SEMANTIC OR ASEMANTIC DIGIT NAMING?

EVIDENCE FROM THE CONDITIONAL NAMING TASK

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Abstract

There has been some discussion whether arabic digits are named via a direct route (like words) or via a semantically mediated route (like pictures). To address this question, we used the conditional naming task, which requires participants to name a stimulus only if it fulfils a semantic criterion (e.g., is smaller than 5). We show that the difference between conditional naming and free naming is the same for arabic digits as for number words. On the basis of this finding, we conclude that there is a direct route from arabic input to spoken output that outperforms the semantically mediated route.

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There has been disagreement among researchers about whether arabic digits are processed like words or like pictures. Single digit numbers resemble words because they are symbols with an arbitrary relationship to their meaning. However, they also differ from words, because they consist of unitary symbols that cannot be decomposed into a series of letters that have a rather consistent mapping to the pronunciation of the word. As such, arabic digits are a prime example of logographs: Each symbol represents a different word with its unique pronunciation and meaning (at least as long as the discussion is limited to single-digit numbers).

The two main differences between word and picture processing are (1) that words are named faster than pictures, and (2) that pictures activate the semantic system faster than words (e.g., Glaser, 1992). This has led to the majority view that words are usually named without semantic mediation, either via direct letter-sound conversion or via the activation of form representations in the lexicon (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Plaut, McClelland, Seidenberg, & Patterson, 1996). In contrast, pictures and other visual stimuli like faces are thought to require semantic mediation for their naming (e.g., Hodges & Greene, 1998; Levelt, Roelofs, & Meyer, 1999).

Particularly convincing evidence for the difference between word reading and picture naming was provided by Damian, Vigliocco, and Levelt (2001). They asked participants to repeatedly name pictures in a semantically homogeneous block (e.g., cat, goat, rat, beaver, tiger, swan) or in a semantically heterogeneous block (e.g., cat, hand, ferry, skirt, broom, leek). Damian et al. observed that participants needed more time to name the pictures in the homogeneous condition than in the heterogeneous condition, and attributed this interference effect to an increased competition in the retrieval of lexical entries in the homogeneous condition because of the semantic overlap among the various stimuli. Interestingly, the interference effect was not present when the pictures were

replaced by words and participants were asked to repeatedly read the words. With these stimuli the researchers even found faster reading times in the homogeneous block than in the heterogeneous block, in line with the associative priming effect usually found in word reading. The difference was not due to the type of stimuli, because the semantic interference effect reappeared when participants were asked to start their response with the correct article of the noun that was depicted (the experiment happened in German, where nouns get different articles depending on their gender). The extraction of gender information, unlike the naming of words, is thought to require semantic mediation.

The debate about commonalities and differences between digit (logograph) and word processing has centered on the question whether digits require semantic mediation for their naming or whether there is an additional direct route from visual input to spoken output[1], like for words. One of the first researchers to defend such an asemantic route for number naming was Coltheart (1978), who claimed that digits, just like abbreviations, form part of the orthographic input lexicon. Other authors who defended the idea, were Deloche and Seron (1987), Dehaene (1992), and Roelofs (in press). In contrast, McCloskey, Caramazza, and Basili (1985), Brysbaert (1995), Fias (2001; Fias, Geypens, Brysbaert, & d'Ydewalle, 1996; Fias, Reynvoet, & Brysbaert, 2001), and Damian (2004) argued in favor of obligatory semantic mediation.

Several arguments have been made for and against the existence of a direct digit naming route. Here we just mention the latest one (see the references above for the other arguments). Fias et al. (2001) argued in favor of obligatory semantic mediation in arabic number naming, because they observed that the naming of arabic digits was 30 ms faster when a distractor number word on the display referred to the same magnitude as the digit (e.g., *6 – six*) than when it referred to a different

[1] Although such a route is sometimes presented as a substitute of the semantic route, McCloskey (1992) rightly pointed out that a direct number naming route cannot replace the semantically mediated route, because the most important task of number processing is number understanding and not number naming. Similarly, we must be able to name numbers on the basis of conceptual information, and not only on the basis of visual input. So, the existence of a semantically mediated route is pivotal in any model of number processing, and a direct route from Arabic input to verbal output requires an additional processing pathway.

