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WHY NAMING TAKES LONGER THAN READING?
THE SPECIAL CASE OF ARABIC NUMBERS

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Short title: Why naming takes longer than reading.

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ABSTRACT

Since the work of Cattell (1885, 1886), it is known that the time to name an object (or a color, a geometric figure, a drawing) is longer than the time to read the name of that object. This result has been confirmed by many authors but the explanation of this phenomenon is still lacking. One good explanation of the reading-naming time difference is the uncertainty factor. Whereas words are associated with a single response name, pictures are linked to several names (the so-called "uncertainty hypothesis"). Another good explanation of this difference is the obligatory retrieval of meaning for pictures but not for words (the so-called "semantic hypothesis"). In the present experiments, subjects had to name Arabic numbers and their corresponding written names. By using Arabic numbers and their corresponding written names, we contrasted these two hypotheses proposed to explain the reading-naming time difference. We exploited the fact that Arabic numbers share a very important attribute with their corresponding written names: their uncertainty is null. Indeed, there is only one way to name 5 and *five*. Our results suggest that the main factor responsible for this reading-naming time difference is the uncertainty factor, since uncertainty being equal, this difference disappeared completely throughout ten (Experiment 1) and five repeated sessions (Experiment 2).

PsychInfo Classification: 2340

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1. Introduction

It is known for more than 100 years that it takes much longer to name pictures of common objects than to read and pronounce the visually presented words that refer to the same objects (Cattell, 1885, 1886). Cattell found a similar difference in naming colors and in reading color names (see also Brown, 1915a; Ligon, 1932; Lund, 1927). Fraisse (1960, 1964, 1968) also showed that a longer time was required to name geometric figures, drawings, and colors than to read the corresponding words. This reading-naming time difference is extremely robust and has been replicated many times as summarized in Table 1.

<Insert Table 1 about here>

Several attempts have been made to account for this difference between naming and reading times but a broadly accepted explanation is still lacking. Fraisse (1969, 1992) reviewed the research literature on the differences between word reading and picture naming (see also the recent review of Theios and Amrhein, 1989). His survey was focused on three major issues: (1) the training effect; (2) the discriminability of stimuli; and (3) the effect of compatibility between stimulus and response (or the number of response alternatives). I will add a fourth important issue concerning the obligatory/optional access of semantic information for pictures and words. Let us examine very briefly the first two issues and in more details the last two issues.

A number of investigations have shown that with extended training the reading-naming time difference cannot be eliminated (Brown 1915a; Fraisse, 1964; Ligon, 1932; Lund, 1927; Theios and Amrhein, 1989). For example, Brown (1915a) found that after 10 days of practice training, colors were still named 131 ms slower than words naming the colors

were read. Therefore, training cannot explain the longer duration of the naming process as compared with the reading process.

It could be argued that the reading-naming time difference is due to the fact that pictures are perceptually less discriminable than are words. Fraisse (1967a, 1969, 1984) showed that this difference cannot be explained by the difference in discriminability which might exist between word and picture stimuli. Therefore, the reading-naming difference is indeed due to the process itself and not to the discriminability of the stimuli (since the difficulty of perceiving the stimulus was equal).

1.1. The Effect of Compatibility Between Stimulus and Response (or The Number of Response Alternatives).

The results reviewed previously show that neither training nor discriminability of the stimulus can explain the reading-naming time difference. Fraisse (1969) outlined a tentative explanation in terms of higher compatibility between written and spoken word, compared to the picture and its name. In particular, he has suggested that the difference between naming and reading times is in fact due to the number of possible responses to the stimulus. In other words, there is a low compatibility between the name and the object it designates. There are always several ways to name a common object, and even in the simplest case there are two possible responses: a categorical and a specific one (Segui and Fraisse, 1968; Rosch, Mervis, Gray, Johnson, and Boyes-Bream, 1976). For instance, to the red color stimulus, it is possible to give at least two responses: "red" and "color". On the other hand, there is an extremely high compatibility between a word and its oral pronunciation: word reading is not dependent on uncertainty (there is only one possible response for the word "RED"). According to Theios and Amrhein (1989, p. 6),

A visual image of something as simple as a geometric form can have a number of possible responses that could be correct in a naming task. For example, the simple outline drawing of a square could be a box, a block, a rectangle, a cube, or a building, as well as a square. A simple outline drawing of a circle could be a disk, a ball, a hoop, a ring, the letter *o*, a wheel, or a lid.

