decision-making process in the lexical decision task. Recently, in fact, a number of researchers have argued that there must be alternative loci for frequency effects not only in lexical decision but in all tasks (e.g., Balota & Chumbley 1984; Balota & Chumbley 1985; Hinto & Lupker 1996, in press; Seidenberg & McClelland 1989). For example, Hino and Lupker (in press) have recently argued that even if the dual-route assumptions are added to the lexical-selection account, this account does not provide an adequate explanation of word frequency effects for Japanese kanji and katakana words. Their reasoning is as follows.

As noted, the character-to-sound relationships are consistent for katakana words. For kanji words, however, the character-to-sound relationships are not consistent because each kanji generally possesses on-reading and kun-reading pronunciations. Given the unpredictability of character-to-sound relationships for kanji words, a lexical route would presumably be needed to name them in all cases (see Wydell, Butterworth & Patterson 1995). Thus, if word frequency effects are due to the lexical-selection process, word frequency effects for kanji words would be expected to be the same in lexical decision and naming. On the other hand, as noted earlier, word frequency effects for katakana words should be smaller in naming than in lexical decision. Further, if word frequencies are well equated across script type, the sizes of the frequency effects in lexical decision should be the same for the two scripts. Hino and Lupker's (in press) results were quite consistent with these predictions. That is, frequency effects for kanji words were identical in the two tasks whereas frequency effects for katakana words were larger in lexical decision than in naming (as observed in the present experiments). In addition, the frequency effects for the two script types in lexical decision were equal.

The problems for the lexical-selection account arose when the same kanji and katakana words were used in a go/no-go naming task, in which participants were asked to name a stimulus aloud only if it was a word. Since lexical selection (and whatever decision-making operations are involved) is assumed to be completed prior to the selection of a phonological code in this task, phonological codes should be readily available from the lexical route (assuming a dual-route framework), in which case the nonlexical route should play no role in this task. Thus, if word frequency effects are due to the lexical-selection process, this task should produce frequency effects identical to those in the lexical decision task. Further, and more importantly, the additive relationship between word frequency and script type (kanji vs katakana) observed in lexical decision should also arise in go/no-go naming. Contrary to expectations, however, frequency effects were significantly larger for kanji words than for katakana words and the sizes of the frequency effects were larger in the go/no-go naming task than in the lexical decision task.

Even with the dual-route assumptions, then, these data could not be accounted for by assuming a frequency-sensitive lexical-selection process. As a result, Hino and Lupker (in press) suggested instead that frequency effects in lexical decision and naming tasks are due to the processes specific to each task. Recent research has, in fact, suggested that there are a number of such processes. For example, as noted above, many researchers (e.g., Balota & Chumbley 1984; Besner 1983; Besner & McCann 1987; Seidenberg & McClelland 1989) have argued that the lexical decision task involves a decision-making process which is carried out based on the orthographic familiarity and/or semantic information derived from the stimuli. Grainger and Jacobs (1996) have even suggested that lexical decisions could be made by monitoring global lexical activity, at least in certain situations. Thus, the basic argument is that lexical decision-making involves a number of task-specific processes in which multiple sources of information such as orthographic familiarity as well as orthographic structure variables (e.g., neighborhood size, the frequency of orthographic neighbors), and semantic variables can all play important roles (e.g., Carr, Posner, Pollatsek & Snyder 1979; Hino & Lupker in press; Posner & Carr 1992). The frequency effect and the additive relationship between frequency and script type would, presumably, be due to these task-specific processes in the lexical decision task.

In contrast to the additive relationship between frequency and script type in lexical decision, Hino and Lupker (in press) observed an interactive relationship between frequency and script type in their naming tasks, both of which require phonological coding in order to produce overt pronunciation responses. Thus, Hino and Lupker suggested that the phonological coding process is frequency-sensitive (even when it is carried out after a lexical unit has been selected) and that the interactive relationship between frequency and script type was due to this phonological coding process. In addition, because the decision-making process and the phonological coding process are assumed to follow in a quasi-sequential order in the go/no-go naming task, the larger frequency effects in go/no-go naming than in lexical decision could also be accounted for.