magnitude (e.g., *6 – four*). No such Stroop-like interference effect was seen when participants were asked to name a number word in the presence of a digit distractor (e.g., naming times were only 1 ms faster for *six – 4* than for *six – 6*). When Fias et al. changed the task to a number parity task, they found symmetric Stroop interference effects (29 ms faster to the target *6* in *6 – six* than in *6 – four*; 41 ms faster to the target *six* in *six – 6* than in *6 – four*). On the basis of the asymmetry of the Stroop effect in the naming task and the symmetry of the effect in the parity judgment task, Fias et al. (2001) concluded that the presence of the Stroop effect in the digit naming task (but not in the number word naming task) meant that digits, unlike words, required semantic mediation to be named. In a recent paper, Roelofs (in press) took issue with this conclusion~~, however.~~ He replicated Fias et al. (2001), but he matched the area covered by the digit to the area covered by the word (Fias et al. presented words and digits in the same font). Using this simple manipulation, Roelofs showed that the Stroop interference effect of arabic digits was the same as that of words, and significantly different from that of die~~dice~~ faces representing numerosities. On the basis of this finding, Roelofs claimed that die~~dice~~ faces require conceptual identification before they can activate lemmas and word forms, whereas arabic digits (just like words) can activate the lemmas and word forms directly.

Job and Tenconi (2002) published a task that could settle the issue of semantic mediation in digit naming more definitely. They reasoned that if semantic mediation is needed to name a stimulus, then it should make little difference if participants first have to make a semantic decision on the input stimulus or not. So, Job and Tenconi presented 48 pictures coming from eight different categories (weapons, furniture, vehicles, clothing, fruits, vegetables, mammals, birds). In one condition participants simply had to name the pictures (free naming); in the other condition they had to refrain from responding when the picture referred either to an artifact or – in a sepearte condition- to a living thing (conditional naming). Job and Tenconi observed naming latencies of 808 ms in the free naming condition and 807 ms in the conditional naming condition. That is, in line with their prediction, there was no difference in picture naming latencies when participants first

had to make a semantic decision or when they did not have to do so. Job and Tenconi then replaced the picture stimuli by words and asked the participants either to read the words (free naming) or to read them if and only if they referred to artifacts or biological organisms. Now the reading latencies were respectively 493 ms and 702 ms. This huge difference of over 200 ms was in line with the assumption that words are read without semantic mediation in a fast naming task.

The extrapolation of Job and Tenconi's paradigm to arabic digits is straightforward. If digits, unlike words, require semantic mediation to be named, then there should be little difference in the naming latency if participants first have to make a semantic decision on the digit or not. In contrast, for number words, we expect a robust difference between free and conditional naming in line with Job and Tenconi's findings. Two semantic number tasks were used. Participants were asked to name digits only when they were smaller (or larger) than 5, and when they were odd (or even for a second group).

Method

Participants. Sixteen students from the University of Padova participated on a voluntary basis. They had normal or corrected-to-normal vision and were unaware of the research hypothesis.

Material and Procedure.

The numbers 1-4 (uno, due, tre, quattro) and 6-9 (sei, sette, otto, nove) were used. They were presented as digits or words, in separate lists. Each item was presented five times in each list, for a total of 40 stimuli per list. List order was counterbalanced between participants. In each session either the digit lists were presented first or the word lists were presented first. All participants performed three tasks with the digits and three tasks with the words. The first task was free naming, in which the participant was required to name aloud all stimuli as they appeared on the screen. This was followed by two conditional naming conditions. In one, the participant was asked to name aloud only the even (half of the participants) or the odd numbers (the other half of the participants). In the second condition, they were asked to name aloud only the numbers smaller than five (half of the participants) or the numbers bigger than five (the other half of the participants). In

the second part of the experiment the participant repeated the three tasks with the lists containing the items in the other format (e.g. words).

Participants were tested individually and the experimenter was seated behind the participant to record errors and equipment failures. Presentation of the stimuli and recording of the responses were controlled by a Macintosh computer with a voice-key connected. arabic numerals were presented as Geneva 36 while word numerals were presented as Geneva 20. Each trial consisted of the following sequence of events: A fixation point appeared in the centre of the screen for 400 ms. The stimulus (a single digit or a single word) then appeared and stayed in view until either the participant produced the vocal response or 1500 ms elapsed. Following an inter-stimulus interval of 1000 ms the fixation point appeared again. Reaction times (RT) in milliseconds were automatically recorded from the word's onset.

Within each block, stimuli were presented in random order, with the constraint that the same number could not appear consecutively more than three times. Participants were instructed to name each stimulus as distinctly and quickly as possible and to try to avoid producing irrelevant sounds that might trigger the voice-key. Before the experimental session, 10 practice trials were used to familiarize participants with the task, and to control for the sensitivity of the voice-key. The experimental session lasted about 30 minutes.

