

Sex differences in the processing of odd and even numbers

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Abstract. Previous research has shown that decisions about odd numbers take longer than decisions about even numbers (the "odd effect"). It has also been shown that females are better at processing linguistic stimuli and males are better at processing spatial stimuli. In the present experiment, male and female subjects made odd *versus* even classification judgments on numbers presented visually in three different formats: digits, number words, and dot patterns. Males showed longer decision times for odd numbers only when the numbers were presented in the dot pattern format. Females showed this effect only when the stimuli were presented in the word format. These results suggest that a differential speed of response to odd and even numbers is found most strongly when the stimuli are presented in a format which is processed more efficiently by the subjects. This finding may imply that the effect is being produced by some higher order cognitive process, based on higher order representations that do not necessarily involve linguistic or verbal coding.

Short
communication

Key words: number processing, sex differences, odd vs. even

It has been shown under a variety of conditions that subjects make judgments about odd digits more slowly than they make the same judgment about even digits (Hines 1990). Specifically, when subjects perform a same/different judgment task in which non-identical pairs of odd (i.e., 7 5) and even (i.e., 6 2) digits are both to be judged as "same," reaction time to judge the odd pairs as same is approximately 100 ms longer than the time needed to judge a pair of even digits as same. The effect is not limited to same/different judgments, but is also found in classification tasks. That is, when pairs of non-identical digits must be classified as either both even or both odd, classification is longer for the odd digit pairs. This effect is also present when a single digit is classified as being odd or even, although Hines (1990) found the effect for single digits in error rate, not reaction time. The effect is not due to a strategy of testing whether a digit is even before testing whether it is odd. Hines et al. (in preparation) varied the proportion of odd and even digits across trial blocks and still found slower responses to odd digits in a block where the great majority of digits was odd. Nor is the effect due to a quirk of the English language such that the word "odd" means not only "not divisible evenly by two" but also "strange or unusual." This is not the case in Polish and non-English speaking Polish subjects also show a substantial slowing of responses to odd digits (Hines et al., in preparation).

Hines (1990) suggested that the odd effect might be due to the linguistically marked nature of the concept "odd", the concept "even" being unmarked. There is evidence in the psycholinguistic literature (Zimmer 1964, Sherman 1976, Skowronski and Yan 1992) that marked concepts take longer to process than unmarked ones. Following this logic, Hines (1990) showed that subjects took longer to make judgments about names of non-living (a marked concept) as opposed to names of living (an unmarked concept) objects. This was found even though the names were equally frequent in the language.

If the odd effect is due to the linguistic nature of the internal representation activated by the stimuli presented, then the size of the effect would be ex-

pected to vary as a function of the degree to which the specific stimuli used activate a specifically linguistic internal representation. Thus, it would be expected that a greater effect would be seen with word stimuli than with digit stimuli. And a greater effect should be seen with digit stimuli than with some even more non-linguistic stimulus type, such as dot patterns. Further, more efficient linguistic processors might be expected to show the effect to a greater degree than less efficient linguistic processors. There is literature suggesting that females are better at linguistic tasks than males (Halpern 1992, Kimura 1992) while males are better than females at tasks involving spatial processing (Linn and Petersen 1985, Kimura 1992). To the extent that this is the case, it would be expected that females would show a greater slowing of responses to odd digits than would males. Further, the degree of slowing should also vary as a function of the specific stimulus formats used to represent the number being judged with more linguistic stimuli generating a greater slowing. We tested these hypotheses by using three different formats (number words, digits and dot patterns) in a task in which male and female subjects made an odd versus even classification of a single stimulus.

Subjects were 12 male and 8 female right handed university students with normal or corrected-to-normal vision. Stimuli were presented at the centre of a 14 inch NEC video monitor connected to an IBM PC 486 computer. Stimuli were the numbers 1 through 8, presented in three different stimulus formats. Number words were presented vertically and measured 40' of arc wide and from 1° 20' to 3° high. Single digits measured 40' wide and 1° 30' high. Dot pattern stimuli were in the form of a die face and measured 2° by 2°. All stimuli were centred on the screen. Examples of the three stimulus formats are shown in Fig. 1.

A trial started with the central presentation of a warning dot that was followed, 250 ms later, by the stimulus for that trial. The stimulus remained on the screen until the subject responded. Following a response, the stimulus was erased from the screen and after a 1 s inter-trial-interval, the warning dot for the next trial appeared.