Hino and Lupker (in press) thus argued that the size differences in frequency effects across lexical decision and naming tasks seem to be better accounted for by assuming task-specific loci of frequency effects. A similar argument for this conclusion was made by Hino and Lupker (1996), based on their analysis of polysemy and word frequency effects in naming, go/no-go naming, and lexical decision tasks in English.

Parallel distributed processing (PDP) account

Given the conclusions that frequency effects are not due to the lexical-selection process and that polysemy does interact with frequency in naming, Hino and Lupker (1996) suggested an account of polysemy and frequency effects based on the parallel distributed processing (PDP) models' framework (e.g., Plaut & McClelland 1993; Plaut, McClelland, Seidenberg & Patterson 1996; Seidenberg & McClelland 1989; Van Orden, Pennington & Stone 1990). Hino and Lupker suggested that polysemy affects both the process of computing orthographic codes (on which the decision-making process is carried out) and the process of computing phonological codes (in order to produce pronunciation responses) independently as a result of feedback activation from semantic units.

Since the polysemous words have multiple meanings, semantic activation would be greater for polysemous words and the feedback activation from semantic units to orthographic or phonological output units would also be greater for polysemous words than for nonpolysemous words. Hino and Lupker, thus, suggested that it is this difference in the amount of semantic feedback activation that produces polysemy effects in lexical decision and naming tasks. Further, since it is unlikely that even a skilled reader has had much practice at generating the type of orthographic codes required for making lexical decisions, the connections between the orthographic input units and the orthographic output units would be relatively weaker. Given the weaker connections, the speed of computing orthographic output codes would be slow enough that the semantic feedback activation could affect both high and low frequency words. Thus, an additive relationship between polysemy and frequency would be expected in the lexical decision task.

On the other hand, phonological coding would be used so often in normal reading situations that the connections between the orthographic input units and the phonological output units would be stronger, especially for high frequency words. As a consequence, phonological codes for high frequency words would typically be generated from the orthographic input codes even before the semantic feedback activation affected processing. In contrast, semantic feedback activation would be much more likely to affect the processing of low frequency words. As such, a polysemy by frequency interaction would be expected in a naming task using truly high frequency words, as was observed by Hino and Lupker (1996).

The question then is, can the present results be accounted for by this type of analysis? Needless to say, the fact that there was an additive relationship between polysemy and frequency in the lexical decision task follows from this account.

In the naming task, on the other hand, the process of computing phonological codes is assumed to be sensitive to word frequency. In addition, the speed of this orthographic-to-phonological computation process is also assumed to be modulated by the spelling-to-sound relationships possessed by similarly-spelled words, especially for low frequency words (e.g., Plaut et al. 1996; Seidenberg 1992; Van Orden et al. 1990). In particular, the phonological computations for low frequency words are assumed to be facilitated when the similarly-spelled words possess consistent spelling-to-sound relationships, while being retarded when the similarly-spelled words possess inconsistent spelling-to-sound relationships.

In katakana, the character-to-sound relationships are quite consistent, meaning that the phonological computations would be fairly rapid for low frequency words. Given the weakness of our frequency manipulation, then, the lack of a frequency effect in the naming task would seem to be easily accounted for within this PDP framework.

More importantly, given the lack of frequency effect in the naming task, the speed of phonological computations for our 'high' and 'low' frequency katakana words would appear to be virtually identical. Therefore, the semantic feedback would affect the phonological computation process similarly for our high and low frequency katakana words. As such, identical polysemy effects for our high and low frequency katakana words would be expected.