Results

In order to have comparable data sets in the conditional and the free naming conditions, for each participant only half of the free naming RTs were included in the data analysis (i.e., the RTs to those stimuli that had been responded to in the conditional naming condition). So, for the even/odd condition only the RTs for the even numbers of the free naming condition were taken into account when the participant named the even numbers in the conditional naming condition. Errors, microphone failures, and RTs longer than 1000 ms were excluded from further analyses (less than 5% of the data). Also, a cut-off point of 2.0 SD from a participant's mean was calculated and outlying data were replaced with those values (2% of the stimuli).

The mean RTs of the correct responses are shown in Table 1.

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insert Table 1 about here

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Separate ANOVAs were run for the even/odd data and the smaller/larger than 5 data. In each analysis, number format (digits, words) and naming task (free, conditional) were within-participant factors. In the even/odd ANOVA both factors proved significant but their interaction was not ($F < 1$). Digits were named faster than words ($F(1, 15) = 9.17$, $p=.008$) and RTs in the free naming condition were faster than in the conditional naming condition ($F(1,15)= 89.58$, $p< .001$). In the smaller/bigger than 5 ANOVA both factors and their interaction proved significant. Again, digits were named faster than words ($F(1,15) = 11.96$, $p=.004$), and free naming was faster than conditional naming ($F(1,15) = 51.79$, $p <.001$). The difference between free naming and conditional naming was larger for word stimuli than for digit stimuli ($F(1,15) = 12.25$, $p=003$).

To test the origin of the significant interaction between number format and naming condition in the smaller/ bigger than 5 task (see the Discussion section below), we looked at the effect of the distance between the number to be named and the midpoint 5. It is well established that it is more difficult to decide that $4 < 5$ than that $1 < 5$. Similarly, it is more difficult to decide that $6 > 5$ than that $9 > 5$. This should be reflected in the conditional naming condition but not in the free naming condition. The neatest analysis of this distance effect is to work with the differences in RT between the conditional and the free naming task, and to examine how this difference varies as a function of the distance between the stimulus number and 5. In this way, all participants contributed equally to the analysis, and differences in naming speed and voice registration speed for the different numbers were cancelled out.

Figure 1 shows the results of this analysis. On the ordinate, we have the difference in RT between the conditional and the free naming condition. On the abscissa we have the difference between the stimulus number and 5 (e.g., this difference is~~equals~~ 1 for the stimulus numbers 4 and 6, and 4 for the numbers 1 and 9). The difference between conditional and free naming was 143 ms for the verbal stimuli *quattro [four]* and *sei [six]*, and 78 ms for the stimuli *uno [one]* and *nove [nine]*. For the arabic stimuli *4/6* and *1/9* the differences were 83 ms and 68 ms respectively. A planned linear comparison showed that the distance effect was significant for the words (linear contrast: $F(1,14) = 23.5$, $p < .001$) but not for the digits (linear contrast: $F(1,14) = 2.2$, $p > .15$).

Discussion

This article set out to test whether arabic digits are named like words or like pictures. To do so, we made use of the recent discovery by Job and Tenconi (2002) that there is little difference in picture naming latencies when participants have to name all pictures or only those that belong to a

certain semantic category (living or non-living things). In contrast, for verbal stimuli there was a huge difference in RTs between the free naming and the conditional naming conditions. On the basis of these findings, we hypothesized that if digit naming requires semantic mediation, participants should show but a small difference in naming latencies when they have to name all the digits, or only those of a certain category (odd or even, small or large). In contrast, for word stimuli there should be a large difference.

The results decisively ruled out the possibility that the naming times of arabic digits were based on a semantically mediated pathway whereas those of number words were based on a direct reading route. For a start, there was no difference in the cost of conditional naming between number words and arabic digits in the odd/even task. For both notations, RTs were about 110 ms longer in the conditional naming condition than in the unconditional naming condition. This does not agree with the idea that arabic digit naming requires semantic mediation, whereas word naming does not.

Even stronger evidence was obtained with the conditional magnitude naming task. Whereas it could be argued that information about the odd/even status of a number is not part of the semantic information that is needed for digit naming, no such claim can be made with respect to number magnitude. Magnitude is central in the meaning of numbers and all authors defending pivotal semantic mediation in digit naming have assumed that the required semantic information consists of magnitude information. For instance, Reynvoet, Brysbaert, and Fias (2002; see also Reynvoet & Brysbaert, 2004) used the distance-related priming effect to argue in favour of a semantically mediated route in digit naming. Having found that the target digit 6 was named faster when primed with 5 or 7 than when primed with 4 or 8, Reynvoet et al. repeated their experiment with verbal primes and obtained exactly the same priming results. On the basis of this finding, Reynvoet et al. (2002, p. 1127) wrote: “We argue that the present results are congruent with the idea that the numerals make access to an ordered semantic number line common to all notations, as the results are the same for within-notation priming (arabic–arabic or verbal–verbal) and between-notations priming (arabic–verbal or verbal–arabic).”