Thus, in producing the name of a pictorial stimulus, the subject has to find and select the name of the object from among a number of other plausible alternatives in the mental lexicon. As Fraisse (1969, p. 102) wrote it:

The conclusion is that the duration of a verbal naming reaction is explained by the nature of the process proper of associating the response and the stimulus, or in more specific terms, by the uncertainty of coding.

According to Johnson, Paivio, and Clark (1996), uncertainty is a robust predictor of picture naming difficulty. An operational definition of uncertainty could be the number of connections between an object and its names (e.g., number of different names for a picture across participants). For instance, the picture of a "tricycle" would have a high level of uncertainty because it is linked to various name representations such as *tricycle*, *bicycle*, *trike*, *bike*, *toy*, and *vehicle*. In fact, pictures with a single dominant responses are named more quickly and accurately than those with multiple possible responses (Butterfield and Butterfield, 1977; Johnson and Clark, 1988; Lachman and Lachman, 1980). Furthermore, uncertainty affects naming independently of the effects of correlated attributes, such as word frequency and rated age of name acquisition (Johnson, 1992; Lachman, 1973; Lachman, Shaffer, and Hennrikus, 1974; Paivio, Clark, Digdon, and Bons, 1989). Words are associated with a single response name, but pictures or colors may be linked to several names. Thus, the greater uncertainty of pictures or colors than words may contribute to the reading-naming difference.

1.2. Obligatory vs. Optional Access to Semantic Information in Picture and Word Naming.

According to Theios and Amrhein (1989), the number of possible responses to the stimulus is only partly responsible for the difference between naming and reading times. As they put it (p. 22):

Pictures and colors are named more slowly than words are read because picture and color naming entails two additional subprocesses that are not involved in word naming: determining the conceptual meaning of pictorial and color stimuli, and finding (and selecting) the name of the stimulus in the mental lexicon. On the other hand, in reading out loud (word naming), determining the meaning takes place at the same time or after the response selection process because of an automatic grapheme-to-phoneme (spelling-to-sound) transformation that occurs in reading words out loud.

The hypothesis of a faster access to the semantic system for pictures rather than for words is well accepted by the community (e.g., Ferrand, 1997; Glaser and Glaser, 1989; Potter and Faulconer, 1975; Riddoch and Humphreys, 1987; Seifert, 1997). In particular, Potter and Faulconer (1975; see also Seifert, 1997, for a recent replication) demonstrated that subjects were faster to name a word than they were to name the picture of the item that that word denoted. In contrast, subjects were faster at categorizing the picture of an item than they were at categorizing the item from its written word form. This at least implies different orders of access to the representations subserving naming and categorization for pictures and words. Pictures seem to have relatively fast access to a semantic representation and relatively slow access to a phonological (name) representation, whilst words have relatively slow access to a semantic representation and relatively fast access to a phonological representation. This result is consistent with the idea that pictures may only access name information following access to semantic representation (e.g., Glaser, 1992; Humphreys, Riddoch, and Quinlan, 1988; Morton, 1984; Riddoch and Humphreys, 1987; Seifert, 1997; Warren and Morton, 1982), whilst words

may have direct (non-semantic) access to name information (e.g., Bub, Cancelliere, and Kertez, 1986; Morton and Patterson, 1980; Schwartz, Saffran, and Marin, 1980). Therefore, according to Theios and Amrhein (1989), the difference in time between the naming of pictures and the reading of corresponding words is due to two extra processes: 1) retrieving the meaning of the picture and 2) finding just the right name in the mental lexicon.

1.3. The Present Study: The Special Case of Arabic Numbers

Besner and Coltheart (1979) classified visual symbols that represent language into three broad categories. The simplest, and historically the first to evolve, is the pictographic: the visual symbol is a picture of the word or idea. The second, the ideographic principle, resembles the pictographic in that a single visual symbol stands for a whole word or idea, but differs in that the relationship of symbol to word or idea is arbitrary rather than pictorial: it is the case of Arabic numbers. A third principle is the alphabetic: here orthographic symbols correspond to components of speech, roughly phonemes. It corresponds to written numbers.