Note also that this analysis is quite consistent with Strain et al.'s (1995) finding of an imageability effect only for low frequency irregular words, especially if one does assume that imageability is a weaker semantic variable than polysemy. In fact, Strain et al.'s account is quite similar to the one offered above. Strain et al. assumed that high-imageability words possess richer semantic representations than low-imageability words. Thus, the semantic activation would be greater for high-imageability words than for low-imageability words. As a consequence, the semantic feedback activation would be greater for high-imageability words than for low-imageability words. Thus, the phonological computation would be faster for high-imageability words than for low-imageability words when this computation is affected by the semantic feedback activation.

The effects of this feedback, however, are modulated by the speed of the phonological computation. As noted, the speed of this process is assumed to be influenced by word frequency as well as spelling-to-sound consistency. Thus, an imageability effect would be most likely to occur for low frequency irregular words in the naming task, for which the phonological computation would be the most inefficient and slowest.

The PDP framework, therefore, seems to provide a better account for the present data, as well as Strain et al.'s (1995) data, than accounts in which the lexical-selection process is seen as the locus of frequency and semantic (polysemy and imageability) effects, regardless of whether those accounts are couched within the dual-route framework or not. It should be noted, however, that these types of models are not without their critics (e.g., Besner in press; Besner, Twilley, McCann & Seergobin 1990; Coltheart et al. 1993). In particular, Besner et al. clearly pointed out that Seidenberg and McClelland's (1989) model has a very difficult time explaining lexical decision data. An additional point to note, of course, is that the lexical decision data in the present study (as well as lexical decision data in general) are not well explained by any extant model (for a recent attempt to model this process, see Grainger & Jacobs 1996). Thus, at present, perhaps the best approach would be to acknowledge that each of these frameworks has its respective limitations and, thus, they all need to be developed further in order to provide a better understanding of our reading processes.

Conclusions

In order to evaluate lexical-selection accounts of polysemy effects, the effects of polysemy were examined as a function of word frequency for Japanese katakana words using lexical decision and naming tasks. Since katakana words possess consistent character-to-sound correspondences, it was assumed that the naming of low frequency katakana words is more influenced by sub-word level phonological coding than the naming of high frequency katakana words as postulated by the dual-route model. Thus, if the polysemy effects were due to the lexical-selection process, the effect sizes should be modulated by word frequency in the naming task. In particular, the polysemy effect should be more diluted for low frequency words than for high frequency words due to the influence of the nonlexical phonological coding. Consistent with these predictions, a significant frequency effect was observed in the lexical decision task, and this effect was eliminated in the naming task. Inconsistent with these predictions, however, polysemy effects were identical for high and low frequency words in both tasks, although the overall effect sizes were smaller in the naming task.

We attempted to explain these results based on a lexical-selection account by considering (a) an extension to the dual-route account, in which semantic effects are assumed to be due to a third route, and (b) a framework in which semantic effects are attributed to the lexical-selection process but frequency effects are not. We also attempted to explain our results within a PDP framework, in which semantic effects are attributed to feedback from semantic representations. At least at a general level, both the lexical decision and naming data seem to be best accounted for in terms of the PDP framework.

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Notes

1. Orthographic neighorhood sizes were calculated using a computer-based dictionary with 36,780 word entries (‘sakuin.dat’ in National Language Research Institute 1993).
2. Frequency counts for Japanese katakana words (National Language Research Institute 1971) were taken from frequency counts for Japanese words in National Language Research Institute (1970). Thus, these frequency norms are based on the same data.

Appendix

Polysemous and nonpolysemous katakana words used in Experiments 1, 2 and 3 along with their English translations

High frequency

Polysemous		Nonpolysemous	
タイ	Thailand tie sea bream	ゴム	rubber
ポスト	postbox position	ガス	gas
マッチ	match for ignition match for pairing	ヒント	hint
ベース	base used in baseball base as basis bass	アルミ	aluminum
パンチ	punch to strike punch, a kind of drink a specific form of a permanent wave	パルプ	pulp
ライト	light right	スープ	soup
ケース	case for holding something case, what actually exists or happens	プラン	plan
ボーイ	boy waiter	バイク	motorbike
タイプ	type for classification type for typewriting	ギター	guitar
クラブ	club as an organization club to hit a golf ball	ビール	beer
スター	star in a constellation star, an outstandingly talented performer	リーグ	league
カラー	color collar	スケート	skating
サークル	circle shape circle as an organization	ボーナス	bonus
アルバム	a photo album a record album	コーラス	chorus
レコード	a music record record, registering something permanently	タクシー	taxi
コーナー	corner as an intersection corner as a remote place	デパート	department store

