

discriminate happy from neutral face stimuli easier than they can discriminate angry from neutral face stimuli. Therefore, d' was higher on happy trials than on angry trials, although the task was only for the participants to determine whether the face was emotional or not. After standardization of d' , the happy-superiority advantage seems to be decreased, in that there is no difference between male-angry and male-happy faces. This indicates that there might not be a superiority effect of emotion, but a superiority of particular stimuli.

However, there seems to be a partial happy-superiority effect, in that d' for female-angry face stimuli remained lower than for the other stimuli. This result, however, should be taken with caution; there might be something specific occurring with the female-neutral facial stimuli. For example, the stimuli might not be equivalent to the male-neutral facial stimuli, thus again creating a larger difference between female-angry and female-neutral face stimuli than the difference between male-angry and male-neutral face stimuli.

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DO THE PROCESSING OF ARABIC NUMBERS AND NUMBER WORDS DIFFER IN TASKS OF MAGNITUDE?

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Abstract

Virtually all numbers that people experience in everyday life appear either as Arabic numerals or as verbal names. The two notations may engender different kinds of processing. In order to tap them, an Arabic number and a number word appeared on a trial, and the observer's task was to decide if the Arabic number was larger or smaller than a standard. In a complementary condition, the relevant number for comparison was the number word. Comparisons with Arabic numbers were free of interference from the irrelevant number words. In contrast, the comparisons of number words were affected by the irrelevant Arabic numerals. This pattern of results supports Dehaene's (1992) triple code model by which Arabic but not verbal numerals have privileged access to an analog-magnitude representation.

In the current study we tested the hypothesis that the processing of numbers depends on the task at hand and on the notation in which the numbers appear. People use numbers in a variety of tasks. Sometimes they merely name or read them just like they do words. At other times people must retrieve the arithmetic properties of numbers when, for example, they compare a number to another number in magnitude. Numbers also appear in various dressings. Two of the most popular are Arabic numerals and number words. The two notations may engender different kinds of processing. Arabic numbers are most closely associated with the rules and operations of arithmetic. Verbal numbers, by contrast, form part of the vocabulary of ordinary language. They are words whose processing is subject to known principles of reading and understanding words. Both variables, task and notation, have been tested in the literature, although not in a fully comprehensive manner. In this study, we consider a hitherto untested condition: judgments of magnitude with Arabic and verbal numerals.

Our tool was an adaptation of the Stroop task (Stroop, 1935) into numerical cognition. Two numbers were presented on each trial, an Arabic numeral and a number word. In one block, the relevant stimulus for responding was the Arabic numeral. In a complementary block the target stimulus was the number word. The irrelevant numeral conveyed the same value on half of the trials and a different value on the remaining trials. The ability to ignore the task irrelevant numeral was measured through the Stroop effect: the difference in performance with the target numeral on congruent (the two numbers match in magnitude) and incongruent (the two numbers conflict) trials. Because Arabic numbers are strongly associated with the semantic of numbers (Dehaene, 1992) we expected Arabic numbers to be more immune to intrusions from the number words than vice versa. This pattern is expected especially as the present task concerns numerical magnitude. We expected to record large Stroop effects for number words but much smaller effects with Arabic numbers.

The Effect of Task and Notation

In a study by Fias, Reynvoet, and Brysbaert (2001), a written numeral appeared along with an Arabic numeral on each trial (e.g., SEVEN and 7, a congruent pair, or FOUR and 6, an incongruent pair). The participant's task was to name the word while ignoring the Arabic numeral. In a complementary condition, the task was to name the Arabic numeral and ignore the number word. Asymmetric Stroop effects appeared in this naming task. Naming the Arabic numeral suffered interference from the irrelevant verbal numeral, but naming the verbal numeral was not similarly impaired by the presence of an Arabic numeral. However, when the task was changed to that of parity judgment, a semantic task, the respective effects were more closely balanced. Deciding that a numeral was odd or even suffered from a parity-incongruent numeral (or gained from a parity-congruent numeral) in the other notation, regardless of the notation of the target numeral.