According to Besner and Coltheart (1979), pictures and Arabic numbers are processed ideographically, whereas written numbers are processed alphabetically. This notion gains support from neuropsychological studies of alexic patients. Hécaen (1979) describes a version of alexia without agraphia (the patient manifests a reading disorder without a deficit in writing), in which patients are unable to read letters or words despite the relatively normal ability to read single- and multiple-digit numbers. Hécaen and Kremin (1976) report four cases of such patients who were better at reading aloud Arabic numbers than at reading words. Therefore, Arabic numbers can be viewed as graphic symbols: they are markedly more similar to pictures than to words since, as for pictures, there is no physical overlap between a number and its corresponding written name.

As pictures, Arabic numbers have visual, phonological as well as semantic representations (e.g., Dehaene, 1992; Ferrand, 1995). Semantic representations of Arabic numbers are assumed to specify the basic quantity in a number, and the power of ten associated to each (McCloskey, Sokol, and Goodan, 1986; McCloskey, 1992). As for pictures, models of number processing (e.g., McCloskey et al., 1986; McCloskey, 1992) suggest that reading aloud an Arabic number (such as 5) always involves first generation of a semantic representation and then the conversion of the semantic representation into the appropriate sequence of phonological number-word representations. As Dehaene (1997, p. 88) put it:

When we see an Arabic number, the brain builds rapidly a continuous and compressed representation of the quantity associated to it. This conversion into quantity is very fast, unconscious and automatic. It is impossible to see the Arabic number 5 without converting it, almost instantaneously, into the quantity five, and this, even though this conversion is not useful. Understanding numbers acts therefore like a reflex.

A substantial body of evidence suggests that semantic representations are indeed computed and used in various types of numerical processing. For example, when subjects judge which of two Arabic numbers is larger in magnitude (e.g., 7 or 4), responses are slower the closer in magnitude the numbers are (e.g., Moyer and Landauer, 1967; McCloskey and Macaruso, 1995). This effect suggests that numerical comparisons are carried out on internal semantic representations that reflect magnitude or quantity relations among numbers. Some evidence suggests that these semantic representations are also activated in situations where they are irrelevant to the task at hand (e.g., Dehaene, Bossini, and Giraux, 1993; Henik and Tzelgov, 1982). McCloskey and colleagues have proposed that numerical processing is a semantically mediated process, that is, the Arabic number is converted to a number-semantic representation, which is then transformed to the desired response format. This semantic transcoding view for Arabic numbers reflects the central role assigned to semantic representations. For example, reading aloud an Arabic number (such as 5) is assumed to

involve an Arabic numeral comprehension process that converts the Arabic number into an internal semantic representation, and then a verbal numeral production process that converts the semantic representation into a sequence of phonological number word representations (e.g., *five*).

However, for reading number words (such as *five*), the generation of a semantic representation may not always be necessary. Studies of reading suggest that there are other means by which a word may be read aloud. It is generally assumed that nonwords and words that have not previously been encountered and therefore are not represented in the phonological lexicon, are read aloud via the application of grapheme-to-phoneme conversion rules (e.g., Coltheart, 1978, 1980). Thus, pronunciations of written number words presumably could be generated through grapheme-phoneme conversion. For words whose pronunciation cannot reliably be deduced from the orthography (because they are irregular for instance), there is evidence that they might be read aloud via direct nonsemantic access to stored phonological representations. In particular, some studies show that phonological representations may be activated directly from an orthographic representation of a stimulus word, without mediation of a semantic representation (Bub et al., 1986; Schwartz et al., 1980).

