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Imagine a mouse and an elephant: Hemispheric asymmetries of imagination

Seda Dural^a, Hakan Çetinkaya^a and Onur Güntürkün^b

^aDepartment of Psychology, Izmir University of Economics, Balçova, Izmir, Turkey;

^bDepartment of Biopsychology, Ruhr University, Bochum, Germany

ABSTRACT

The present study aimed to explore the existence of an asymmetrical bias in the imagination of pairs of objects of unequal size. We assumed that such pairs are conceptualized with the smaller object being placed on the left, creating an ascending size order from left to right. Such a bias could derive from a cognitive strategy known from the mental number line. Sixty-four participants were instructed to imagine stimulus-pairs that were staggered from those showing very prominent intra-pair size differences (e.g., elephant vs. mouse) to very low size differences (e.g., orange vs. apple). The results showed that the tendency to imagine the bigger object on the right side increases with the size difference of the two stimuli. Such a visual field bias was also present in stimulus-pairs including numbers so that the participants imagined smaller and larger numbers on the left and the right side of the visual fields, respectively. Taken together, our findings could imply that the left-to-right orientation observed in our object imagining task may share the same cognitive mechanism as the mental number line.

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Introduction

Do you remember how Mowgli was dancing with Baloo on the floor of the Indian rain forest? Can you recall the masterpiece of Pablo Picasso where he sketched with just a few lines Don Quixote with his devoted sidekick Sancho Panza? Can you imagine one of the immortal cartoons when Asterix and Obelix were returning to their village from one of their victorious battles against the Roman army? All of these scenes have one aspect in common: The smaller person is drawn on the left, creating an ascending object sequence from left to right. After encountering much similar visualizations, we pondered about the possibility that this is not pure chance but represents a systematic bias. If such a bias indeed exists, which cognitive

CONTACT Seda Dural  seda.dural@ieu.edu.tr

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mechanism could explain it? The present paper is the result of the pursuit to find answers to these questions.

A theoretical basis for this bias could be the mental number line. The mental number line refers to representing numbers along a spatially left-to-right-oriented continuum. This kind of representation involves a relationship between number processing and spatial attention. In order to investigate the relationship between number processing and spatial attention, Dehaene, Bossini, and Giraux (1993) asked their participants to make odd and even judgements by using their right or left hands. They found that participants responded more rapidly to small numbers with their left hand and to large numbers with their right hand. This is known as the SNARC effect (Spatial-Numerical Association of Response Codes). Similarly, Fischer, Castel, Dodd, and Pratt (2003) describe the finding that participants detect peripheral stimuli flashed into their left visual field faster when a small number had previously been presented in the centre of their visual field. The same subjects detect right-sided stimuli faster after having centrally seen larger numbers. These studies suggest that smaller and larger numbers are primarily associated with the left and the right spatial side, respectively. Subsequently, left-to-right-oriented mental number mappings have been demonstrated recurrently by various research methods that reach from behavioural observations to transcranial magnetic stimulation (e.g., Göbel, Walsh, & Rushworth, 2001), and involve healthy humans (for review see Dehaene, 2011) and patients with neurological disorders (e.g., Zorzi, Priftis, & Umiltà, 2002).

Until recently, most scientists assumed that such a left-to-right bias is human-specific and culturally bound. However, Rugani, Vallortigara, Priftis, and Regolin (2015) suggested that the mental number line might exist in similar ways also in newborn chicks. These chicks were trained to circumnavigate a target number (e.g., five), and then underwent both a small number test (e.g., two vs. two) and a large number test (e.g., eight vs. eight). The authors found that chicks chose left and right sides in the small and large number tests, respectively. If chicks have a similar bias as humans, a biology-bound explanation becomes more likely.

It is conceivable that such a cognitive strategy is not restricted to numbers but includes a spatial mapping of object sizes from left to right. This is what we set out to test.