This pattern is comparable with that typically found with the picture-word version of the Stroop naming task (e.g., Ariei & Algom, 2002): Words intrude on picture naming more than vice versa. A common explanation for this pattern is that one can name words but not pictures without engaging the semantic system. A time consuming activation of the semantic system is inevitable when naming the pictures. Possibly, Arabic numbers behave like pictures in the naming task in the sense that one cannot name them without engaging the semantic system. Fias et al. (2001) entertained this possibility although they allowed for the existence of a non-semantic digit-sound mapping, too.

In another study on Arabic and verbal numbers, Damian (2004) used both a naming and a magnitude judgment task. However, he did not present the Arabic and the word numerals jointly in an interference paradigm. On a trial, either an Arabic number or a number word appeared. Two conditions were created. In one, all the numbers appeared in one notation throughout the block. In another mixed block condition, notation alternated in a random fashion. There were two tasks: naming and magnitude judgment. In the latter, the participant indicated whether a number was larger or smaller than 5. The main finding was the different pattern of performance in the two tasks. In the naming task, performance was better with written numerals than with Arabic numbers. In contrast, in the magnitude judgment task performance was better with Arabic numbers than with words.

These illustrative studies are typical. The influence of notation has been tested in the literature in several tasks in and out of the Stroop interference paradigm. Notably, existing research did not include tasks of magnitude judgment in a Stroop design. We accomplished that in the present study.

Method

Participants Twenty-two Tel-Aviv University undergraduates participated in partial fulfillment of course requirements.

Stimuli and Apparatus The stimulus set comprised all Arabic numbers and number words between 1-9 (one to nine) except 5 (five). The stimuli were generated by an IBM-compatible microcomputer (PC 486) and displayed on a 600X800 pixels VGA color monitor. Each trial consisted of the simultaneous presentation of an Arabic number and a number word (in Hebrew). The numerals appeared black over a white background above and below the central fixation point. Top or bottom position of each notation varied from trial to trial in a random fashion.

Procedure The participants were tested individually in a dimly lit room. They were seated approximately 60 cm from the center of the screen. An Arabic number appeared along with a number word on each a trial. In one block, the observer's task was to decide while timed,

whether the Arabic number was (numerically) larger or smaller than the fixed standard of 5 while ignoring the number word. In another block, target and distractor were reversed: The participant responded to the word (larger or smaller than five), ignoring the Arabic numeral. The order of the blocks was counterbalanced between participants. Participants were encouraged to respond quickly, but accurately. Responses were made by pressing one of the marked keys ('Z' in the left, and 'M' in the right) standing for "smaller" and "larger" responses.

Results

Overall, classification of magnitude was faster with Arabic numbers than with number words when each was presented singly (means of 499 ms and 565 ms). Figure 1 gives the results with concurrent presentation of an Arabic numeral and a number word. What is most revealing about the data of Figure 1 is the differential effect of the task-irrelevant numeral. When the target stimulus was an Arabic number, the effect of the concurrent number word was negligible. Our participants responded to the Arabic numeral at the same speed when the irrelevant number word was of the same value as the Arabic number or of a different value. In sharp contrast, the irrelevant Arabic numbers affected performance with number words. Performance was noticeably better when the irrelevant Arabic number matched the value of the number word than when it conflicted with the number word.

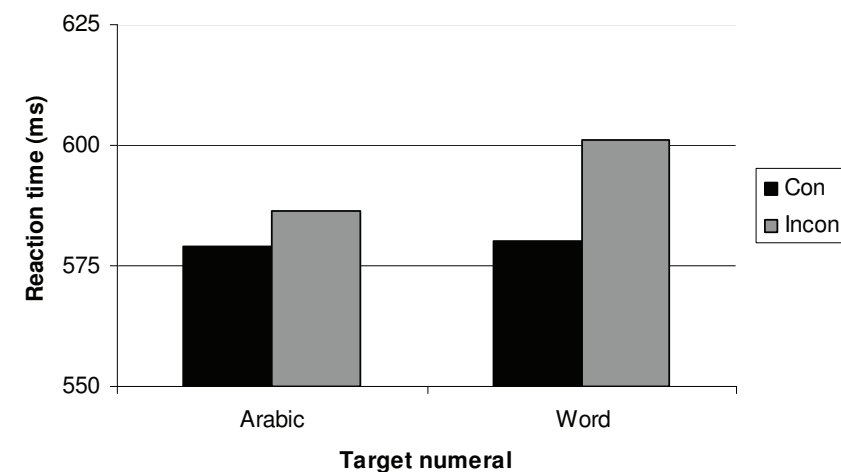


Figure 1 The time needed to decide magnitude (larger or smaller than 5) as a function of notation and congruity.