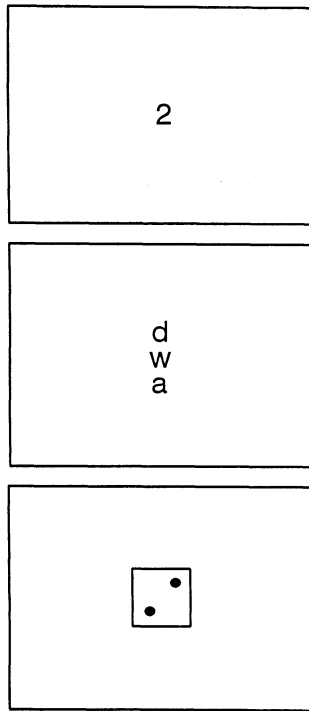


Fig. 1. Examples of three stimulus formats used in the experiment: digits, number words, and dot patterns.

Subjects responded by pressing one of two response keys to indicate whether the stimulus was odd or even. Which key signalled which response was counterbalanced across subjects. There was a total of 240 trials, divided into three blocks of 80 trials each. In each block, each number was randomly presented 10 times. Trial blocks of each of the three stimulus formats were counterbalanced across subjects.

Table I shows the means and standard deviations of reaction times for the three stimulus formats

broken down by odd and even type and by sex of subject.

A three-way ANOVA (sex by stimulus format by odd/even) was performed on these data. There was a significant main effect of stimulus format ($F(2,18)=13.16$; $P<0.001$). Neither the sex nor the odd/even variable had a significant main effect on reaction time. There was, however, a significant three way interaction between the three variables entered into the ANOVA ($F(2,18)=3.96$; $P=0.028$). Decomposition of this interaction *via* the performance of two separate two way ANOVAs on the data for male and female subjects showed a significant main effect of stimulus format for both male ($F(2,22)=13.85$; $P<0.001$) and female ($F(2,14)=3.99$; $P=0.041$) subjects. The nature of this effect differed for the two sexes, however. For females responses to odd numbers were slower than responses to even numbers only for the word format stimuli ($t(7)=2.86$; $P=0.024$). For males, there wasn't a hint of any such slowing for the word stimuli, but the effect was significant only for the dot pattern stimuli ($t(11)=2.77$; $P=0.018$).

The results partly bear out the predictions made at the beginning of this paper. Females showed a significant slowing of responses to odd stimuli, but only when stimuli were presented in the word format, the most directly linguistic format used in this study. Males showed no such effect for word stimuli, but did show a slowing of responses to odd numbers when the numbers were presented in the dot format. Thus, it appears that subjects in this study showed the greatest slowing of responses when they

TABLE I

Means and standard deviations of reaction times to odd vs. even numbers presented in three different formats: digits, number words, and dot patterns

Material		Digits		Dots		Words	
		Odd	Even	Odd	Even	Odd	Even
Females	Mean	622	616	603	606	671	648
	SD	48	47	46	55	73	71
Males	Mean	585	578	617	602	645	647
	SD	84	69	67	95	78	87

were making judgments about the stimulus format which they processed most efficiently. This finding may imply that the effect is being produced by some higher order cognitive process, based on higher order representations that do not necessarily involve linguistic or verbal coding. Such a representation might be termed "supra-linguistic".

That we did not find an overall slowing of reaction time for judgments of word stimuli may appear to contradict the findings of Hines (1990, experiment 5) in which a 20 ms slowing was found on this type of task. However, in the subject pool Hines used, the great majority of subjects were female, although the exact proportion was not reported for that particular experiment. Given our present results, a high proportion of females in an experiment would be sufficient to generate an overall slowing of responses to names of odd digits.

Our findings support the general hypothesis that there will be a greater effect of the odd/even variable when stimuli are presented to a processor specialized for the stimulus format used. There is a huge literature showing that the two hemispheres of the human brain are differently specialized for processing different stimulus formats. This suggests that the size of the difference in response times to odd and even stimuli will vary as a function of which hemisphere processes the stimuli. Our current research is investigating this possibility.

We thank K. Sutkowski for his technical assistance. This study was supported by statutable grant to the Nencki Institute from State Committee for Scientific Research.

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Paper presented at the 2nd International Congress of the Polish Neuroscience Society; Session: Learning, memory and cognitive functions