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Dynamics in Spatial Interactions

What kind of space is remembered in spatial span?

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The Corsi Blocks Test is a familiar and standard technique for measuring short-term spatial memory in neuropsychological cases and in experimental psychology. In its concrete form, it consists of a rectangular board, on which nine cubes are arranged in a fixed but irregular pattern. The experimenter sits on one side of the board, and the participant on the other. The experimenter demonstrates a spatial sequence by tapping the blocks in turn at a constant rate, and the participant tries to reproduce the sequence. In the standard version of the test, the initial sequences are easy and short, and they get progressively longer and harder until performance breaks down. Typically for intact adults the spatial span is around 5–6 ordered locations.

Although it has been in use as a psychometric test since about 1970, it is only recently that investigators have begun to study the Corsi test and its variants in detail. These studies fall broadly into two groups. First there are interference studies that examine the degradation of performance caused by concurrent tasks and irrelevant stimuli (e.g. Jones et al. 1995; Pearson and Sahraie, 2003; Smyth and Scholey 1994). These studies attempt to identify component procedures involved in spatial memory, relating the observed decrement in performance to the supposed properties of interference. Secondly, there are studies of the properties of sequences that provide valuable insights into the way that spatial sequences are internally encoded (e.g. DeLillo 2004; Kemps 2001; Parmentier et al. 2006).

One aspect of the Corsi task that has been neglected is the spatial reference frame (or frames) used to remember a spatial sequence. The reference frame is provided by a location can be specified relative to other positions. For set of reference locations and directions such that a new the Corsi task, the locations making up a sequence could be specified in several possible ways: (a) egocentric encoding of position relative to the position of the stationary observer, (b) encoding in relation to the local environment, such as the table top or the walls of the testing booth, or (c) encoding of position with respect to the other blocks and the board, which we will refer to as the template. If the board is moved relative to the observer or the local environment, then the position of a block with respect to extrinsic reference frames such as the observer (a), or the local environment (b), will change. However, location specified by a template-centred reference frame will not be affected by translation of the template (Avons 2006).

A discussion of reference frames is essential to understanding spatial short-term memory, for two reasons. First, the reference frame(s) used provide a fundamental level of description on which subsequent information processing occurs. It does not make sense to describe a task as spatial and not say what the reference frame is. Secondly, it is possible that failure to consider the reference frame has resulted in misinterpretation of some interference studies.

In the experiments described here, a variation of the Corsi task was presented on the vertical screen of a computer monitor. The template consisted of a rectangular frame in which nine squares (1.4 cm) were displayed. The squares were positioned at random on every trial, with the constraint that no two squares could be closer than three times the diagonal of a square. Sequences of seven squares were displayed by selected squares turning black for 0.5 s with a 0.5 s ISI. After the sequence a tone sounded to indicate recall, the mouse cursor became visible and participants were instructed to click on the squares in the same order that they were shown.

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The independent variable was the presence or absence of movement of the template at some point during the task. In all cases the template moved in rigid translation across the screen. Each movement lasted for 0.5 s and was followed by a stationary period for 0.5 s. The extent of each movement was approximately 5 cm, in a random direction chosen so that that the template did not drift off the screen. Thus, the movement of the template used in all these experiments was unpredictable in direction, and intermittent. In all experiments conditions were run in blocks of 20 trials, of which the first 5 were discarded as practice. The order of conditions was counterbalanced across participants.

Experiment 1

Movement of the template occurred during presentation. At the start of the trial the template was shown for 1 s in the centre of the screen, followed by the display of the first square (0.5 s). Then the template moved to a new position, followed by the display of a second square. The cycles of display of one square followed by template movement continued until all seven squares had been shown. After the tone, participants recalled the sequence. In the control, no movement condition, the template remained in the centre of the screen throughout.
Clearly, in the control condition, with a static observer, the sequence locations could be remembered in template-centred or extrinsic frames of reference, singly or in combination. However, when the template moves during the ISI between the display of discrete locations, the extrinsic coordinates at which the squares were displayed do not correspond to the locations of the squares on the template at the time of recall. Hence, we would expect that if extrinsic reference frames contribute to recall in the static conditions, performance would be impaired in the moving condition.