Indeed, congruent and incongruent stimuli yielded comparable performance for Arabic numbers (means of 579.03 ms and 586 ms). For number words, the Stroop effect was appreciable. Responses to congruent stimuli were faster by 20 ms than responses to incongruent stimuli (means of 580 ms and 600 ms).

Summary

Stroop effects plagued performance with number words but not with Arabic numerals in a task of magnitude judgment. The results are best understood within the framework of Deheane's triple code model (1992) by which processing is task specific, with each task performed best with its favored notation. If a number is presented in a format that is

inappropriate for the required task, a time consuming translation is required. Arabic but not verbal numerals have privileged access to an analog-magnitude representation. A translation into a new representation is needed only with number words and not with Arabic numbers. Therefore performance is faster with Arabic numbers than with number words and the former are immune to interference from the latter in tasks involving numerical magnitude.

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SENSATION WEIGHTING IN PREFERENCE JUDGMENTS CREATES A GOODNESS-LEVEL DEPENDENT WORD-ORDER EFFECT

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Abstract

Hellström (2003) found a goodness-level dependent word-order effect (WOE) for preference judgments. However, Hellström used preference scales adapted to each stimulus pair, and goodness was rated for whole stimulus pairs. Therefore, participants might not have judged preference, and statistical testing of the stimulus weights was not possible. In the present study, 211 participants indicated within-pair preferences for 25 stimulus pairs by choosing one of six written (same for all stimuli) preference expressions (e.g., "apple I like more than pear"). Within-pair presentation order was reversed for half of the participants. Participants also rated each stimulus's goodness by choosing one of seven written expressions (e.g., "Apple I generally like"). Results replicated Hellström's results; there was a greater weight for the left stimulus and a positive correlation between WOE and goodness level. These results strengthen the evidence that the WOE is due to differential sensation weighting rather than, for instance, semantic congruity.

Two physically equivalent stimuli separated by time or by space are often reported as subjectively different on some appropriate continuum. Fechner (1860) named these respective phenomena time-order error (TOE) and space-order error (SOE), defined as positive (negative) when the first/left (second/right) stimulus is overestimated relative to the other. Since Fechner's days the literature on TOEs and SOEs has grown greatly, and now spans order effects on a wide range of psychophysical continua. Many factors have been found to influence the sign and magnitude of TOEs and SOEs (see, e.g., Hellström, 1985 for review). For example, TOEs in esthetic comparisons varied linearly with pleasantness (Koh, 1967), and SOEs in comparisons of line lengths changed from negative to positive when stimulus magnitude varied from low to high at longer durations (Hellström, 2003a).

Plenty of analogous examples of choice-alternatives' presentation orders' affecting the outcome of judgments have been reported in cognitive psychology. For example, presentation order influenced answers to poll-type questions (Wänke, Schwarz, & Noelle-Neumann, 1995) as well as consumer-type choices between alternatives presented as written descriptions (Houston & Sherman, 1995). However, researchers in cognitive psychology do not seem to have noted the psychophysical literature on order effects. In particular, the dependence of the magnitude and sign of TOEs and SOEs on stimulus magnitude does not seem to have been acknowledged in the cognitive psychology literature. In fact, Hellström (2003b) seems to have been the first to investigate the possibility that the sign and magnitude of order effects depend on stimulus levels in choices between stimuli represented by verbal descriptors (i.e., everyday objects and phenomena).

In Hellström's (2003b) study, participants made preference judgments by agreeing to one of six written preference statements for each of 10 stimulus pairs and rated their general opinion on the stimuli. The results showed a positive linear relation between a *word-order*