1. Introduction

Numbers are an integral part of everyday life. We possess a strong visual sense of number that is used to rank, estimate and quantify everything we see in the environment (e.g., a crowd of people, number of students surrounding a table). Humans can estimate numerosities over a broad range, between one to hundreds or thousands of items without involving cognitive processes, such as counting, which are ineffective at short viewing times [1]. Numerosity estimation is fast and accurate when the number of items is less than 4 which has led to the concept of subitising [2].

Objects in natural scenes rarely occur in isolation but are surrounded by other groups of objects or textured surfaces which can vary in their spatial organisation. Thus, it is likely that spatial characteristics of the surrounding context affect numerosity perception. However, little if any is known about the effect of context on numerosity perception.

How does spatial organisation of context elements affect numerosity estimation of target elements and the ERP responses to numerosity?

2. Methods

- Small number of 3 to 6 target elements presented either in isolation or in context (36 elements – target).
- Target and context elements were dissociated by luminance polarity i.e., white target - black context or vice-versa.
- We varied spatial configuration of target and context elements:
  - Target elements were placed either mirror symmetric, on the vertices of simple geometric shapes (equilateral triangle, square, pentagon, and hexagon) or randomly.
  - Context elements were organised either in a grid, mirror-symmetric, translation symmetric, or randomly.
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- Stimuli were presented for 120 ms.
- Participants performed a numerosity estimation task and were instructed to indicate as quickly and accurately as possible the number of target elements.
- We recorded accuracy and RTs as well as Electroencephalography (EEG).
• lower accuracy and slower RTs for all target-types when presented in context than in isolation, and for larger (5,6) than smaller (3,4) target numerosity.
• comparable magnitude of accuracies and RTs between random, symmetric, and translation symmetric context.
• significantly higher accuracies and faster RTs with the grid compared to mirror-symmetric, translation and random contexts, except for 6 target-elements condition where the grid context yielded the lowest accuracy.
How does context affect ERPs?

- Early (P1,N1) components for no context condition peaked later and slightly decreased in amplitude compared to all context conditions.
- Larger N2 amplitude (250 – 350ms) for the grid than random context context conditions, manifested as a prominent right posterior negativity.
- Comparable N2 amplitude (250 – 350ms) for the random and symmetric context conditions.

![Graph showing ERP topography](image)

Topography indicates differences between

- Grid – Random context (250 to 350 ms)
- Symmetric – Random context (250 to 350 ms)

Conclusions

- The presence of symmetric, translation symmetric and random organisations of context elements inhibits target-numerosity encoding stronger than grid/regular context.
- Numerosity estimation is separated later over Left Mid-Frontal electrode sites (LMF effect), measured between 400-650 ms, with larger ERP amplitude for low number of elements. LMF effect appears to separate low (3,4) and high (5,6) number of elements irrespective of context type and/or absence of context, complementing previous findings with no-context from [3].
- Larger N2 amplitude between 250-350 ms for grid context compared to all other context types.
- All context (i.e., different texture backgrounds) vs no-context conditions produce early ERP differences in the latency and amplitude of P1 and N1 components, suggesting the involvement of different neural mechanisms with different time courses. This complements our earlier finding showing that texture processing begins before contour-shape processing [4].

References