ORAL PAPER

"Two cues are not better than one" the integration of geometric and featural information in the reorientation paradigm

Luciana Picucci • Andrea Bosco

Keywords Reorientation · Geometric cues · Featural cues · Navigation

Background

A large body of evidence has shown that to navigate in the environment, animals need to define a direction with respect to some frames of reference that specify position of that individual and its direction. In natural environment, usually, a large number of cues could be used in order to establish heading (Gallistel 1990). In a very simple environment without distinctive landmarks, the shape of the environment itself could be used as reference for orientation and navigation. This kind of reference is called geometric cue. Recently, Cheng and Newcombe (2005) had reviewed a large number of works in animals and humans highlighting the characteristics of this kind of spatial information and their relationship with the featural (landmarks) cues. In particular, the reorientation paradigm (e.g. Hermer and Spelke 1996) predicted that adult human promptly solve a searching task by integrating geometric (the layout of the environment) and featural information (a distinctive landmark), while children (within 2 years old) failed to integrate landmark information. Geometrical information seemed to be encapsulated. As pointed out by Fodor (2001) the original results of Hermer and Spelke (1996) could represent an important evidence of modular cognitive functioning in the domain of spatial of cognition. Present study intends to discuss the notion of integration among different spatial information, comparing performance of adult humans either in environment with (a) layout information only (rectangular chambers), (b) landmark information only (square chambers with one distinctive landmark) and (c) combination of layout and landmark information (rectangular chambers with one distinctive landmark). It is worthwhile to note that in the environments with layout information only, correct responses are ambiguous, since both correct site and its rotationally equivalent are legal. In contrast, the environments with only landmark information possess unambiguous information since the sense relation between landmark and target (e.g. "target is on the right of the landmark") is adequate to solve the task. Consequently, adding coherent layout information to a landmark cue, leads to expect an improvement of performance with respect to an environment characterized by landmark information only.

Experiment 1

The aim of the present experiment was to evaluate different level of performance in a series of searching task. The navigable virtual environments were characterized by (a) layout information only, (b) landmark information only, and (c) a combination of layout and landmark cues. The distance between landmark and target was also manipulated, controlling the relevance of the landmark information.

Method

Participants

Thirty-six University students (18 women) ranging between 19–25 years old, voluntarily participated to the experiment.

Material

A series of three-dimensional virtual environments (CG Arena, http//w3.arizona.edu/~arg/data.htm) was presented on a 21" computer screen. Each trial was

L. Picucci • A. Bosco (✉)
University of Bari, Bari, Italy
e-mail: a.bosco@psico.uniba.it

characterized by a study room in which target was visible and a testing room in which target was hidden. Between study and testing rooms a black screen was presented. Visited corners were recorded.

Procedure

Participants were involved in six experimental conditions each (order of trials was randomized) in which they were requested to identify the corner hosting the target. They faced both (a) "Rectangular" and (b) 'Square" rooms. For each condition, a series of rooms (1) without landmarks, (2) with one coloured wall near to the target, and (3) with one coloured wall far from the target, were presented. The target was located in one of the corner. Participants were informed that their facing position at the beginning of the testing phase, varied randomly with respect to the study room, consequently they self referencing system was systematically perturbed. The locations of hidden object and the initial positions of the participants in the searching task were approximately balanced across trials.

Results and discussion

A 2 x 3 ANOVA (within factors design) was performed on proportion of correct responses. Independent variables were "layout" (square or rectangular), and "landmark proximity" (absent or near/far to the target). Interaction between independent variables was significant ($F(2, 70) = 4.98$; $P < 0.01$). The square room without landmark (and non distinctive layout) did not provide any spatial information, indeed mean proportion of searching in the correct corner was 0.27 (SE = 0.03), approximately a quarter of the total searching trials. The manipulation of virtual disorientation seemed to work correctly. The rectangular room providing geometrical information on the layout of the room, showed a mean proportion of correct searching of 0.45 (SE = 0.05), about a half of the total. Distinctive shape of the room seemed to be well recognized by participants. Comparing the performance in square and rectangular rooms did not emerge any difference, as showed by Fig. 1 (first graph). One objection should be that in the condition "landmark near the target" we obtain a "ceiling effect" in the square room since is not proper to expect an improvement of performance for the rectangular room. However in the condition "landmark far from target" the performance in the square room (mean P = 0.85, SE = 0.03) was not high enough to contrast the enhancement of performance in the rectangular room. Nonetheless in the rectangular room things did not change (mean P = 0.85, SE = 0.03). The concurrence of different and congruent information (sense relation of target with landmark and the distinctive layout of the room) did not work better than the landmark information alone. However this experiment leads to suspect that performance was biased by the opportunity for participants to compare square and rectangular rooms. Second experiment was realized in order to eliminate this possible source of bias.

Experiment 2

In order to clarify and replicate the results of the first experiment, a second experiment was carried out with a larger sample, in a between-subjects design avoiding the interference between experimental conditions.

Method

Participants

Seventy-two University students ranging between 19–25 years old were randomly divided into two groups: (a) Rectangular room group and (b) Square room group.

