

Comment on the ERP data and the behavioural experiments

Before going on, we will make a brief comment to clarify the reasons why we used different tasks in the ERP study and in the subsequent behavioural experiments.

The behavioural results of our ERP study showed no difference in processing times (RTs) and accuracy between the numerical quantity (judging if a number between 11 and 19 is smaller or larger than 15) and the numerical order tasks (judging if a number between 11 and 19 comes before or after 15 in the counting sequence). Moreover, both tasks entailed a similar distance effect with numbers close to the standard eliciting longer RTs than numbers farther apart. As we have argued in the paper, this suggests that both numerical quantity and numerical order processing relied, in these particular tasks, on a comparison mechanism. In fact, using a serial search process would have caused a reverse distance effect to occur that is, faster processing for numbers close to the standard and longer RTs for numbers farther apart. A standard distance effect was also found in the alphabet order tasks. Thus suggesting that judging the order of letters in the alphabet also relies on a comparison mechanism.

Contrary to the behavioural results, however, the ERP data revealed certain differences between the two numerical tasks with respect to the spatio-temporal course of the distance effect: the distance effect aroused earlier (less than 200 ms after stimulus presentation) and was left-lateralized over parietal areas in the quantity task, whereas it was slightly delayed (it aroused just after 200 ms) and was bilaterally distributed over parietal areas in the numerical order task. Besides, the numerical order task was shown to recruit frontal areas more than the numerical quantity task.

The data from this first study thus reveal that whereas behavioural results show no difference between the numerical tasks, ERP data suggest that processing the quantity or the relative position of a number in the sequence may recruit slightly different mechanisms.

One way we thought of testing the hypothesis of dissociated mechanisms underlying numerical quantity and numerical order judgments, was to examine the influence of a factor (that was not correlated with either the quantity of digits or their relative position in the sequence) upon each kind of processing. If different mechanisms were recruited, in fact, during quantity and order processing, they might be differentially affected by that factor. The factor we chose was the physical size of digits (in fact, whether a digit is numerically smaller or larger than another or comes before or after another in the sequence does not determine its relative physical size with respect to another digit). Consistent evidence in the literature suggests that the physical size of digits affects performance in number comparison (i.e. quantity) tasks (e.g. Besner & Coltheart, 1979; Thzelgov, Meyer, & Henik, 1992; Henik & Tzelgov, 1982). However, whether the physical size of digits would equally affect performance when judging the relative order of numbers in the conventional sequence, had not been previously investigated. We thus devised a Stroop-like number (magnitude) comparison task and manipulated pair-distance (close, consecutive, number pairs were compared to far, distance 3, pairs), pair-order (whether numbers were presented in the conventional ascending order, 2 3, or not, 3 2) and the physical size of digits: in congruent pairs, the numerically smaller number was also the physically smaller (e.g. 2 3); whereas in incongruent pairs, the numerically smaller number was the physically larger e.g. 2 3; neutral pairs (e.g. 2 3) were included as well. In the quantity-comparison task, subjects were asked to select the numerically smaller (or larger) number of the pair. With respect to the corresponding numerical order task, we discarded using the equivalent ‘before/after’ instructions, as we did in the ERP study, since behavioural results from that study showed no difference in RTs between processing of numerical quantity and numerical order. We thus decided to use a new ‘order-verification’ task and asked subjects to tell, for each number pair, whether it was shown in the conventional, ascending, sequence order. The two numerical tasks were performed over the same number pairs. An equivalent (alphabetic) order-verification task with letter stimuli was also included.

The results of this experiment (Experiment 1 in the paper presented in the next section) showed a similar size congruity effect in the two numerical tasks, suggesting that the physical size of digits similarly affected numerical quantity and numerical order processing. We could thus not differentiate the mechanisms underlying numerical quantity and numerical order with respect to that factor. Nonetheless, two specific effects were observed in the numerical order-verification task (and absent in the quantity task), namely, a pair-order effect (faster processing of ascending relative to descending pairs) and a reverse distance effect. This latter finding refers to faster verification of the order of numbers in a pair when these numbers were close (adjacent) in the counting sequence, rather than farther apart, and presented in the conventional (ascending) order. This result was taken as evidence for the involvement of a serial search strategy when processing the order of numbers in the sequence. However, this crucial effect was only marginal (p -value = 0.06) and needed to be confirmed in another experiment (Experiment 2). Moreover, because we only included two pair-distances in Experiment 1 (Distances 1 and 3) we could not tell whether the reverse distance effect was explained by special processing mechanisms for consecutive-numbers, or whether the serial search mechanism would vary parametrically with the distance between numbers in the pair.

Thus, the purpose of Experiment 2 was not only to reinforce the findings of Experiment 1, but also to better understand the serial search process. To do so, we included two additional distances (Distances 2 and 4); besides, because the physical size of digits was shown to affect numerical order and numerical quantity processing in equal ways, it was removed from Experiment 2. Apart from these two adaptations (4 different distances and removal of physical size difference), Experiment 2 was in all other ways identical to Experiment 1. The results for the number (quantity) comparison task were similar to those of Experiment 1. Crucially, Experiment 2 confirmed that the order of consecutive numbers was verified faster than the order of non-consecutive numbers thus corroborating the reverse distance effect observed in Experiment 1. Yet, serial search did not appear to vary parametrically with the distance between numbers.

Overall, these experiments showed that processing the quantity or the relative order of numbers in the sequence entails different behavioural effects (i.e., standard or reverse distance effect, and a pair-order effect exclusively in the order verification task) that could be explained by the involvement of different cognitive mechanisms.