Low frequency

Polysemous		Nonpolysemous	
ピース	peace a name of cigarettes	ランク	rank
マスク	mask, a cover for a face mask for concealing	リール	reel
ソフト	soft softball	ライム	lime (fruit)
ダウン	down a down jacket	ギフト	gift
ロック	rock lock	モラル	morals
アウト	out in baseball outside	ゲリラ	guerrilla
マーク	mark, a sign, token mark for assessment or rating	テニス	tennis
リング	ring, a circular band ring to sound	ロープ	rope
デスク	desk, a table desk, a division of an organization	グレー	gray
チップ	tip, money in appreciation of a service tip as a small piece	ナッツ	nut
バット	bat, a stick used in hitting a ball bat, a flying mammal	ミルク	milk
フライ	fly deep-fry	テント	tent
オーバー	overcoat exaggeration	コンビ	pair
ライター	lighter writer	サンダル	sandals
マスター	master, an owner of a bar master, gaining a thorough understanding	レーサー	racing driver
ブリッジ	bridge, a structure bridge, a card game	カクテル	cocktail

References

Balota, D.A. & Chumbley, J.I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage, *Journal of Experimental Psychology: Human Perception and Performance* 10: 340–357.

Balota, D.A. & Chumbley, J.I. (1985). The locus of word-frequency effects in the pronunciation task: Lexical access and/or production? *Journal of Memory and Language* 24: 89–106.

Balota, D.A., Ferraro, R.F. & Connor, L.T. (1991). On the early influence of meaning in word recognition: A review of the literature. In: P. J. Schwanenflugel (ed.), *The psychology of word meanings* (pp. 187–221). Hillsdale, NJ: Erlbaum.

Balota, D.A. & Paul, S.T. (1996). Summation of activation: Evidence from multiple primes that converage and diverge within semantic memory, *Journal of Experimental Psychology: Learning, Memory, and Cognition* 22: 827–845.

Besner, D. (1983). Basic decoding components in reading: Two dissociable feature extraction processes, *Canadian Journal of Psychology* 37: 429–438.

Besner, D. (in press). Basic processes in reading: Multiple routes in localist and connectionist models. In: R.M. Klein & P.A. McMullen (eds.), *Converging methods for understanding reading and dyslexia*. Cambridge, MA: MIT Press (in press).

Besner, D. & Hildebrandt, N. (1987). Orthographic and phonological codes in the oral reading of Japanese kana, *Journal of Experimental Psychology: Learning, Memory, and Cognition* 13: 335–343.

Besner, D. & McCann, R.S. (1987). Word frequency and pattern distortion in visual word identification and production: An examination of four classes of models. In: M. Coltheart (ed.), *Attention and performance*, Vol. 12 (pp. 201–219). Hillsdale, NJ: Erlbaum.

Besner, D., Twilley, L., McCann, R.S. & Seergobin, K. (1990). On the association between connectionism and data: Are a few words necessary? *Psychological Review*, 97: 432–446.

Borowsky, R. & Masson, M.E.J. (1996). Semantic ambiguity effects in word identification, *Journal of Experiment Psychology: Learning, Memory, and Cognition* 22: 63–85.

Brown, P., Lupker, S.J. & Colombo, L. (1994). Interacting sources of information in word naming: A study of individual differences, *Journal of Experimental Psychology: Human Perception and Performance* 20: 537–554.

Carr, T.H., Posner, M.I., Pollatsek, A. & Snyder, C.R.R. (1979). Orthography and familiarity effects in word processing, *Journal of Experimental Psychology: General* 108: 389–414.