Results

Compared to the stationary condition, performance was impaired in the moving condition (Fig. 1). This was a modest impairment, corresponding to a decrease of 13.6% relative to the control. One interpretation is that the spatial sequence of the Corsi blocks task is at least partially encoded using extrinsic coordinates. If this is the case, then similar impairments should be observed during other task phases such as during recall, or during the retention interval.

Experiment 2

Here movement of the template took place during recall. The sequence was presented with the template static in the centre of the screen. When the tone sounded the participant recalled the first location of the sequence using the mouse. At this point, in the movement condition the mouse cursor disappeared, and the template moved across the screen for 0.5 s. Then the second location was recalled, and so on until seven squares had been selected. In the control condition the template did not move during the recall phase.

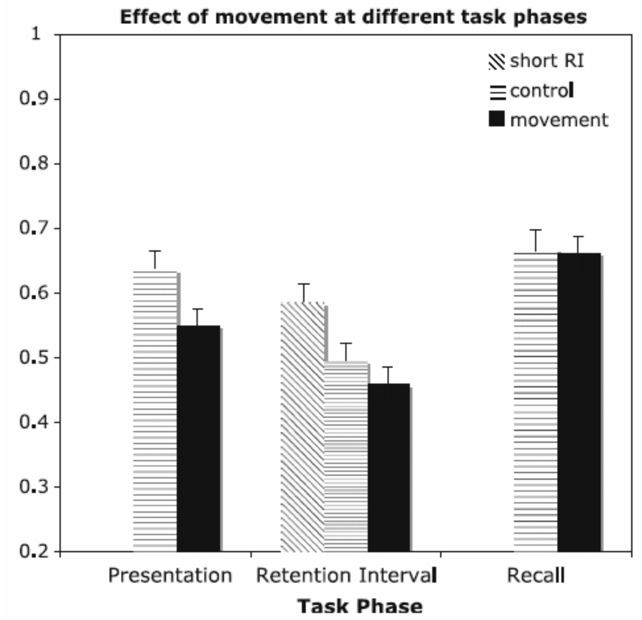

Fig. 1 Mean accuracy with and without movement during each task phase. Bars indicate standard errors

Results

No impairment was seen when the template moved during recall, relative to the control condition (Fig. 1). This must mean that at the time of recall participants were not relying on extrinsically coded spatial information. All effective positional memory was coded in terms of template-centred coordinates.

Experiment 3

The effect of movement of the template during retention was investigated by introducing a 7-s retention interval between presentation and recall. During this interval the template either moved as in the input phase of Experiment 1, or was stationary. A second control condition used a stationary template at input and recall but with a short 1 s retention interval, as in Experiments 1 and 2.

Results

There was a clear effect of retention interval: memory was much poorer after an extended retention interval. However, moving the template during the retention interval had only a relatively small effect, which was statistically non-significant (Fig. 1). The decrease in the movement condition relative to the stationary control was 7.0%.

Discussion

Taken together, the results suggest that positional information in the Corsi task is mainly encoded with respect to a template-centred reference frame. Locations are specified relative to the "board" and the other "blocks" of the Corsi task, or their 2D analogues. The one exception is that of movement during input, which causes a modest but significant impairment. This may indicate that extrinsic, possibly egocentric information is used in encoding the sequence, possibly as temporary representations of egocentric location (McNamara 2003). Subsequently, information about the sequence is template-centred and consequently is immune to movement of the template.

The results of all three experiments are consistent. However, the small effect of movement of the template during the retention interval does not sit comfortably with a number of experiments using variations of the Corsi Blocks Test, showing that it is highly sensitive to directed eye movements or other attentional shifts during the retention interval (e.g. Pearson and Sahraie 2003; Smyth and Scholey 1994). In our experiments, following the random movements of the template during the retention interval led to little or no interference. In other words attention shifts are not necessarily harmful to spatial STM, even if they are uncorrelated with the spatial sequence that is remembered. In our studies, attention was maintained on the relevant reference frame, which was present throughout the trial.

In previous studies, the target stimuli that were tracked were presented after the template was removed, or were presented outside the reference frame provided by the Corsi template. A consequence of this is that these stimuli were presented in a different frame of reference. Working memory studies have generally interpreted these findings as indicating that some form of movement encoding underpins spatial and visual imagery tasks, and this movement is opposed by unrelated attention shifts to external stimuli. An alternative interpretation is this: that the requirement to track or respond to an irrelevant extrinsic moving stimulus imposes a new spatial reference frame within which the stimuli of the main task cannot be accommodated.

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