Now, Arabic numbers share a very important attribute with their corresponding written names: their uncertainty is null. There is only one way to name 5 and *five*. By using arabic numbers and their corresponding written names, we can test and contrast the different hypotheses proposed to explain the reading-naming time difference. According to Fraisse (1969, 1992), this difference is exclusively due to the compatibility between stimulus and response. In the present study, because Arabic numbers and their corresponding written names have no uncertainty, the naming latencies should be equal. But according to Theios and Amrhein (1989), there is one additional processing time: the retrieval of meaning. We have seen before that current models of number processing agree to suggest that for Arabic

numbers, as for pictures, semantic retrieval is an obligatory step before name retrieval. So, if the reading-naming time difference is also due to this additional process for numbers (retrieval of semantic information), naming times should be longer for Arabic numbers than for their written names (uncertainty being equal here).

It is interesting to note that before us, Brown (1915b) compared naming times of number-names and number-symbols (Arabic numerals). Subjects had to read aloud 100 items on sheets containing either the written words *one*, *two*, *three*, and *four*, or the Arabic numerals *1*, *2*, *3* and *4*. The subjects received eleven days of practice. The results showed a small difference between Arabic numbers and their corresponding names. On average, Arabic numbers were named faster than their corresponding written names. However, one potential problem with this experiment is that a stopwatch was used to measure reading speeds. This manual operation of the stopwatch to measure RTs is far from being ideal in terms of timing and accuracy. Furthermore, only four different stimuli were used in this experiment. Finally, another important criticism of such a recording technique is the possibility of experimenter effects. During the procedure, the experimenter was aware of each condition being tested and also controlled RT data collection by manually starting and stopping the stopwatch at the beginning and end of each list. The present experiments were designed to avoid these problems of sensitivity and possible experimenter effects. The stimuli were generated automatically, and RTs were measured and recorded by a computer.

There is one more study that contrasted Arabic number naming and number word naming, and that showed a benefit for the Arabic numbers (Wimmer and Goswami, 1994). However, in that study, the subjects were children, and the difference between processing the two types of stimuli was attributed to differential practice with the two types of stimuli: with increasing practice on the number words, the difference between the two types of stimuli disappeared.

Therefore, it seemed to us essential to replicate Brown's (1915b) experiment with better timing control and more stimuli, and to test adult subjects (in contrast to Wimmer and Goswami, 1994, who tested children). In the present study, we compared naming times for arabic numbers and their corresponding written names. In Experiment 1, subjects received ten sessions of 20 trials. We used an independent group design in which half of the subjects received only Arabic numbers and the other half received only their corresponding written names. This was done in order to avoid positive cross-modality transfer from words to numbers (as shown recently by Ferrand, 1995). Indeed, Ferrand (1995) showed that number naming (e.g., 12) was facilitated by prior (masked) presentation of the written name of the Arabic number (e.g., twelve). Experiment 2 was a replication of Experiment 1 in which we used a mixed design: subjects received five sessions of 40 trials (20 Arabic numbers and their 20 corresponding written names).

2. Experiment 1

2.1. Method

2.1.1. Subjects

Thirty psychology students at René Descartes University, Paris, took part in the experiment for course credit, half received Arabic numbers only and the other half received their corresponding written names.

2.1.2. Stimuli and Design

Twenty Arabic numbers (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20) and their corresponding written names (un, deux, trois, quatre, cinq, six, sept, huit, neuf, dix, onze, douze, treize, quatorze, quinze, seize, dix-sept, dix-huit, dix-neuf, vingt) served as experimental stimuli. In addition, there were ten practice Arabic numbers or written words. At

a visual distance of 60 cm, each character covered 0.38° of visual angle. We used an independent group design in which half the subjects received only Arabic numbers (throughout ten repeated sessions) and the other half received their corresponding written names (also throughout the repeated sessions).

2.1.3. Procedure

Stimuli were presented on the center of the display screen of an 486 personal computer. The items appeared on the screen as white characters on a dark background. Stimuli remained on the screen until the subjects responded. Subjects were asked to name as rapidly and as accurately as possible the Arabic number or the corresponding written name and naming latencies were the main dependent variable. The computer recorded the naming times, measured from target onset to the triggering of the voice key by the subject's response (via a Sennheiser MD211N microphone). The experimenter sat in the same room as the subject in order to check and note the responses of the subject. The next sequence followed after a 2-second delay. Stimulus presentation was randomized with a different order for each subject.