Chumbley, J.I. & Balota, D.A. (1984). A word's meaning affects the decision in lexical decision, *Memory & Cognition* 12: 590–606.

Clark, H.H. (1973). The language-as-fixed-effect fallacy: A critique of language statistics in psychological research, *Journal of Verbal Learning and Verbal Behavior* 12: 335–359.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (ed.), *Strategies of information processing* (pp. 151–216). London: Academic Press.

Coltheart, M., Curtis, B., Atkins, P. & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches, *Psychological Review* 100: 589–608.

Coltheart, M., Davelaar, E., Jonasson, J.T. & Besner, D. (1977). Access to the internal lexicon. In: S. Dornic (ed.), *Attention and performance*, Vol. 6 (pp. 535–555). New York: Academic Press.

Fera, P., Joordens, S., Balota, D.A., Ferraro, F.R. & Besner, D. (1992). *Ambiguity in meaning and phonology: Effects on naming*. Paper presented at the 33rd annual meeting of the Psychonomic Society, St. Louis, MO, November 1992.

Forster, K.I. & Bednall, E.S. (1976). Terminating and exhaustive search in lexical access, *Memory & Cognition* 4: 53–61.

Forster, K.I. & Chambers, S.M. (1973). Lexical access and naming time, *Journal of Verbal Learning and Verbal Behavior* 12: 627–635.

Frost, R., Katz, L. & Bentin, S. (1987). Strategies for visual word recognition and orthographical depth: A multilingual comparison, *Journal of Experimental Psychology: Human Perception and Performance* 13: 104–115.

Gernsbacher, M.A. (1984). Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy, *Journal of Experimental Psychology: General* 113: 256–281.

Grainger, J. & Jacobs, A.M. (1996). Orthographic processing in visual word recognition: A multiple read-out model, *Psychological Review* 103: 518–565.

Hino, Y. & Lupker, S.J. (1996). The effects of polysemy in lexical decision and naming: An alternative to lexical access accounts, *Journal of Experimental Psychology: Human Perception and Performance* 22: 1321–1335.

Hino, Y. & Lupker, S.J. (in press). The effects of word frequency for Japanese kana and kanji words in naming and lexical decision: Can the dual-route model save the lexical-selection account? *Journal of Experimental Psychology: Human Perception and Performance*.

James, C.T. (1975). The role of semantic information in lexical decisions, *Journal of Experimental Psychology: Human Perception and Performance* 1: 130–136.

Jastrzembski, J.E. (1981). Multiple meanings, number of related meanings, frequency of occurrence, and the lexicon, *Cognitive Psychology* 13: 278–305.

Jastrzembski, J.E. & Stanners, R.F. (1975). Multiple word meanings and lexical search speed, *Journal of Verbal Learning and Verbal Behavior* 14: 534–537.

Kellas, G., Ferraro, F.R. & Simpson, G.B. (1988). Lexical ambiguity and the timecourse of attentional allocation in word recognition, *Journal of Experimental Psychology: Human Perception and Performance* 14: 601–609.

Kucera, H. & Francis, W.N. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

McClelland, J.L. & Rumelhart, D.E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings, *Psychological Review* 88: 375–407.

Millis, M.L. & Buttons, S.B. (1989). The effect of polysemy on lexical decision time: Now you see it, now you don't, *Memory & Cognition* 17: 141–147.

Monsell, S. (1991). The nature and locus of word frequency effects in reading. In: D. Besner & G.W. Humphreys (eds.), *Basic processes in reading: Visual word recognition* (pp. 148–197). Hillsdale, NJ: Erlbaum.

Monsell, S., Doyle, M.C. & Haggard, P.N. (1989). Effects of frequency on visual word recognition tasks: Where are they? *Journal of Experimental Psychology: General* 118: 43–71.

Morton, J. (1969). Interaction of information in word recognition, *Psychological Review* 76: 165–178.