Method

Participants

A total of 64 participants (48 females, aged between 19 and 58; mean \pm SD, 28.30 ± 9.57) were included in the study. All participants were right-handed (handedness scores over 50) according to the Edinburgh Handedness

Inventory (Oldfield, 1971) which allows to assess the dominance of a person's right or left hand in everyday life. The study was approved by the ethics committee of the Faculty of Psychology of the Ruhr University, where the study was also carried out. All participants gave their written consent to participate, and received course credits, if applicable.

Materials

We used 24 stimulus-pairs that were staggered from those showing very prominent intra-pair size differences (e.g., elephant vs. mouse) to very low size differences (e.g., orange vs. apple). The pairs were determined by a pilot study in which 32 participants evaluated 40 stimulus-pairs by using a scale between -5 (the first stimulus is extremely smaller than the second stimulus) to $+5$ (the first stimulus is extremely larger than the second stimulus). Absolute values of mean size differences were calculated. Hence, the lower scores indicated higher pair similarities and vice versa. Equal numbers of stimulus-pairs with difference scores of greater than four, between one and four, and less than one were selected for high difference (HD), average difference (AD), and low difference (LD) conditions, respectively. We developed two stimulus sets matched for their mean size differences to control the error variance that might arise from stimulus characteristics other than their sizes (see upper part of [Figure 1](#) for two matched stimulus sets used in the study). The use of the stimulus sets was counterbalanced across subjects. The equity of the two stimulus sets was evidenced by a paired t -test (see the upper part of [Figure 1](#)). Additionally, two stimulus-pairs constituted by numbers (78 vs. 25 for the first set and 85 vs. 32 for the second set) were used as control stimuli.

Procedure

After having filled out the Edinburgh Handedness Inventory, the participants were randomly assigned to one of the stimulus sets. The stimulus-pairs were presented in word form, as one-under-the-other, at the centre of a 19-in. computer screen with black background. A different stimulus-pair appeared on the computer screen in each trial, and the presentation of pairs and the position of elements of the pairs were randomized across trials. The participants were instructed to first read the stimulus-pair, to then close their eyes and to imagine one of the stimuli on one side of their visual field and the other one on the other side. Then they had to indicate which stimulus was imagined on which side of the visual field by pointing to a computer screen that was divided by a vertical line. Participants used one hand in the first half of the trials and the other hand in the other half. The order of hand use was randomized across participants. The trials with numbers were conducted at the end of the task to avoid a possible priming effect. The stimulus imagined and the