Material

Material was the same of the first experiment.

Procedure

Participants were involved in three experimental conditions each (order of conditions was randomized) in which they were requested to identify the corner hosting the target. They faced (a) "Rectangular" or (b) "Square" rooms. For each condition, a series of rooms (1) without landmarks, (2) with one coloured wall near to the target, and (3) with one coloured wall far from the target, were presented. The other aspects of the procedure were the same of Experiment 1.

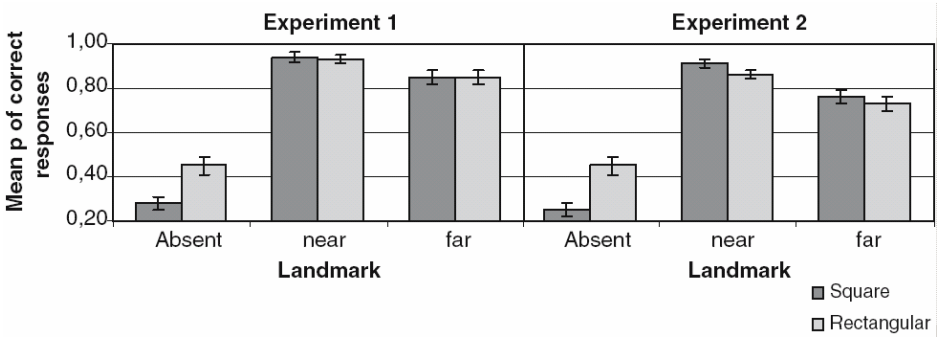

Fig. 1 Mean proportion of correct responses (standard errors on bars) as function of layout of environments and landmark characteristics

Results and discussion

A 2 x 3 ANOVA (mixed factors design) was performed on proportion of correct responses. Independent variables were "layout" (square or rectangular), and "landmark proximity" (absent or near/far to the target). Again the interaction between independent variables was significant, $F(2, 140) = 13.21$; $P < 0.001$. Concerning both square and rectangular rooms without landmark, results were comparable with those in Experiment 1. As showed in Fig. 1 (second graph), the difference in the level of performance as effect of layout appeared larger than in the Experiment 1. In particular participants in rectangular room condition performed worst than those in square room condition, the difference in condition with landmark near to the target reached the statistical significance ($F(1 , 70) = 4.21$; $P < 0.05$; square room mean $P = 0.94$, $SE = 0.03$; rectangular room mean $P = 0.86$, $SE = 0.02$). If the comparison between square and rectangular rooms is precluded, subjects in the rectangular condition showed a worst performance compared with participants that faced square rooms. The results of the second experiment did not support the idea of integration between layout and landmark information. Indeed results lead to suppose a sort of cue competition (Cheng and Newcombe 2005) due to the peculiarities of different memory cues.

Conclusions

This study presents two experiments implementing the reorientation paradigm in a desktop virtual environment. It reconsiders the notion of integration between different aspects of geometric information (layout of the rooms) and featural information (landmark cues) involved in a searching task. Integration of geometric and landmark information is more demanding than landmark information solely (it is worthy to observe that landmark information holds implicitly a geometric information denoted by the sense relation between target and landmark). When geometric information is available (a distinctive layout of the room), it interferes with spatial mental representation and consequently impairs the performance, at least when participants cannot compare their performance in square and rectangular rooms (as in Experiment 1). Two theoretical frameworks support our findings. First, Cheng and Newcombe (2005) proposed a model with modular components, a memory box containing a metric frame deputed to coding only the geometric information. Featural information may be pasted onto the frame in addition. In this model featural information may fail to be input into memory. This failure can cause systematic rotational errors. These are more frequent when the individuals are not aware of the difference between square and rectangular environments (as in Experiment 2) since they cannot compare directly differences in layout. Second, the dichotomy of procedural and declarative memory systems (e.g. Schacter and Tulving 1994) could explain this pattern of results. Indeed, a searching task is characterized by action, thus geometric information seems to be promptly accessible in memory, in a partially aware manner. On the contrary, featural characteristics (like landmark information) have a more clearly declarative status; they are less promptly accessible in memory for action when geometrical information is also present. However it is perfectly suitable to solve the searching task when geometrical cue is absent. Finally, when square and rectangular layouts can be directly compared (as in our Experiment 1), individuals tend to assembly geometrical and featural cues avoiding rotational errors. The integration of cues is achievable only under specific conditions. Otherwise geometric cues tend to compete with featural characteristics of the environments in guiding spatial navigation tasks.

References

Cheng K, Newcombe NS (2005) Is there a geometric module for spatial orientation? Squaring theory and evidence. Psychon Bull Rev 12:1–23

Fodor JA (2001) The mind doesn't work that way. MIT Press, Cambridge

Gallistel CR (1990) The organization of learning. MIT Press, Cambridge

Hermer L, Spelke SS (1996) Modularity and development: the case of spatial reorientation. Cognition 61:195–232

Schacter DL, Tulving E (1994) Memory systems. MIT Press, Cambridge