Morton, J. & Sasanuma, S. (1984). Lexical access in Japanese. In: L. Henderson (ed.), *Orthographies and reading: Perspectives from cognitive psychology, neuropsychology and linguistics* (pp. 25–42). Hillsdale, NJ: Erlbaum.

National Language Research Institute (1970). *Studies on the vocabulary of modern newspapers, Vol. 1: General descriptions and vocabulary frequency tables*. Tokyo: Shuei Shuppan (in Japanese).

National Language Research Institute (1971). *Studies on the vocabulary of modern newspapers, Vol. 2: Vocabulary tables classified from the lexicological and grammatical point of view*. Tokyo: Shuei Shuppan (in Japanese).

National Language Research Institute (1993). *Bunrui Goi Hyou [Floppy Disk Version]*. Tokyo: Shuei Shuppan (in Japanese).

Paap, K.R., McDonald, J.E., Schvaneveldt, R.W. & Noel, R.W. (1987). Frequency and pronounceability in visually presented naming and lexical decision tasks. In: M. Coltheart (ed.), *Attention and performance* Vol. 12 (pp. 221–243). Hillsdale, NJ: Erlbaum.

Paap, K.R. & Noel, R.W. (1991). Dual-route models of print to sound: Still a good horse race, *Psychological Research* 53: 13–24.

Plaut, D.C. & McClelland, J.L. (1993). Generalization with componential attractors: Word and nonword reading in an attractor network. *Proceedings of the 15th annual conference of the Cognitive Science Society* (pp. 824–829). Hillsdale, NJ: Erlbaum.

Plaut, D.C., McClelland, J.L., Seidenberg, M.S. & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains, *Psychological Review* 103: 56–115.

Posner, M.I. & Carr, T.H. (1992). Lexical access and the brain: Anatomical constraints on cognitive models of word recognition, *American Journal of Psychology* 105: 1–26.

Rubenstein, H., Garfield, L. & Millikan, J.A. (1970). Homographic entries in the internal lexicon, *Journal of Verbal Learning and Verbal Behavior*, 9: 487–494.

Rubenstein, H., Lewis, S.S. & Rubenstein, M.A. (1971). Homographic entries in the internal lexicon: Effects of systematicity and relative frequency of meanings, *Journal of Verbal Learning and Verbal Behavior* 10: 57–62.

Rumelhart, D.E. & McClelland, J.L. (1982). An interactive activation model of context effects in letter perception: Part 2. The contextual enhancement effect and some tests and extensions of the model, *Psychological Review* 89: 60–94.

Seidenberg, M.S. (1992). Beyond orthographic depth in reading: Equitable division of labor. In: R. Frost & L. Katz (eds.), *Orthography, phonology, morphology, and meaning* (pp. 85–118). Amsterdam: North-Holland.

Seidenberg, M.S. & McClelland, J.L. (1989). A distributed, developmental model of word recognition and naming, *Psychological Review* 96: 521–568.

Sternberg, S. (1969). The discovery of processing stages: Extensions of Donders' method, *Acta Psychologica* 30: 276–315.

Strain, E., Patterson, K. & Seidenberg, M.S. (1995). Semantic effects in single-word naming, *Journal of Experimental Psychology: Learning, Memory, and Cognition* 21: 1140–1154.

Theios, J. & Muise, J.G. (1977). The word identification process in reading. In: N.J. Castellan, D.B. Pisoni & G.R. Potts (eds.), *Cognitive theory*, Vol. 2 (pp. 289–321). Hillsdale, NJ: Erlbaum.

Van Orden, G. C., Pennington, B.F. & Stone, G.O. (1990). Word identification in reading and the promise of subsymbolic psycholinguistics, *Psychological Review* 97: 488–522.

Wydell, T.N., Butterworth, B. & Patterson, K. (1995). The inconsistency of consistency effects in reading: The case of Japanese kanji, *Journal of Experiment Psychology: Learning, Memory, and Cognition* 21: 1155–1168.

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