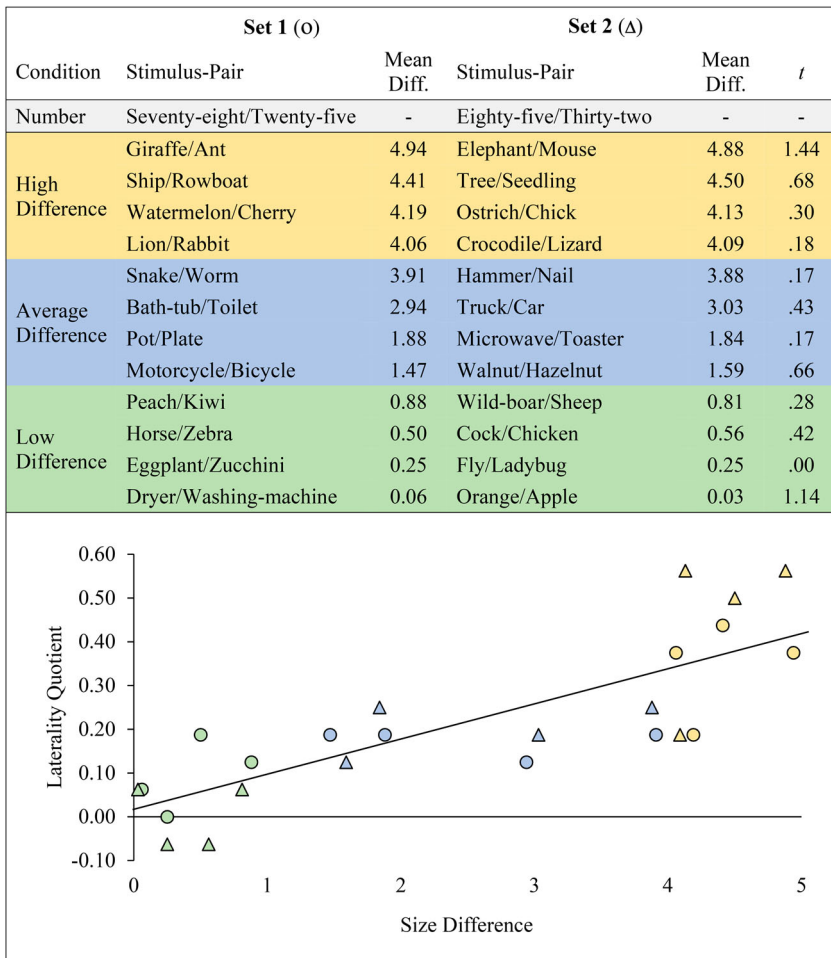


Figure 1. List of the stimuli employed in the study along with their size-difference relationships to LQ. In the upper part all information about the two stimulus sets along with their mean size differences and *t* values are given. The lower part shows the relationship between size differences obtained from the pilot study and LQs obtained from the main study (To view this figure in color, please see the online version of this journal).

visual field used were recorded by the researcher after each trial. A total of 13 trials included 4 HD trials, 4 AD trials, 4 LD trials, and 1 number trial for each participant.

Results

For each stimulus-pair the laterality quotient (LQ) was calculated by using the $[(R-L)/(R+L)]$ formula where R and L represent the number of participants that

had imagined the bigger stimulus in the respective visual field. Both linear and logarithmic regression models were tested to examine the possibility of a relationship between size differences and LQs. Both the linear ($F_{(1, 22)} = 41.43$, $p < .05$) and the logarithmic ($F_{(1, 22)} = 18.47$, $p < .05$) models significantly fitted the data. The linear model produced a higher goodness-of-fit value than the logarithmic model with R -square values of .65 and .46, respectively. The tendency to imagine the larger object on the right side of the visual field increased as the size difference between two stimuli increased ($n = 24$ stimulus-pairs, $r = .81$) (Figure 1, lower panel). The data from the numerical stimulus-pairs were not included in the regression analysis, since they represented clear cut number differences and thus a possibly overlapping but still different process from the pictorial imaginations.

In addition to the model testing, LQs were merged for LD, AD, HD, and number conditions and compared with a one-way ANOVA. The analysis indicated that there was a significant effect of stimulus conditions on LQs, ($F_{(3, 22)} = 18.64$, $p < .05$, $partial \eta^2 = .72$) (Figure 2). Planned contrasts revealed that LQs obtained from stimulus-pairs in the LD condition were significantly lower compared to AD, HD, and number conditions, $t_{(22)} = 6.16$, $p < .05$ (1-tailed). Similarly, LQs obtained from stimulus-pairs in the AD condition were lower compared to HD and number conditions, $t_{(22)} = 4.03$, $p < .05$ (1-tailed). Contrast analysis did not reveal any difference between LQs for stimulus-pairs in HD and number conditions $t_{(22)} = .14$, $p > .05$ (1-tailed).

Finally, right or left visual field preferences of the participants for bigger stimuli in LD, AD, HD, and number conditions were compared by using paired t -tests to examine any possible tendency to locate stimuli in any visual fields with regard to their sizes. In AD ($t_{(7)} = 11.23$, $p < .05$; mean = 19.00, SE = .27 for right and mean = 13.00, SE = .27 for left), HD ($t_{(7)} = 7.56$, $p < .05$; mean = 22.38, SE = .84 for right and mean = 9.63, SE = .84 for left), and