2.2. Results

Mean naming latencies with standard deviations are given in Table 2 throughout the 10 repeated sessions. Type of stimuli (Arabic numbers vs. their corresponding written names) and repetition (10 sessions) were entered as main factors in an analysis of variance (ANOVA). The main effects of type of stimuli and repetition failed to reach significance ($F(1,28)=0.16$, $p>.30$ and $F(9,252)=1.32$, $p>.22$ respectively). The type of stimuli X repeated sessions interaction also failed to reach significance ($F(9,252)=0.86$, $p>.43$). Planned comparisons showed absolutely no significant difference between Arabic numbers and their corresponding

written names for each session (all $F_s < 1$). Because the error rates were consistently too low (less than 1%), no ANOVA was conducted.

3. Experiment 2

In Experiment 2, we used a mixed design: subjects received five sessions of 40 trials (20 Arabic numbers and their 20 corresponding written names). The presentation of Arabic numbers and their corresponding written names was mixed and randomized with a different order for each subject. This was done in order to check if the null results found in Experiment 1 were not due to the peculiarity of the design used.

3.1. Method

3.1.1. Subjects

Twenty additional psychology students at René Descartes University, Paris, took part in the experiment for course credit. All were native speakers of French, with normal or corrected-to-normal vision and had not participated in the previous experiment.

3.1.2. Stimuli and Design

The stimuli were exactly the same as those used in Experiment 1. We used a mixed design in which all the subjects received Arabic numbers and their corresponding written names throughout five repeated sessions

3.1.3. Procedure

Exactly the same procedure as that in Experiment 1 was used.

3.2. Results

Mean naming latencies with standard deviations are given in Table 3 throughout the 5 repeated sessions. Type of stimuli (Arabic numbers vs. their corresponding written names) and repetition (5 sessions) were entered as main factors in an analysis of variance (ANOVA). The main effect of type of stimuli failed to reach significance ($F(1,19)=2.30$, $p>.14$) but there was a main effect of repetition ($F(4,76)=2.63$, $p<.05$). The type of stimuli X repeated sessions interaction also failed to reach significance ($F(4,76)=0.71$, $p>.40$). Planned comparisons showed absolutely no significant difference between Arabic numbers and their corresponding written names for each session (all $F_s<1$). Because the error rates were consistently too low (less than 1%), no ANOVA was conducted.

4. General Discussion

The important result of the present study is the absence of any reading-naming time differences between Arabic numbers and their corresponding written names throughout the repeated sessions both in Experiment 1 and 2.

Note that our results have important theoretical implications if we are ready to accept the null hypothesis. For the null hypothesis to be appropriately accepted, Frick (1995) proposed the following criteria: (1) there should be many subjects (we had 30 in Experiment 1 and 20 in Experiment 2); (2) there should be many trials per subject (we had 20 trials repeated ten times in Experiment 1, and 40 trials repeated five times in Experiment 2); and (3) major sources of variance should be controlled (here the naming response was identical in each condition since we compared Arabic numbers with their corresponding written names). Furthermore, the p value corresponding to the type of stimuli (Arabic numbers vs. their corresponding written names) was greater than .30. Also, the observed size of the effect (+6.5 ms in Experiment 1 and +6.6 ms in Experiment 2) is far from the size one would expect if

there was an effect (see Table 1: on average, the reading-naming time difference was +207 ms). So, it seems appropriate to conclude that there was no effect. As Frick wrote (1995, p. 134), "Ideally, in accepting the null hypothesis, there will be little observed effect (and a corresponding high value of p)". This is exactly what we found.

According to Fraisse (1969), the reading-naming time difference is exclusively due to the greater uncertainty for colors and pictures than for words. On the other hand, according to Theios and Amrhein (1989) the reading naming time difference would be due to two extra processes: (1) retrieving the meaning of the picture; and (2) finding just the right name in the mental lexicon.