In Reynvoet et al.’s (2002) model of digit naming, arabic digits first activate part of a semantic number line, a hypothetical substrate in which number magnitudes are ordered from small to large. Digits initially activate a rather broad range of the number line (this accounts for the distance-related priming: the primes 5 and 7 partially co-activate the semantic representation of the target number 6). Gradually, the range narrows until a unique number magnitude remains. At that moment, the number name can be retrieved. If this model is correct, then it should not make much difference whether participants are asked to name a digit right away or only after having decided whether it is smaller or larger than 5. Because the magnitude information must be activated before

the digit name can be retrieved, the only extra process in the conditional condition is the comparison of the activated magnitude with 5. For words, the difference should be much bigger because the difference between the unconditional and the conditional naming condition is a difference between a direct non-semantic naming route and a semantic route in which a number magnitude must be activated and compared with 5.

The data provide little evidence in favour of Reynvoet et al.'s model. It took participants 74 ms longer to name a digit in the conditional condition than in the unconditional condition. This is only a fraction smaller than the 100 ms observed with number words. In addition, the model makes the straightforward prediction that if the comparison process is easy, conditional naming times for digits should be very close to unconditional naming times. Figure 1 shows that this is not the case: Participants took 68 ms longer to name the digits 1 and 9 when these digits first had to be compared relative to 5 than when they did not. This difference was very close to the difference observed for the word stimuli *uno [one]* and *nove [nine]* (78 ms).

Figure 1 further shows that the difference between the verbal and the arabic notation was particularly strong for the numbers *4/quattro* and *6/sei*. It took participants 143 ms longer to name *quattro* and *sei* in the conditional condition than in the unconditional condition, whereas the difference was only 83 ms for the stimuli *4* and *6*. This is in line with previous evidence that arabic digits activate their number magnitude better than number words, so that number comparison is easier when stimuli are presented in arabic format than when they are presented in verbal format.

All in all, the data of the present study strongly suggest that the similarities between digit naming and word naming are larger than the differences. For both notations, naming times were faster when the stimuli could be named as such than when a semantic decision had to be made first. The cost between for the conditional naming was nearly the same in both notations. The only difference between arabic and verbal numbers was that participants found it easier to decide that the magnitude 4 was smaller than 5 with arabic input than with verbal input.

What the findings of the present study therefore show, is that arabic input activates the meaning of the numbers faster than verbal input, but that there still is a direct route from arabic input to spoken output which outperforms the semantically mediated route in a fast naming task. The most likely reason why the direct route outperforms the semantically mediated route is that it takes quite some time to activate the appropriate spoken output on the basis of number magnitude. Researchers in numerical cognition indeed have tended to underestimate the processes needed to

turn a semantic preverbal message (number magnitude) into a correct string of lexemes (spoken number words; Levelt et al., 1999). [2]

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[2] Another interesting finding of the present study is that the Arabic digits were named faster than the number words. This goes against Damian (2004), who obtained faster naming times for words than for digits. The most likely reason for this discrepancy is that we presented our digits in a larger font than the number words, whereas Damian (2004) presented his words and digits in the same font. This is the same discussion as the one between Roelofs (in press) and Fias et al. (2001), who found different effects depending on the magnitude of the digits relative to that of the words. Because there is no way to decide how the magnitudes of Arabic digits and number words must be equated, the dependence of the naming times on the physical magnitude of the digits means that pure asymmetries between Arabic and verbal input are difficult to interpret. For this reason, the present comparison between free and conditional naming is a much better way of testing the semantic hypothesis, because it circumvents a direct comparison of naming speed for digits and words.

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Table 1 Response Times (in ms) to name Arabic numerals and Word numerals as a function of task~~tasks~~ and stimulus format.

Even/odd

	Arabic	Words
Free	413	428
Conditional	518	545

Greater and smaller than 5

	Arabic	Words
Free	414	427
Conditional	488	527

Figure 1 : Differences in RT between conditional naming (smaller or larger than 5) and free naming as a function of the input format (words vs. digits) and the distance between the stimulus and the number 5.