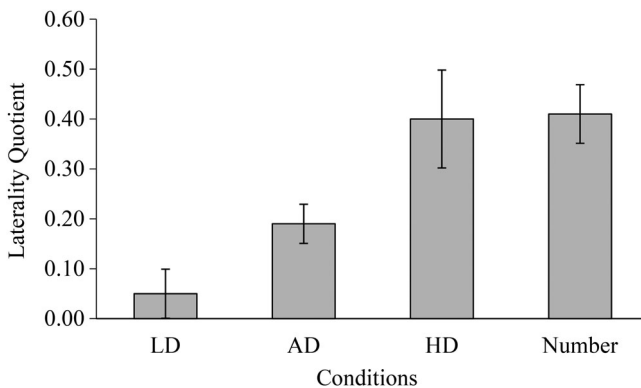


Figure 2. Mean LQs obtained from stimulus-pairs in low difference (LD), average difference (AD), high difference (HD), and number conditions. Error bars represent SEM.

number ($t_{(1)} = 13.00, p < .05$; mean = 22.50, SE = .50 for right and mean = 9.50, SE = .50 for left) conditions, participants preferred to imagine the bigger stimuli on the right side of the visual field. No such preference was visible in the LD condition ($t_{(7)} = 1.53, p > .05$; mean = 16.75, SE = .49 for right and mean = 15.25, SE = .49 for left).

Discussion

We discovered that pairs of objects of unequal size are imagined with the smaller one being placed on the left. More specifically, our data reveal that the tendency to imagine the bigger object on the right side increases directly proportional to the size difference of the two stimuli. Consequently, side preferences disappear when size differences between stimuli are low or even absent. These results imply that smaller stimuli are associated with the left and bigger stimuli with the right visual field. Thus, our study demonstrates for the first time that imaginations of objects seem to follow an ascending size order from left to right. Such a visual field bias was also present in the number condition so that the participants imagined smaller and larger numbers on the left and the right side of the visual fields, respectively. Together, our findings could imply that the left-to-right orientation observed in imagined objects may share the same cognitive mechanism as the mental number line.

We do not know if our results are explained by a cultural bias. After all, without a single exception all of our participants were used to read and write from left to right. However, there are strong evidences that the left-to-right-oriented mental number line has, at least in part, biological roots. It has been demonstrated that interaction between numerical processing and spatial attention arise from common parietal circuits (for review see Hubbard, Piazza, Pinel, & Dehaene, 2005). Furthermore, areas associated with mental representations (e.g., in the case of imagination) have been found to activate areas overlapping with spatial attention (Nobre et al., 2004). A recent brain imaging study conducted by Harvey, Fracasso, Petridou, and Dumoulin (2015) provided further evidence that processing of object sizes and numbers might be associated in overlapping maps. Also the study of Rugani et al. (2015) in newly hatched chicks suggests the existence of a left-to-right mental number line in a species in which our last common ancestor lived more than 300 million years ago. Thus, it is conceivable that our findings result from a mixture of nature and nurture. So, our study may provide a starting point for future studies to explore further relationships between spatial mapping of object and number.

Finally, to examine the relationship between size differences and LQs we tested two regression models (linear and logarithmic) and found that the linear model produced a higher goodness-of-fit value than the logarithmic

one. We would, however, refrain from taking a strong standpoint on the debate on the linear versus the logarithmic nature of the mental number line. Both of our regression models produced significant results and we believe that more studies and analyses are needed before proper conclusions can be drawn. Currently, there is no consensus among researchers about this topic. While Gallistel and Gelman (1992) have argued that the linear model should be preferred, Dehaene and Changeux (1993) have proposed a logarithmic model. However, what we now can say is that these discussions should not only be restricted to the representation of numbers but should also incorporate the imagination of objects.

Taken together, the fact that Baloo is dancing on right side of the jungle, that Picasso depicted Don Quixote on the right side of his canvas, and that Obelix walks on the right side of Asterix reflects a common cognitive mechanism that biases the imagination of the various artists who sketched these immortal scenes with a specific orientation.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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