Now, our results show no reading-naming time difference between Arabic numbers and their corresponding written names, uncertainty being equal here. Therefore, the present results are in favor of Fraisse's hypothesis (the uncertainty hypothesis). This hypothesis is supported by previous results showing that uncertainty is a robust predictor of picture naming difficulty (whilst this factor has no effect on word reading). In particular, several investigators have shown that pictures with as single dominant response are named more quickly and accurately than those with multiple responses (Butterfield and Butterfield, 1977; Johnson and Clark, 1988; Lachman, 1973; Lachman and Lachman, 1980; Lachman et al., 1974; Paivio et al., 1989). Furthermore, uncertainty increased naming but not object-decision RTs for the same pictures, suggesting that it affected a post-identification stage unique to naming (Johnson, 1992). This experimental finding strengthens the argument that uncertainty effects represent the influence of multiple object-name links, over and above the influences of other attributes that increase name difficulty.

It could be argued that number naming does not require obligatory access to semantic. However, as reviewed in the Introduction, current models of number processing (e.g., McCloskey, 1992; McCloskey et al., 1986) strongly suggest that reading aloud an Arabic

number (such as 7) necessarily requires access to the semantic information before name retrieval. In that sense, Arabic numbers behave like pictures. Numbers, just like pictures, constitute a semiotic system. Indeed, a lexicon (the Arabic elements), a syntax (rules of succession), and semantics (the quantity represented) may be defined for the numerical domain, and many aspects of number processing may be considered as psycholinguistic activities. We have suggested that Arabic numbers are coded like non-alphabetic forms or ideographs.

Overall therefore, our results suggest that the main factor responsible for the reading-naming time difference is the uncertainty factor (as already suggested by Fraisse, 1969), since uncertainty being equal, the difference vanished completely.

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TABLE 1

Summary of the reading-naming time differences found by different authors.

Authors	Reading-Naming Differences
Cattell (1885)	+ 250 ms
Brown (1915a)	+131 ms
Lund (1927)	+196 ms
Ligon (1932)	+268 ms
Fraisse (1960)	+219 ms
Fraisse (1964)	+135 ms
Fraisse (1967b)	+166 ms
Potter and Faulconer (1975)	+260 ms
Durso and Johnson (1979)	+207 ms
Biederman and Tsao (1979)	+266 ms
Smith and Magee (1980)	+348 ms
Carr, McCauley, Sperber, and Parmelee (1982)	+143 ms
Irwin and Lupker (1983)	+173 ms
Glaser and Dünghoff (1984)	+222 ms
Potter, So, Von Eckart, and Feldman (1984)	+257 ms
Bajo (1988)	+178 ms
Bajo and Canas (1989)	+153 ms
Glaser and Glaser (1989)	+133 ms
Theios and Amrhein (1989)	+145 ms
Biggs and Marmurek (1990)	+158 ms
Ferrand, Grainger, and Segui (1994)	+210 ms
Wimmer and Goswami (1994)	+260 ms
Marmurek (1994)	+334 ms
Seifert (1997)	+213 ms

TABLE 2

Mean Naming Latencies (In Milliseconds) With Standard Deviations (Into Brackets) For Arabic Numbers And Their Corresponding Written Names For The Ten Sessions In Experiment 1.

Sessions	1	2	3	4	5	6	7	8	9	10	Means
Arabic Numbers	474 (50)	462 (53)	463 (56)	465 (54)	477 (51)	474 (63)	466 (58)	466 (58)	471 (61)	465 (54)	<u>468.3</u>
Written Names	474 (54)	459 (50)	462 (41)	464 (42)	462 (51)	462 (49)	457 (45)	458 (45)	457 (50)	463 (48)	<u>461.8</u>
Difference	0	+3	+1	+1	+15	+12	+9	+8	+14	+2	<u>+6.5</u>

TABLE 3

Mean Naming Latencies (In Milliseconds) With Standard Deviations (Into Brackets) For Arabic Numbers And Their Corresponding Written Names For The Five Sessions In Experiment 2.

Sessions	1	2	3	4	5	Means
Arabic Numbers	486 (56)	486 (47)	480 (54)	477 (42)	485 (45)	<u>482.8</u> (49)
Written Names	484 (45)	481 (44)	470 (41)	466 (36)	480 (46)	<u>476.2</u> (42)
Difference	+2	+5	+10	+11	+5	<u>+6.6</u>